PA 440/1-73/004

Development Document for Proposed Effluent Limitations Guidelines
d New Source Performance Standards for the
FEEDLOTS
Point Source Category

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

AUGUST 1973

Publication Notice

This is a development document for proposed effluent limitations guidelines and new source performance standards. As such, this report is subject to changes resulting from comments received during the period of public comments of the proposed regulations. This document in its final form will be published at the time the regulations for this industry are promulgated.

DEVELOPMENT DOCUMENT

for

EFFLUENT LIMITATIONS GUIDELINES

and

NEW SOURCE PERFORMANCE STANDARDS

FEEDLOTS POINT SOURCE CATEGORY

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ABSTRACT

This document presents the findings of an extensive study of the feedlot industry for the purpose of developing proposed regulations, providing guidelines for effluent limitations and Federal standards of performance for the industry to implement Sections 304 and 306 of the Federal Water Pollution Control Act Amendments of 1972.

Feedlots for the following animal types were considered in this study; beef cattle, dairy cattle, swine, chickens, turkeys, sheep, ducks and horses.

Guidelines are set forth for effluent reduction attainable through the application of the "Best Practicable Control Technology Currently Available", the "Best Available Technology Economically Achievable" and for New Source Performance Standards. The proposed recommendations require no discharge of process wastewaters to navigable water bodies by 1 July 1977 except for precipitation event(s) in excess of the 10 year, 24 hour, storm for the location of the point source for all animal types except ducks. Duck growing operations will be required to meet a limitation on BOD and bacterial pollutants using biological treatment (e.g. 2.0 pounds of BOD per 1000 ducks). By 1983, the no discharge limitation will apply to all animal types except for precipitation event(s) in excess of the 25 year, 24 hour rainfall. The latter limitation also applies to all new sources.

Supportive data and rationale for development of the proposed guidelines for effluent limitations are presented.

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CONCLUSIONS

Among the conclusions derived in the course of this study is that the animal feedlot industry may be segmented into eighteen subcategories for the purposes of establishing effluent limitations. The main criteria for categorization of the feedlot industry were animal type and production process employed. Secondary criteria were product produced, prevalence of the production process employed, and characteristics of waste produced. The factor of raw materials used is mainly concerned with the feed used by the animals and its influence is reflected in animal type and the characteristics of the waste produced. Age of facilities and equipment were found to have no meaningful effect on categorization. Location and climate greatly influence feedlot management but represent such a diversity as to be an inefficient basis for categorization. Treatability of the wastes was considered but not found to have a significant effect on categorization because no known practical treatment system exists which can reduce or alter feedlot wastes (with the exception of duck feedlot wastes) to the point where they can be discharged.

With the exception of the duck feedlot subcategories, it is further concluded that animal feedlot subcategories can achieve a level of waste control which prevents the discharge of any wastes into waterways by July 1, 1977. The duck industry requires until 1 July 1983 to meet the no discharge requirement.

There exists a number of promising refined waste management concepts such as manure processing and reuse which offer potentially viable alternatives to land utilization. These concepts are all at, or past the level of "breakthrough" and should be pursued to establish practical applicability.

SECTION II

RECOMMENDATIONS

It is recommended that no discharge of wastewater pollutants to navigable waterbodies be the effluent limitation effective July 1, 1977 for existing feedlots for all animal types except ducks: beef cattele, dairy cattle, swine, chickens, turkeys, sheep, The no discharge requirement should apply to all flushing or washdown waters used to clean pens barns or other animal confinement facilities, all waters from continuous overflow watering systems and all rainfall runoff except that storm event(s) in excess of the 10 year, 24 hour storm as defined by the U.S. Weather Bureau for the location of the point source. This elimination of discharge should be achieved by the recycling of wastes to land for efficient utilization as moisture and nutrients by growing crops.

The effluent limitation for discharges to navigable water bodies from existing feedlots, for the animal tye ducks, applicable for July 1, 1977 should be less than 0.9 kilograms (two pounds) of BOD_5 per day per 1000 ducks being fed and less than the National Technical Advisory Committee recommended values for total viable coliform counts in shellfish producing waters. The resulting coliform limitation for ducks shall be a median of less than 10 million and a maximum of less than 33 million counts per day per 1000 ducks being fed.

It is recommended that no discharge of waste water pollutants to navigable waterbodies constitute the effluent limitation for all animal types and subcategories thereof effective July 1, 1983, and no discharge of waste water pollutants constitute the standard of performance for new ources. The no discharge requirement should apply to all flushing or washdown waters used to clean pens, barns or other animal confinement facilities, all waters from continuous overflow watering systems and all rainfall runoff except that storm event(s) in excess of the 25 year, 24 hour storm as defined by the U.S. Weather Bureau for the location of the point source.

SECTION III

INTRODUCTION

PURPOSE AND AUTHORITY

On October 18, 1972, the Congress of the United States enacted the Federal Water Pollution Control Amendments of 1972. The Act in part requires that the Environmental Protection Agency (EPA) establish regulations, providing guidelines for effluent limitations to be achieved by "point" sources of waste discharge into navigable waters and tributaries of the United States.

Specifically, Section 301(b) of 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 requires 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 requires 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) to 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 determined to be achievable through application of the best available demonstrated control technology, processes, operating methods, or other alternatives, including, where practicable, a standard permitting no discharge of pollutants.

Section 304(b) of the Act requires the Administrator to publish within 1 year of enactment of the Act, regulations providing guidelines for effluent limitations setting forth the degree of effluent reduction attainable through the application of the best practicable control technology currently available and the degree of effluent reduction attainable through the application of the best control measures and practices achievable including treatment techniques, process and procedure innovations, operation methods and other alternatives. This study recommends effluent limitations guidelines pursuant to Section 304(b) of the Act for the animal feedlot industry.

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 performances for new sources within such categories. The

Administrator published in the Federal Register of January 16, 1973 (38 F.R. 1624), a list of 27 source categories. Publication of the list constituted announcement of the Administrator's intention of establishing, under Section 306, standards of performance applicable to new sources within the listed categories. This study recommends the standards of performance applicable to new sources within the animal feedlot industry which was included within the list published January 16, 1973.

The guidelines in this document identify in terms of chemical, physical, and biological characteristics of pollutants, the level of pollutant reduction attainable through the application of the best practicable control technology currently available, (BPCTCA), and the best available technology economically achievable, (BATEA). The guidelines also specify factors which must be considered in identifying the technology levels and in determining the control measures and practices which are to be applicable within given industrial categories or classes.

In addition to technical factors, the Act requires that a number of other factors be considered, such as the cost and non-water quality environmental impacts (including energy requirements) resulting from the application of such technologies.

BASIS FOR DEVELOPMENT OF GUIDELINES AND PERFORMANCE STANDARDS

The feedlot industry is extremely diverse with individual operations utilizing management techniques which vary due to animal type, size and weight, crops available, market available, geographical location, climate, traditional practices, and management experience and education. This study has been based upon the available data and the best estimates and judgements by recognized experts in the feedlot industry field. To perform a more exact study would require extensive new and/or original investigative work. The results are felt to properly reflect the present situation in the industry and form a basis for the development of effluent guidelines.

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

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

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

The data and recommended effluent guidelines within this document were developed based upon review and evaluation of available literature, consultation with recognized experts in specific animal fields, and visits to 91 exemplary feedlots in 17 major "feedlot" states.

Eight animal types were included in the study; beef cattle, dairy cattle, swine, chickens, sheep, turkeys, ducks, and horses. Specifically excluded from the purview of the report are those facilities used to raise pets (dogs, cats, small animals), small game, and wild game.

Five consultants and a technical contractor (cited in Section XII) were employed to provide the most current and accurate data for these animal types. The consultants were chosen based upon their long established interest, expertise and current participation in the field of animal waste management, as well as their recognition by Government and the agricultural industry as experts in their field.

No consultant was utilized for horses due to the diversity of the industry and the lack of scientific attention horses have received relative to the other animals. The consultants provided overall animal industry statistics and specific information on production methods and types of wastes and waste treatment systems prevalent. The contractor provided similar data for horses based on literature searches and conversations with individuals in the industry.

DEFINITION OF A FEEDLOT (See FIGURES 1A and 1B)

In accordance with the Federal Water Pollution Control Amendments of 1972, animal feedlots are defined as "point sources" of pollution. It is necessary, therefore, to distinguish between animals grown in feedlots and those grown in nonfeedlot situations. For the purposes of this document, the term feedlot is defined by the following three conditions:

1. A high concentration of animals held in a small area for periods of time in conjunction with one of the following purposes:

a. Production of meat
b. Production of milk
c. Production of eggs
d. Production of breeding stock
e. Stabling of horses

2. The transportation of feeds to the animals for consumption.

3. By virtue of the confinement of animals or poultry, the land or area will neither sustain vegetation nor be available for crop production.

These criteria must be met by a facility in order to be classified as a feedlot. Facilities which meet the first condition invariably meet all conditions also. However, pasture and range operations do not meet the first condition but on occasion do meet the second condition. In pasture and range situations, the animals are at such a low density in terms of numbers of animals per acre that the growth of grasses and other plants is not inhibited. In these cases the animals receive the major portion of their sustenance from these plants and in turn return nutrients to the soil in the form of wastes. These wastes are then assimilated by the plants in a natural recycle system. Under pure pasture or range conditions no pollutional source is ever reliably identifiable. In some instances supplementary feed may be brought to the animals (usually in the winter) but this level of feeding does not introduce a situation wherein the ability of the natural ecosystem to absorb the animal wastes is exceeded.

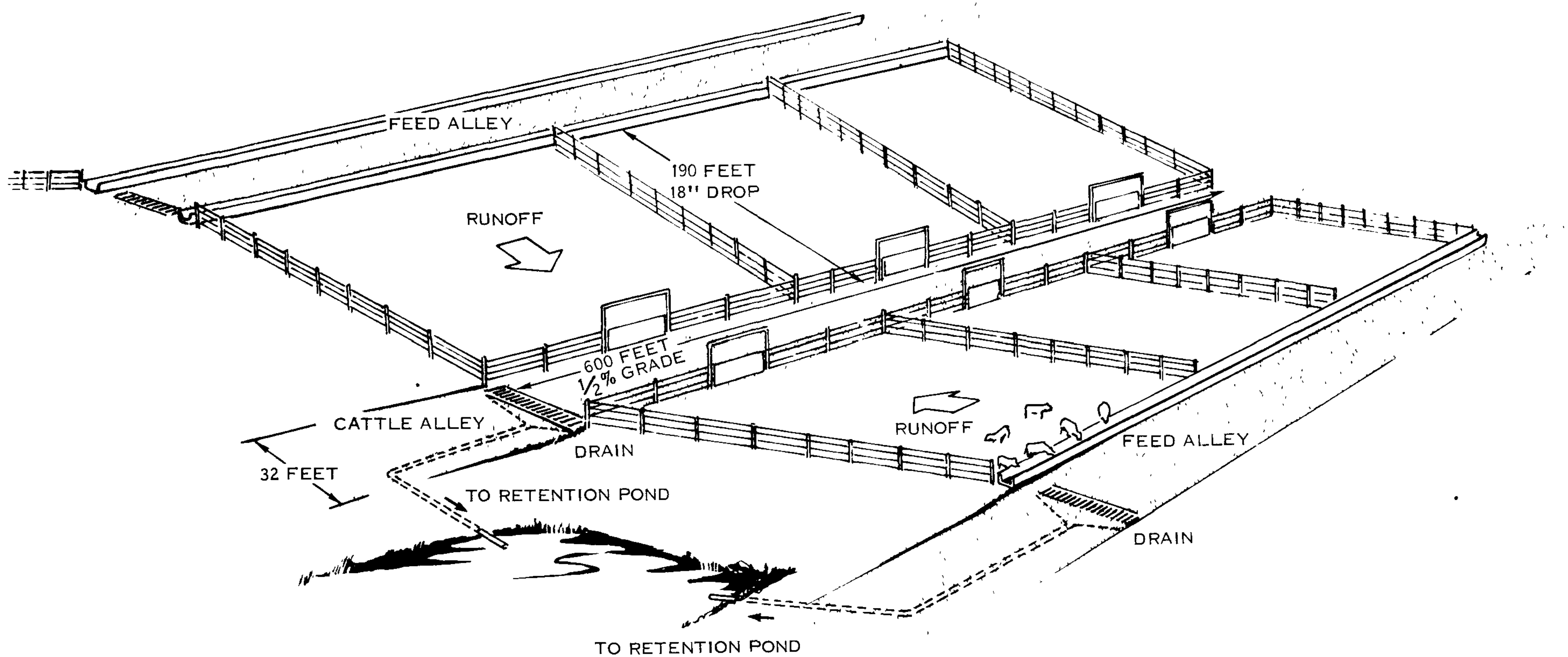


FIGURE 1A. SKETCH OF A CHARACTERISTIC OPEN BEEF FEEDLOT FACILITY

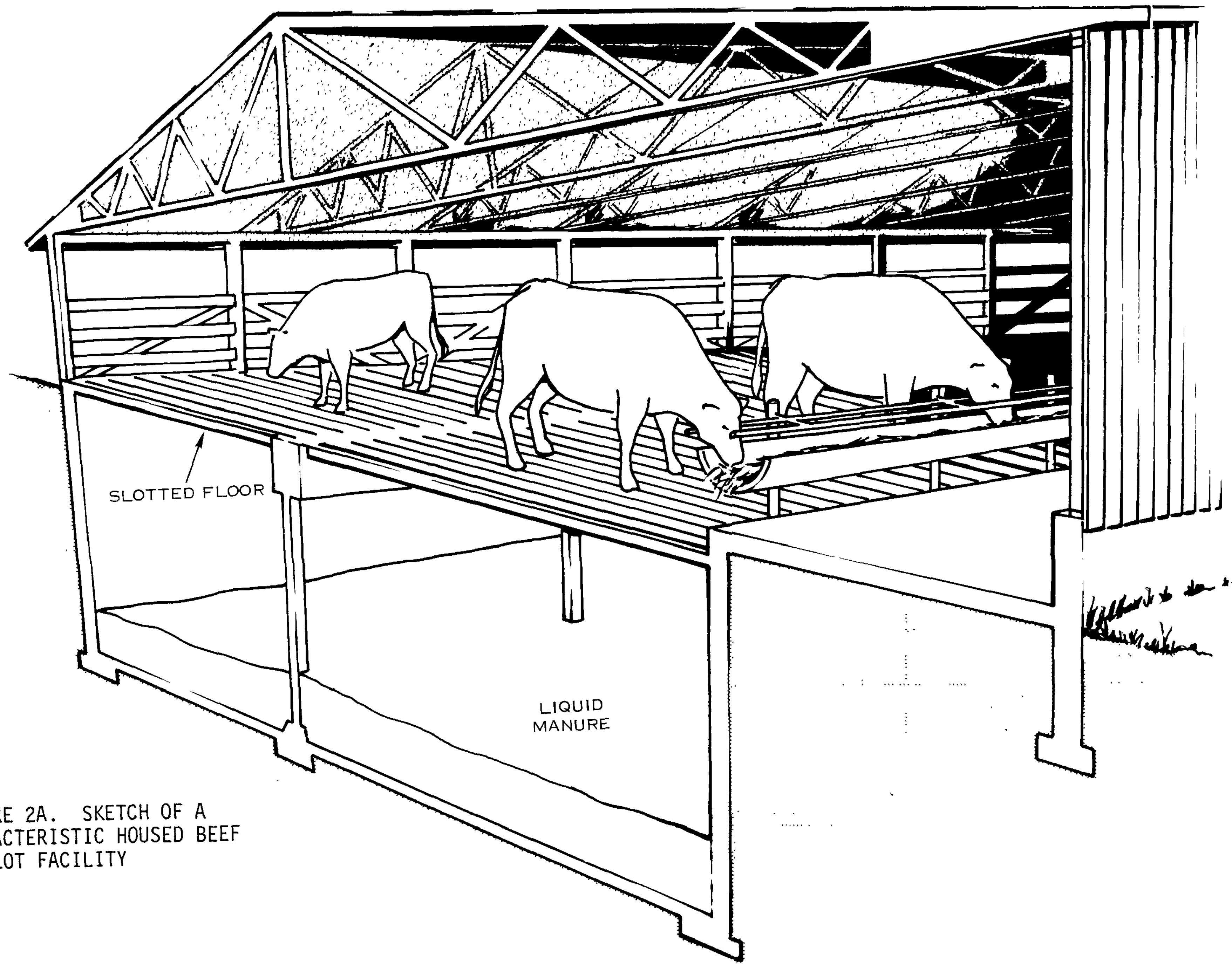


FIGURE 2A. SKETCH OF A CHARACTERISTIC HOUSED BEEF FEEDLOT FACILITY

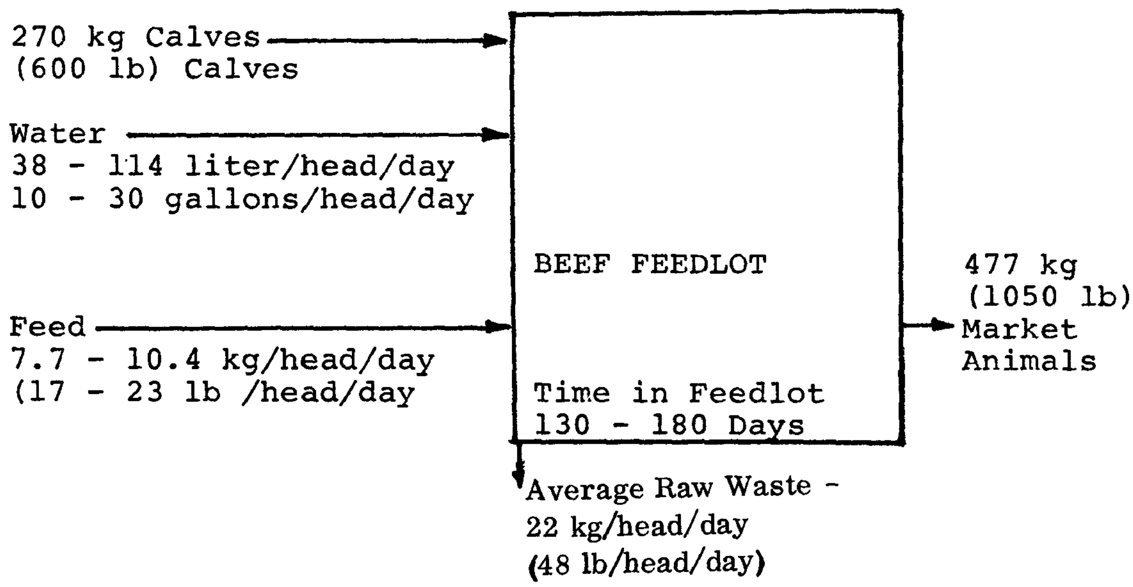
There are animal management schemes where the animals are on the range or pasture for part of their growth cycle and in a feedlot, or confined area, the remainder of the time. Under these circumstances only the wastes from the feedlot were considered as being subject to the effluent limitations defined in Sections IX, X and XI. Where management schemes bordered on being a pasture or range situation, only the higher density type operations were addressed as being subject to the technical analyses and conclusions developed herein.

The following paragraphs provide a general description of each animal industry, including the range/feedlot relationships.

BEEF CATTLE

The production and early growth of beef calves is accomplished on range. As of January 1973 there were approximately 101 million head of beef cattle in the United States. Of this number only 14 million head were in feedlots. The rest of the animals which include bulls, brood cows, and calves were on range. Figure 1 shows a generalized flow diagram of a beef cattle feedlot operation which may be operated as either an open or housed confinement facility. The feed usually contains a high proportion of cereal grains such as corn, barley and milo and protein supplements such as soybean meal with 5% to 20% roughage such as silage or alfalfa to promote proper digestion.

The exact proportion of each constituent depends on a number of factors, including the availability and cost of each constituent and the weight, grade, and sex of the animal. On large feedlots, the ration is programmed by computer based on these factors, and then mixed and brought to the cattle by a variety of mechanical means.



TYPICAL BEEF FEEDLOT FLOW DIAGRAM

FIGURE 1

When calves on range reach a weight of 160-275 kilograms (350-600 pounds) they are sold to feedlots as "feeder" calves. The calves are fed highly concentrated feeds for a period of 130 to 180 days until they reach a weight of 450 to 550 kilograms (1000 to 1200 pounds). At this point they are slaughtered. On occasion calves are grown on a feedlot to only about 365 kilograms (800 pounds) and then transferred to a "finishing" lot where they complete their growth.

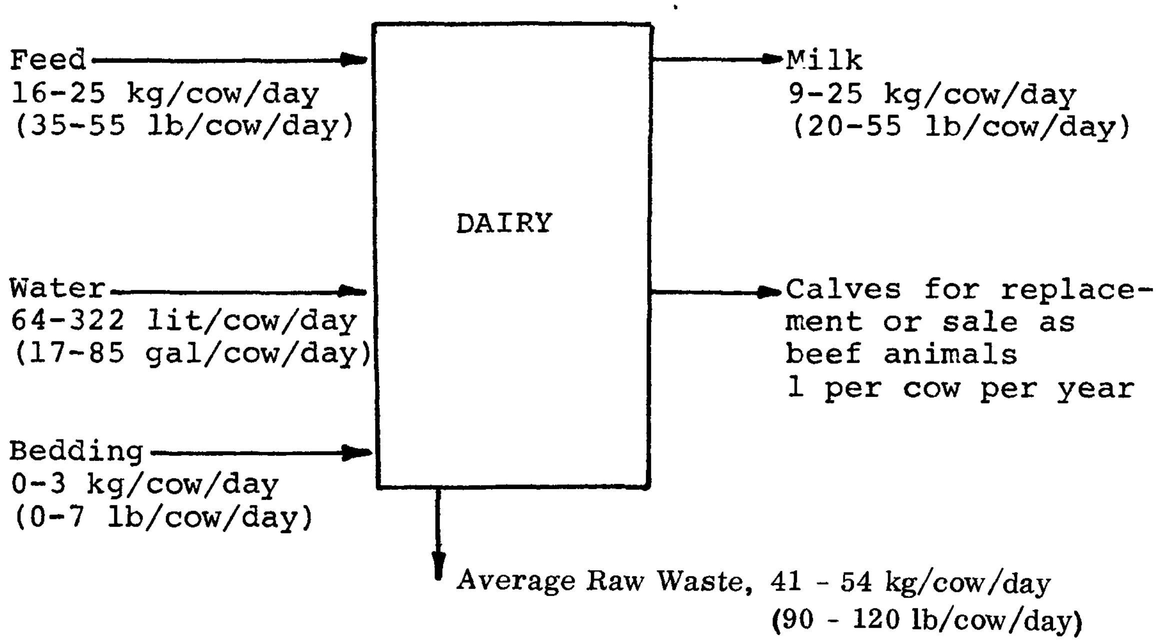
The type of feed provided to cattle in feedlots consists of 5.0 to 20% roughage with the remainder being concentrated grains and protein supplements. A total of about 7 to 9 kilograms of feed are required for every kilogram of grain on the animal. Approximately 45 billion kilograms (100 billion pounds) of feed were consumed by feedlot cattle in 1972. A total of about 27 million cattle (approximately 12 billion kilograms ±27 billion pounds1) were marketed for slaughter by feedlots in 1972 with an approximate gross income of 10 billion dollars.

The vast majority of cattle feedlots are open dirt lots and are located mainly in the West Central and Southwest parts of the country. The small percentage of lots which are housed facilities are in the Midwest. The ten leading states in feedlot cattle production (1972) are as follows:

State	Cattle Marketed
Texas	4,308,000
Nebraska	3,990,000
Iowa	3,896,000
Kansas	2,405,000
Colorado	2,291,000
California	2,062,000
Illinois	1,003,000
Minnesota	935,000
Arizona	899,000
Oklahoma	626,000

DAIRY CATTLE

Milk cows, replacement heifers and dairy breeding stock total about 16 million head in the United States. Of this number 11.5 million are milk cows, which are the only dairy cattle partially or completely fed under feedlot conditions. The rest of the dairy cattle are on pasture. At the age of about two years heifers are bred and after the birth are started as milk cows. From that point on they are bred once each year so milking can be continued. When they are no longer acceptable milk cows they are sold as utility or commercial grade beef. Eighty-five to ninety-five percent of all the milk cows in this country are Holsteins and weigh about 590 to 635 kilograms (1300 to 1400 pounds). Their diet consists of 35 to 40% concentrate ration and 60 to 65% roughage, which may be supplied by pasture. Total daily consumption is 16 to 25 kilograms (35 to 55 pounds) of feed per cow. Water consumption is 57 to 95 liters (15 to 25 gallons) per cow per day. Total feed consumption by all milk cows is 71 billion kilograms (157 billion pounds) of feed per year. Of this, an undetermined amount comes from pasture. Figure 2 is a flow diagram showing input and output parameters of a typical dairy. The water input is shown is for drinking and washing. In operations that use water to flush manure from the facility, this value is approximately 132 to 473 liters (35 to 125 gallons) per cow per day. Dairy cattle are fed some cereal grains and protein supplements but roughage provides 60% to 65% of the diet. In some cases, the cattle are allowed to graze on pasture, and depending on the quality and type of pasture, the diet may be supplemented as necessary.



TYPICAL DAIRY FARM FLOW DIAGRAM

FIGURE 2

In 1972 the average production per milk cow was 4663 kilograms (10,271 pounds) of milk and 172 kilograms (377 pounds) of milkfat. Total for the dairy industry was 54, 606 million kilograms (120,278 million pounds) of milk and 2,006 million kilograms (4,420 million pounds) of milkfat, for a per capita consumption of milk and milkfat of 270 killograms (595 pounds) per year. Gross farm income from diary products in 1972 was 7.3 billion dollars. The ten leading milk production states in 1972 were:

		Millions of Pounds of Milk Plus Milk Fat	Gross Income (Millions of Dollars)
1.	Wisconsin	20,370	1,070
2.	California	10,803	611
3.	New York	10,560	645
4.	Minnesota	9,925	486
5.	Pennsylvania	7,293	482
6.	Michigan	5,098	299
7.	Ohio	4,708	284
8.	Iowa	4,671	236
9.	Texas	3,502	243
10.	Missouri	3,135	169

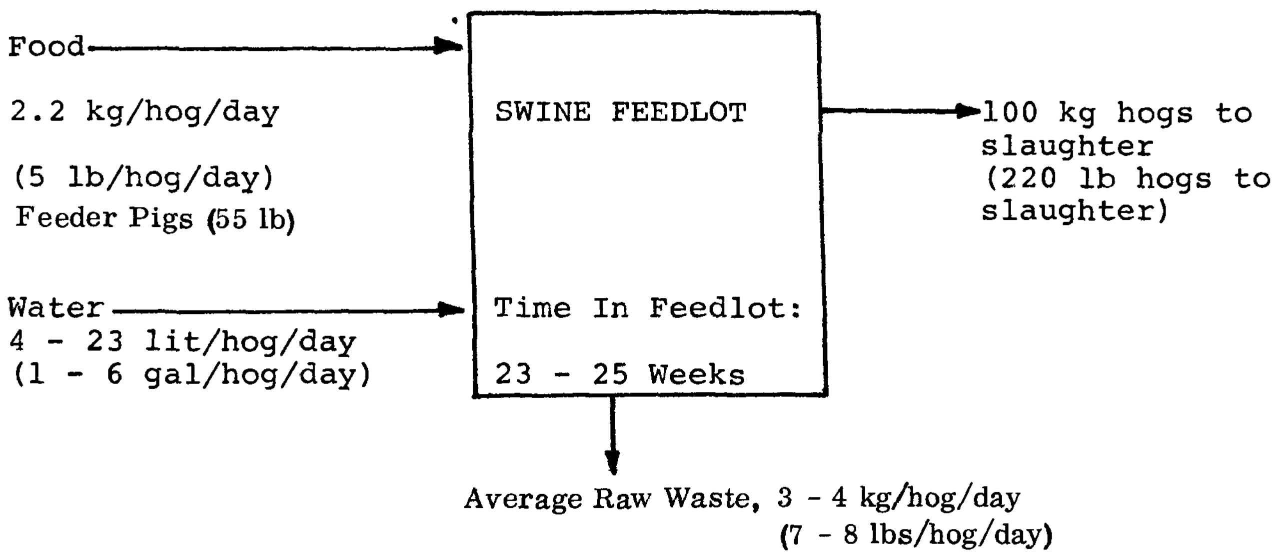
The distribution of dairies throughout the country follows closely the population distribution. The major influence is the distance from a market. Generally market distance is less than 480 kilometers (300 miles) for fluid milk and less than 160 kilometers (100 miles) for cheese plants. Climate and land values are probably the most important factor in determining the type of facility used. Cowyard facilities are almost exclusively located in the Southern half of the country. Free stall barns are mainly used in the North with only a small percentage in the South. Stall barns are almost exclusively found in the North. Pasturing of milk cows is more generally seasonal in the North.

SWINE

Nearly all swine are born and raised under feedlot conditions. The June 1, 1972 swine inventory was approximately 62 million. Of this figure about 15% are breeding animals and 85% are market animals. Market hogs reach a weight of about 100 kilograms (220 pounds) prior to slaughter; this takes about 23 to 25 weeks. Feed for an average 45 kilogram (100 pound) hog is approximately 23 kilograms (5 pounds) per day. The feed includes little or no roughage and consists mainly of grains, minerals and protein supplements. Hogs require from 3 - 4 kilograms of feed per every kilogram of grain. Total feed consumption for market hogs in 1972 was about 36.9 billion kilograms. Figure 3 shows typical input - output relationships for a swine feedlot.

A total of 91.5 million hogs were marketed for slaughter in 1972 providing an industry gross income of 5.5 billion dollars. The ten leading 1972 hog producing states are:

State	Hogs Marketed (1000 Head)	Gross Income (Millions of Dollars)
1. Iowa	20,795	1,270
2. Illinois	10,908	688
3. Indiana	7,201	468
4. Missouri	6,984	405
5. Minnesota	5,374	319
6. Nebraska	5,199	322
7. Ohio	3,889	226
8. Kansas	3,240	200
9. Wisconsin	3,096	163
10. South Dakota	2,905	176



TYPICAL SWINE FEEDLOT FLOW DIAGRAM

FIGURE 3

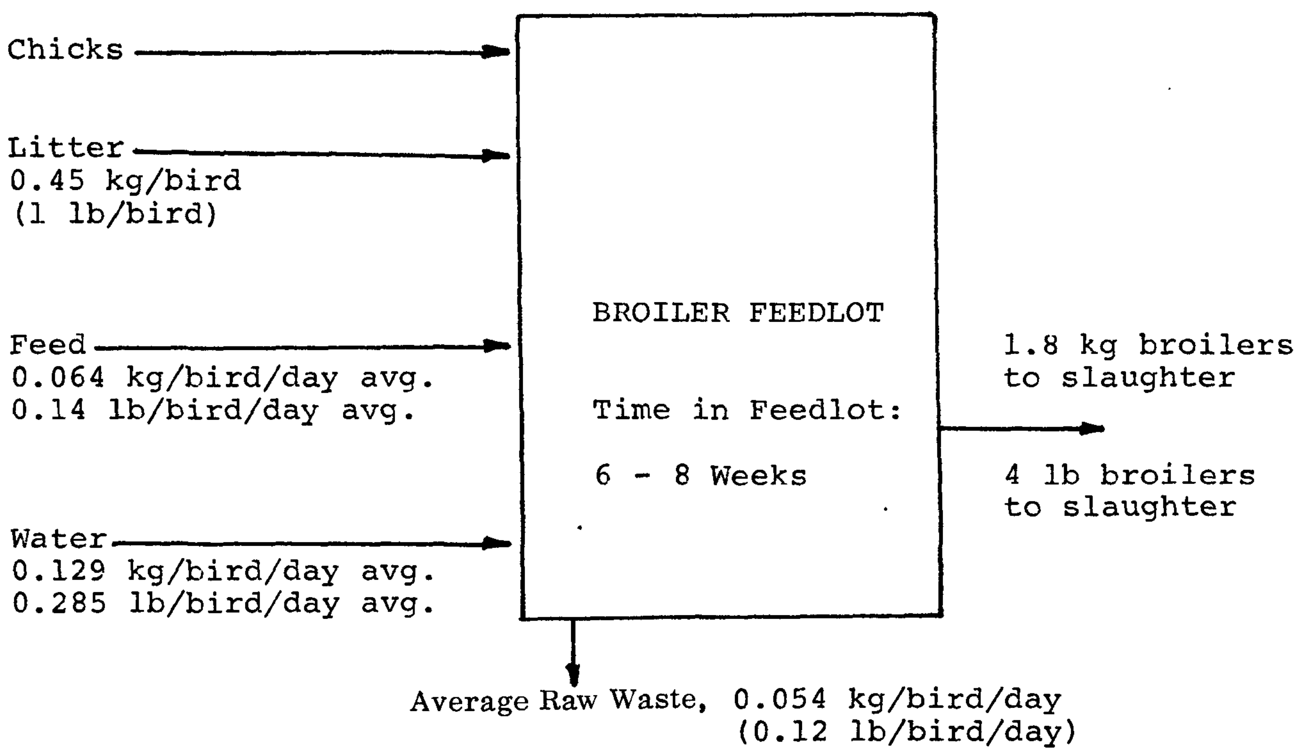
Solid concrete floor and slotted floor swine feedlots are becoming more prevalent in states with severe winters, however, open dirt lots are still the most common type of swine facility. The number of hogs per acre on dirt lots is sometimes low enough to provide a pasture situation where the wastes are absorbed naturally by the pasture. These cases do not represent feedlot conditions as previously defined. Depending on a variety of conditions the allowable animal density for pasture can be a maximum of about 75 (30) hogs per hectare (acre). Since the exact number of hogs raised under pasture conditions cannot be determined, the industry categorization in Section IV treats the swine industry as being completely operated on a feedlot basis. However, if a particular swine facility is able to operate under pasture or range conditions, it should not be subject to the feedlot effluent limitations outlined in Sections IX, X and XI.

CHICKENS

The chicken industry is comprised of two distinct types of operations; production of meat by the slaughter of broilers, and the production of eggs by laying hens.

Broilers

Figure 4 is a flow diagram of a typical broiler growing operation.



TYPICAL BROILER FEEDLOT FLOW DIAGRAM

FIGURE 4

All broilers are hatched and raised under feedlot conditions. There are approximately 468,000,000 broilers in feedlots at present of which 25,000,000 are breeding stock. At the time of slaughter, a broiler is 6 to 8 weeks old and weighs approximately 1.70 kilograms (3.75 pounds). Over this period of time feed con-sumption is 3.86 kilograms (8.5 pounds) per bird, for a feed

consumption per kilogram of gain of approximately 2.3 kilograms. The feed consists of grains, minerals and protein supplements. Total consumption of feed by growing broilers in 1972 is estimated to have been 12 billion kilograms (27 billion pounds).

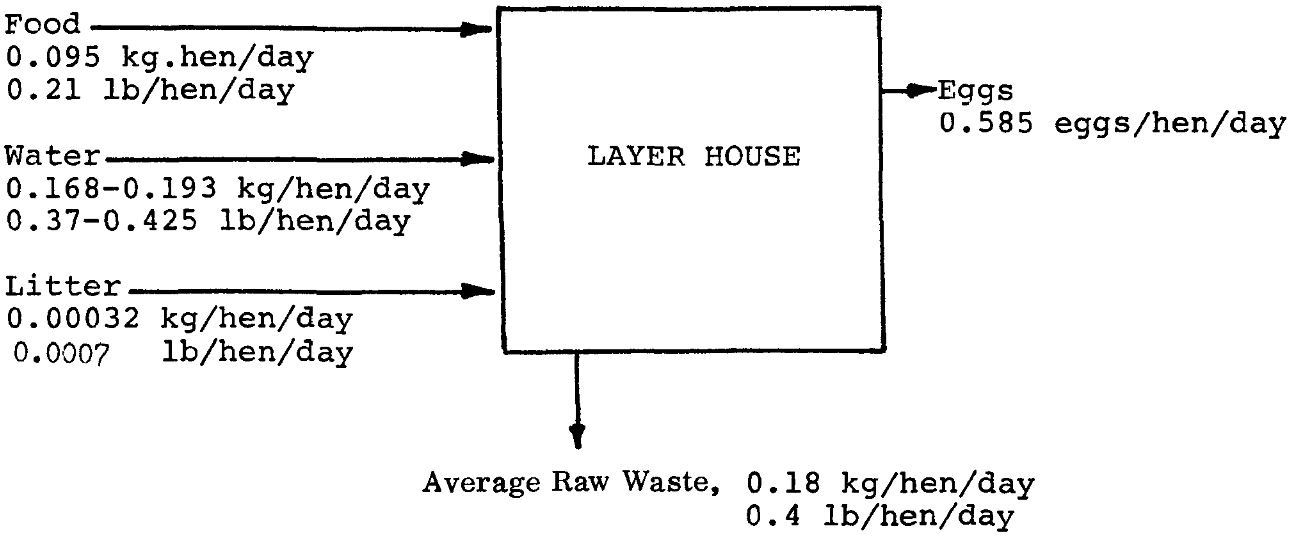
Broiler production in 1972 was 3.1 billion birds, which represents 5.2 billion kilograms (11.5 billion pounds). Total gross income was 1.62 billion dollars. The ten leading broiler producing states in 1972 were:

State	Production	Gross Income (Thousands of Dollars)
1. Arkansas	532,135	255,159
2. Georgia	442,937	214,692
3. Alabama	399,274	188,298
4. North Carolina	301,772	163,591
5. Mississippi	256,264	125,159
6. Texas	178,511	93,790
7. Maryland	177,247	108,528
8. Delaware	131,873	80,746
9. California	86,022	63,226
10. Virginia	77,238	41,987

Broilers are produced almost exclusively in floor litter houses. As can be seen from the above listing, the major production area is in the Southern states.

Layers

Like broilers, laying hens spend their entire life in feedlots. The present population of layers is 478,000,000. Beginning egg production at approximately six months of age, laying hens produce for about one year at which time they are slaughtered, usually for use in soup. Feed for laying hens consists of grains, minerals and protein supplements. Total feed con-sumption per bird is about 43 kilograms (95 pounds) over its 18 month life span. During this time the hen will produce about 18 dozen eggs. Feed consumption per dozen eggs on a gross basis is approximately 2.4 kilograms (5.3 pounds). On the basis of only the feed received during the laying period, this number drops to 1.9 kilograms (4.3 pounds). Total feed consumed by laying hens in 1972 is estimated to be 13.6 billion kilograms (30 billion pounds). Figure 5 is a flow diagram for a typical egg laying operation.



TYPICAL LAYING OPERATION FLOW DIAGRAM

FIGURE 5

Total egg production in 1972 was approximately 70 billion, for a gross income of 1.80 billion dollars. The ten leading states in egg production for 1972 were:

State	Number of Eggs (Millions)	Gross Income (Millions)
1. California	8,652	203.0
2. Georgia	5,465	160.0
3. Arkansas	3,795	114.0
4. Pennsylvania	3,599	91.5
5. North Carolina	3,433	98.4
6. Indiana	3,036	73.4
7. Alabama	2,852	81.0
8. Florida	2,840	58.9
9. Texas	2,685	75.4
10. Minnesota	2,584	44.1

Distribution of egg production across the nation follows somewhat the population distribution. Regional shares of production for 1971 were as follows:

Region	Percent of Production
North Atlantic	14
East North Central	14
West North Central	14
South Atlantic	21
South Central	20
Mountain	2
Pacific	15
	100

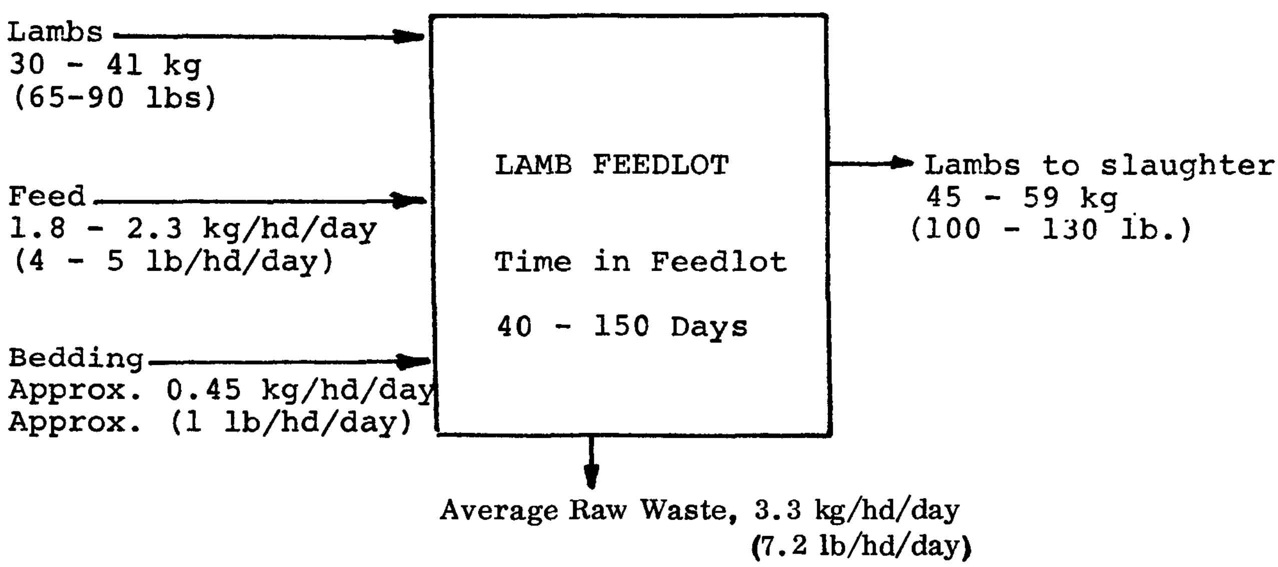
Although there are several different methods for confinement housing of laying hens, in different areas of the country, there is no evidence of a preference for particular systems. Worthy of note, however, is that about one hundred large layer operations exist which employ liquid manure handling systems - and a trend toward this type of system may become established.

SHEEP

The great majority of sheep and lambs in the United States are maintained on pasture or range land. Of those which are associated with feedlot operations, only a portion are maintained in feedlots on a full time basis. A significant number of sheep and lambs are maintained on pasture part of the time and in feedlots the remainder. As with swine, only the effluents from the feedlot situation are subject to the limitations of Sections IX, X, and XI.

The total population of sheep in the country on January 1, 1973 was 17,726,000 head. The January 1 date is used because it is the time of the highest population of feedlots. In the summer months, the number of sheep and lambs in feedlots is very low. Of the total number only 4,214,000 are in feedlots. Of this number 2,066,000 are in feedlots which do not use supplemental pasture. The remaining 2,148,000 utilize supplemental pasture on the average of 50% of the time. Figure 6 is a flow diagram for a typical sheep feedlot.

Feedlot lambs are generally born and raised to a weaning weight of 30 to 40 kilograms (65 to 90 pounds) on range or pasture. The remainder of growth to about 45 to 60 kilograms (100 to 130 pounds) (slaughter weight) is accomplished in the feedlot. An average lamb receives about 1.7 kilograms (3.8 pounds) of feed per day. The feed consists of 85% concentrate ration and 15% roughage. Feed conversion efficiency for a lamb is about 5 to 7 kilograms of feed per kilogram of grain.



TYPICAL LAMB FEEDLOT FLOW DIAGRAM

FIGURE 6

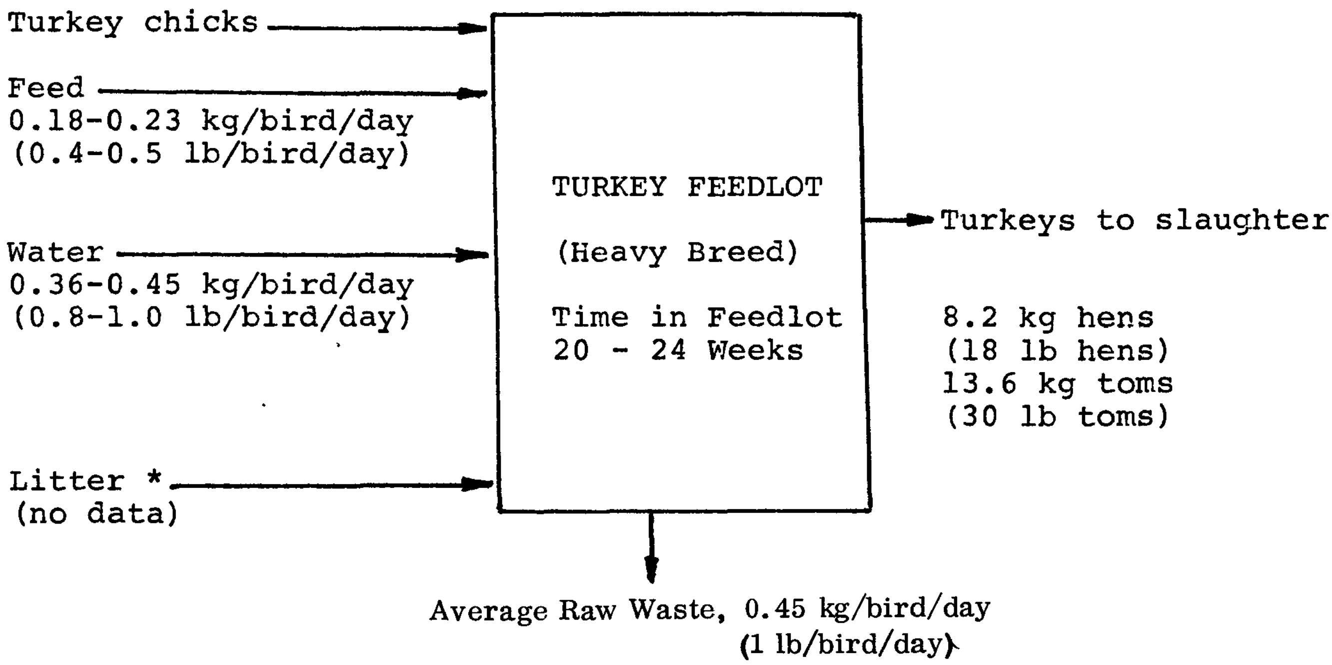
In 1972, 630 million kilograms (1.4 billion pounds) of sheep and lambs were marketed. Of this total number, it is not known what percentage was from feedlots. Gross income was 358 million dollars. The ten leading sheep producing states were:

State	Pounds Marketed	Gross Income (Millions)
1. Texas	207	54
2. Colorado	201	57
3. Wyoming	96	19
4. California	89	24
5. South Dakota	84	22
6. Iowa	75	20
7. Idaho	74	19
8. Utah	65	17
9. Montana	54	12
10. Ohio	45	12

The distribution of feedlot operation throughout the country is somewhat vague; however, Texas and Colorado are the most important feedlot states followed next by Wyoming, Nebraska and Minnesota. Note that not all of these states fall in the top ten production lists. This again emphasizes that many lambs are raised under non-feedlot conditions.

TURKEYS

Essentially all turkeys are bred and raised in feedlots. The only exception if that some open facilities operate at such a low density of birds per hectare that vegetative cover can be maintained. This amounts to pasture or range conditions and does not fall under the limitations of Sections IX, X and XI. In the turkey industry the term range is generally used to designate any open facility regardless of whether or not it is a true range operation as defined by this report. In most cases what is called "range" is actually a feedlot for reasons discussed previously.



* For Housed Feedlots Only

TYPICAL TURKEY FEEDLOT FLOW DIAGRAM

FIGURE 7

The summer population (time of maximum number due to seasonal operations) of turkeys in the United States is estimated to be 90,200,000 birds. The turkeys are fed a ration of grains, minerals and protein supplements. Slaughter weights and ages are:

	Heavy Breed		Light Breed (10% of total turkeys)	
	Weight kg (lb)	Age (Weeks)	Weight kg (lb)	Age (Weeks)
Hen	8.2 (18)	20	4.5 (10)	20
Tom	11 (24)	24	8.2 (18)	24

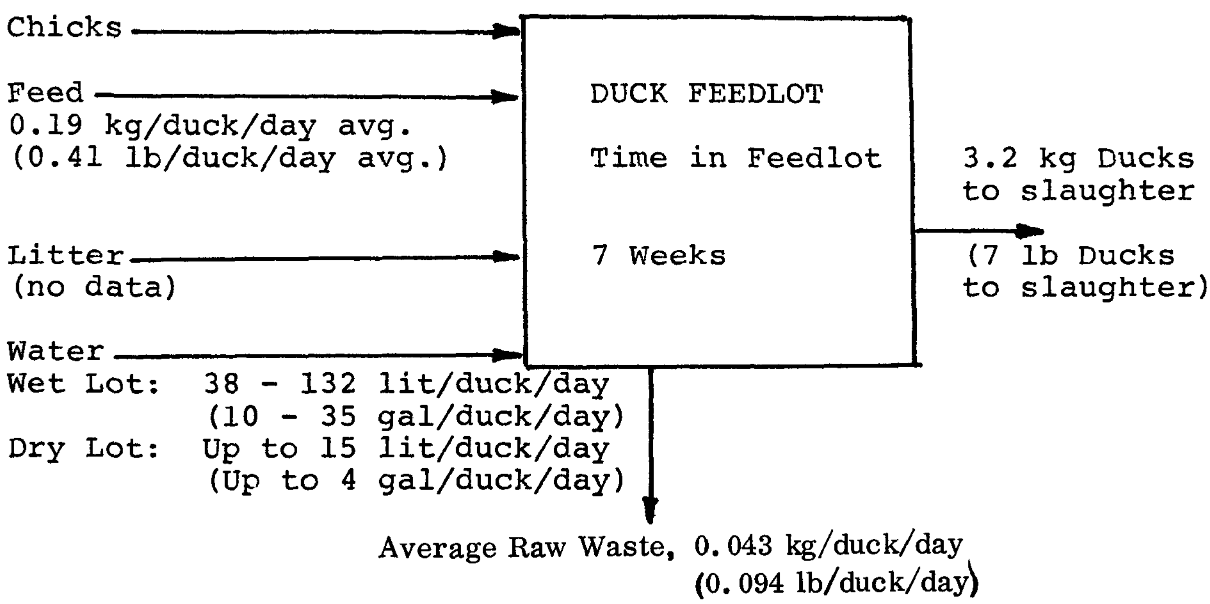
Total turkey production in 1971 was 120,085,000 birds. Live weight slaughtered was 1.02 billion kilograms (2.26 billion pounds) for a gross income of 500 million dollars. The top ten turkey producing states were:

State	Pounds Produced (Millions)	Gross Income (Millions)
1. California	321	70
2. Minnesota	308	66
3. North Carolina	183	42
4. Texas	173	36
5. Missouri	170	36
6. Arkansas	155	36
7. Iowa	131	27
8. Utah	92	20
9. Virginia	92	20
10. Indiana	84	20

Favorable climatic conditions favor the use of open feedlots in the Southern states. Housed facilities are more prevalent in the North.

DUCKS

The total present domestic duck inventory is approximately 1.86 million ducks. The ducks are hatched and raised to a slaughter weight of about 3 kilograms (7 pounds) in 7 weeks. The feed consists of grains, minerals and protein supplements. Feeding efficiency of ducks is about 2.5 to 3.5 kilograms of feed per kilogram of gain. Total feed consumed by the duck industry in 1972 was approximately 124 million kilograms (273 million pounds). Figure 8 is a typical duck feedlot flow diagram.



TYPICAL DUCK FEEDLOT FLOW DIAGRAM

FIGURE 8

A total of about 13 million ducks are produced in this country each year with the largest concentration on Long Island, New York. For 1969, the top ten states for duck production were as follows:

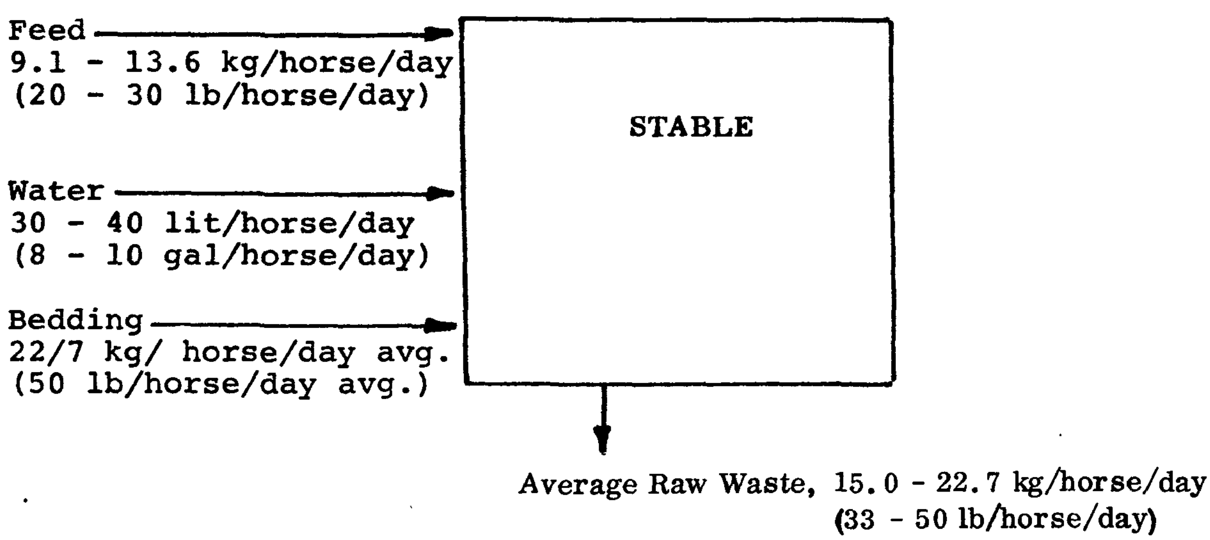
State	Number Produced (Thousands)
1. New York	6,099
2. Indiana	2,989
3. Wisconsin	1,487
4. California	766
5. Illinois	646
6. Virginia	456
7. Ohio	382
8. Missouri	310
9. New Jersey	257
10. Pennsylvania	87

Wet lot duck operations represent 80% of all feedlots and is the predominant method of production in the East. The remaining 20% are dry lots which predominate in the Midwest. Forty-five percent of all ducks produced are raised on Eastern Long Island.

HORSES

There are a total of approximately 7.5 million horses in the United States, comprised of pleasure, farm and track horses. Except for special circumstances such as resort ("dude") ranches in the West, available data shows that pleasure and farm horses do not exist in large groups in close confinement. On the average there is usually a minimum of 0.4 hectare (one acre) grazing area available for each horse and the actual time held in stalls or barns is not significant.

Figure 9 is a flow diagram for a typical horse stable facility.



FLOW DIAGRAM OF TYPICAL RACETRACK

FIGURE 9

Horses housed in stables at racetracks represent an important segment of the industry category of horses which is considered as a feedlot. A total of about 275,000 horses are currently housed at various racetrack operations around the country. Racing horses consume about 9 to 11 kilograms (20 to 25 pounds) of feed per day. When a horse is not racing this may drop to half this value.

The three major types of horse racing are thoroughbred, harness and quarter horse. Tracks of these types and many others are located throughout the country. Including pleasure and farm horses, the following states have the greatest horse population:

1. Texas
2. California
3. Oklahoma
4. Colorado
5. Maryland

SECTION IV

INDUSTRY CATEGORIZATION

GENERAL

The feedlot industry is most logically treated a a function of animal type. For this study, the following animals were included: beef cattle, dairy cattle, swine, chickens, sheep, turkeys, ducks and horses. This section details a description of the process of growing each of these types of animals and the factors utilized in further categorizing each animal type, and identifies the final industry categorization for purposes of effluent limitations.

The subcategories derived as a result of the analyses given in this Section are as follows:

(1) Beet cattle, open lot
(2) Beef cattle, housed lot
(3) Dairy, stall barn
(4) Dairy, free stall barn
(5) Dairy, cowyard
(6) Swine, open dirt or pasture
(7) Swine, slotted floor houses
(8) Swine, solid concrete floor
(9) Chickens, broilers
(10) Chickens, layers
(11) Chickens, layer breed and replacement
(12) Sheep, open lot
(13) Sheep, housed lot
(14) Turkeys, open lot
(15) Turkeys, housed lot
(16) Ducks, wet lot
(17) Ducks, dry lot
(18) Horses, stables

In addition to the general description discussion in Section III, additional details regarding the production methods specific to each subcategory are presented below, followed by a discussion of factors used in arriving at the subcategorization.

Beef Cattle

Open Lot - An open lot is one which cattle are either entirely exposed to the outside environment or in which a relatively small portion of the feedlot offers some protection. The limited protection afforded may be in the form of windbreaks, shed-type buildings with roofs and one to three sides enclosed, roofs only, or some type of lattice-work shade.

The floor of the open feedlot may be of dirt with a flat slope of up to 3%, moderate of 3% to 8% or a steep slope in excess of 8% or may be a paved surface. Cattle in open feedlots are generally maintained at densities of one animal per 6.5 to 27.9 square meters (70 to 400 square feet), if the lot is unpaved, and less than a density of one animal per 6.4 square meters (90 square feet) if it is paved.

Just under 96% of the 14 million head are fed in open lots and 93% of the total are on open dirt lots with flat to moderate slopes. Nearly 3% are on dirt lots with steep slope; the number of paved lots is less than 1.0%. For all of these facilities any waste water discharge that occurs is caused by rainfall with some contribution from watering systems such as overflow waters.

Housed - A housed facility is a building in which cattle are kept under a roof at all times. Buildings may have sides which are either entirely open or completely enclosed, may be equipped with a solid dirt floor or concrete, or may have slotted floors. Solid floor facilities utilize bedding material to absorb the moisture of the excreted wastes and to maintian these wastes in a solid or semi-solid form. Slotted floor facilities utilize either a shallow pit beneath the floor with daily waste removal or deep pits for waste storage. They are generally stocked with cattle at a density of less than about 2.8 square meters (30 square feet) per animal.

Housed operations comprise just over 4% of the total production with slightly under 2% being slotted floor and slightly over 2% being solid floor operations. Of the slotted floor operation, the deep pit facility is predominant.

Dairy Cattle

The inventory of milk cows and replacement heifers on farms, as of January 1, 1971, totaled 16 million head. The 11.5 million milk cows are kept in three major types of production systems -stall barn with milk room, free stall barn with milking center, and cow yard with milking center.

Stall Barn With Milk Room - Just under 60% of the dairy industry is on farms consisting of stall barns with a milk room. This method of production is predominant in the Northeastern and Northcentral portions of the country. Milk cows and replacements are restrained to a fixed location where they are fed and cows are milked. The barns are generally insulated and mechanically ventilated. The amount of time spent in the barn varies from as high as 100% to as low as 20% depending on the climate, land availability and other factors. The remainder of the time the cows are on pasture. Milk is brought manually for small systems, or by pipeline for larger systems, to the milk room where it is cooled and stored. Milking equipment is washed daily and stored in the milk room. Bedding is widely used in the stall area where it absorbs the moisture of the excreted manure, and the total semi-solid waste is collected in gutters and removed by mechnical means. Milk room wastes are the only liquid wastes generated by this production method which must be managed. Runoff from rain will not be contaminated unless the manure removed from barns is stored in the open and subjected to this exposure.

Free Stall Barn With Milking Center - This type of facility is used with approximately 16% of the dairy inventory on farms, but is rapidly increasing in use for larger production systems. Where pasture is not available, milk cows and replacement heifers are kept under roof in barns but are allowed free movement between resting stalls and feeding areas. Where pasture is available, the animals spend as much as 80% of the time on pasture. The barns are generally not insulated and are naturally ventilated. In very severe climates, insulation and mechanical ventilation can be found. The milking center includes a "parlor" and milk room. Cows are milked in the parlor twice daily and the milk is mechanically transferred to the milk room where it is cooled and stored. Milking equipment is cleaned daily in both rooms. Over 90% of the free stall barns still use bedding in the resting area. Manure is usually collected in alleys and mechanically scraped out of the barns. Some used bedding may be added to the manure to improve its handleability. For these systems semi-solid wastes from the barn and milking center are generally the same as those from the stall barn system. The remaining 10% of free stall barns utilize liquid manure systems split equally among three types, solid floors with liquid storage, slotted floors and liquid flush.

In northern regions, solid floor barns with separate liquid manure storage are becoming more popular than slotted floor barns with sublevel storage. In southern regions, liquid flushing systems predominate with collection of the diluted wastes and daily or other periodic irrigation of fluid wastes to the land. The milking center wastes for these liquid manure systems are generally added to the manure storage to reduce the total solids concentration for ease of pumping.

Cow Yard With Milking Center - This method of production is used with approximately 25% of the dairy inventory on farms, and is predominant in the southern portions of the country. Where the climate is hot and dry, milk cows and replacements are maintained in open sided shelters which provide shade, and in cooler climates, the shelters are partially enclosed and include bedded packs or free stalls.

Free access is provided to open dirt or paved exercise yards while feeding areas are normally paved and have fence line feed bunks. These type systems are common for herds larger than 200 animals. Cows are moved twice daily to a milking barn or parlor. Milking equipment is washed daily and the use of "cleaned-in-place" equipment is increasing.

Bedding is seldom used in large yards in the dry climates but often used in shelters in cooler climates. Manure may be removed for field spreading weekly from paved yards, or after the winter season from bedded shelters and partially paved yards. With large earthen yards, manure may be mounded periodically and removed annually for field spreading. The liquid waste discharge from this type of production system consists of milking center wastes and runoff resulting from precipitation on the exposed surfaces of the cow yard.

Swine

The production of piglets for subsequent use as feeder pigs is for the most part accomplished under feedlot conditions. Of the 61.6 million swine on feed in the United States during 1972, 85% were market animals and 15% were breeding animals including those in pedigree operations. These animals were produced in three types of production systems -- open dirt or pasture lots, fully roofed buildings with slotted floors and solid concrete floors with partial or full roofs. Open dirt or pasture lot is the most predominant method of swine production, and accounts for 60% of the national production capacity. Open dirt or pasture units have the lowest density of hogs and are considered a confinement operation since feed is brought into the fenced area. The recommended stocking density is 62 market hogs per hectare (25 market hogs per acre), but densities up to 490 animals per hectare (200 animals per acre) are employed in some cases. The most widely practiced stocking density is estimated to be between 62 and 250 animals per hectare (25 and 100 animals per acre). The recommended pasture stocking density is 49 to 74 animals per hectare (20 to 30 animals per acre) on permanent pasture such as Bermuda grass or fescue and ladino clover. Beyond this density, bare areas will begin to appear. For pasture to survive, animals must be removed during the dormant or nongrowing season or lots rested by a rotation scheme. Lots with 250 or more hogs per hectare (100 or more hogs per acre) will not support vegetative cover. At higher densities, any manure buildup will generally be disked into the soil or scraped up and spread on crop land so that manure packs characteristic of high density beef feedlots do not usually occur.

Runoff is the primary waste output from the pasture or dirt lot production unit. Animal density and annual rainfall are the primary factors to be considered with respect to the degree of pollution in the runoff. Temperature, vegetation, contributing watershed area and snow melt relationships are additional factors which are involved.

Slotted Floor Houses - Building with complete roofing and slotted floors is a recent development in the swine producing industry and presently accounts for 15% of the total production capacity. These buildings generally consist of two types, those with only a portion of the floor space slotted and those with the entire floor space slotted. Slotted floors with temporary storage pits underneath reduce the hand labor required to clean pens and thus are responsible for the continuing trend towards fully enclosed houses with total slotted floors.

The first buildings with partial slotted floors were designed with a pen size of 1.2 meters to 1.5 meters (4 feet to 5 feet) wide and approximately 4.9 meters (16 feet) long with 1.2 meters (4 feet) of this length as slats. Average pit depth under the slats was about one meter (3 feet). With time, more space in each pen was slotted because cleaning time could be reduced. Many units for market hogs were developed on the basis of 0.07 square meters (8 square feet) per animal with one-third slotted. Many of these buildings serve as a combination nursery and finishing unit. A common pen size is 3.0 meters by 7.3 meters (10 feet by 24 feet) for three litters or approximately 30 pigs (about 0.7 square meters, 8 square feet of living area per pig). Storage capacity in the pit is 0.1 to 0.3 cubic meters (5 to 10 cubic feet) per pig for a depth of 0.6 - 1.2 meters (2 to 4 feet).

Buildings with partially or totally slotted floors may have storage pits, oxidation ditches or under-house lagoons incorpor ated as an internal component of the production unit.

Systems with manure storage pits predominate and account for over 90% of all slotted floor operations. Pits are generally filled with a minimum of 15 centimeters (6 inches) to a maximum of 0.6 meters (2 feet) of water before pigs are placed in slotted floor pens, or after complete wastewater discharge. This allows for better cleaning when pits are emptied as well as reducing odors initially. Spillage and overflow from waterers and mist from fogging for summer cooling add to the quantity of liquid which must be handled. The amount of washwater employed to clean different partially slotted units represents the major difference in the volume and concentration of wastes stored in partially or totally slotted production units. Additionally, the manner in which pit waste is discharged will affect concentration. Many storage pits are completely emptied only every three to six months to reduce labor and water precharge requirements. Pits may be equipped with an overflow pipe to control water level and thus supernatant may be continously released or partially discharged as necessary. The concentration of a supernatant overflow or partial discharge will be less than the average concentration of the total waste load for a complete pit emptying.

Systems with integral oxidation ditches under slotted floors are less than 5% of all slotted floor production systems. The variable amounts of washwater used for different slotted floor configurations and management schemes will affect the volume of waste load and the concentration of ditch mixed liquor. Such Any dilution effects due to excessive water use, may mask oxidation ditch operation and performance.

Discharge from the oxidation ditch is considered the waste load from a production facility with such an under-house treatment unit. This waste load consists of the mixed liquor which may be removed continously or periodically depending upon operational and management techniques.

Systems with under-house lagoons also are less than 5% of all the slotted floor production systems. Since these lagoons are usually exposed to the environment at the sides and under the houses, the effect of wash water volume on the quantity and quality of lagoon liquid or overflow, will generally be insignificant compared to the influence of climatic relationships and lagoon performance.

Solid Concrete Floor - Production units with solid concrete floors may be partially or totally roofed. About 25% of the swine production capactiy if of this type and units can vary from those which are partially open having 2.3 square meters (25 square feet) of floor space per market animal, to those which are completely roofed with only 0.9 square meters (10 square feet) of floor space. The most prevalent practice is to have 1.1 to 1.4 square meters (12 to 15 square feet) per animal with one-half to two-thirds under roof.

Bedding of wood shavings, straw or sawdust is used in some farrowing houses and nurseries because of its insulation and absorptive characteristics; however, this prepresents an insignificant portion of the wastes from the swine industry.

Wastes on the concrete pen floors are periodically washed or scraped into a collection gutter. High pressure, low volume hose systems allow more rapid and efficient cleaning and thus, large reductions in washwater quantities. Drinking cup spillage, fogging water and urine continuously flow into the collection gutter. Rainfall and roof runoff that have access to the concrete floors or drainage that enters the waste collection and conveyance system contribute to the amount of wastewater that must be handled. The amount of rainfall that must be handled is small, amounting to an average of about 1.3 to 1.9 liters (1/3 to 1/2 gallons) per day per animal due to the high animal stocking rate. These liquid wastes leaving the gutter may enter a concrete tank or some other temporary storage, a lagoon, or discharged to adjacent land.

Chickens

The category of chickens consists of two primary types of production which prevail on a national basis - broilers and layers. Therefore, discussion of industry categorization will begin at that level.

Broilers - The broiler industry encompasses three basic processes:

a. Development of breeding stock;
b. Production of broiler chicks by breeding stock, and
c. Growth and slaughter of broilers.

These operations may be separate or in combination. The development of breeding stock by specialized farms involves the controlled breeding of high quality birds. The purpose is one of constantly improving broiler birds by selective breeding. The birds produced by such an operation are then used to produce chicks which are grown on a grain and meal concentrate ration and slaughtered as broilers.

Breeder stock is kept in houses which includes nesting, litter covered floor area, and slotted or wire covered perching area over pits. The wastes consist of a mixture of manure and litter plus manure scraped from the pit. The litter, which consists of wood shavings or similar materials, is used for absorbing the moisture in the wastes. The weight of the breeder stock birds is about 2.7 kilograms (6 pounds) for hens and 3.6 kilograms (8 pounds) for roosters with an average of one rooster for every ten hens. At the end of their useful life (1-1/2 years) these birds are usually sold as roasting chickens.

Broilers are usually raised in houses using a floor litter system. The birds are grown to a weight of about 1.8 kilograms (4 pounds) in approximately eight weeks. The waste is in the form of mixed litter and manure. The litter is replaced periodically and may remain in the house for as long as a year. It may be turned with a plow between batches of chicks and various chemicals (to aid in composting) and more litter may be added each time.

<u>Layers</u> - The egg laying industry is comprised of two different operations. These are:

a. Laying hen production
b. Egg production.

The industry operates with a total of 478,000,000 birds. About 5,000,000 of these are breeding stock with a ratio of one rooster for every ten hens. Replacement layers (pullet) account for 158,000,000 birds. The remainder (315,000,000) are producing layers.

Breeding birds are maintained in circumstances similar to broilers and the wastes are similar. Roosters and hens weigh about 3.6 kilograms (8 pounds) and 2.7 kilograms (6 pounds) respectively.

The growing pullets are maintained in cages over pits (20%) or in floor litter systems (80%). In very few cases floor litter systems are used in the first few weeks followed by cage systems until laying age.

Laying hens are maintained in several types of housing systems. These are:

Cages over Dry Pits 70%
Floor Litter/Pit Perch 20%
Slat-Wire/Litter Pit 5%
Cages over Dry Pits (Ventilated) 3%
Cages over Wet Pits 2%

The cage systems use several set-ups for the cages which are only different in geometry with no effect on the waste load. Both dry pit systems utilize mechanical removal of wastes. Fans are used in the ventilated system for drying the wastes. The pit in this type of system is generally deeper than pits used in the other system. In the wet pit system, water is added to facilitate pumping of the waste in the form of a slurry.

The floor litter/pit perch system utilizes a litter covered floor area with nests for laying and perches mounted over pits. Food and water are available in the floor area. The slat-wire/ litter pit system is essentially the same except that slatted floors or wire meshes are used over the pits and food and water are placed in this area.

Sheep

As shown in Section III, the total population (January 1970) of breeder sheep and lambs on feedlots was 4,214,000; 3,604,000 of which are on open lots and 610,000 of which are housed. These statistics are somewhat misleading in that they are not in anyway indicative of the distribution of sheep and lambs at any other time of the year. Actually, there are more sheep and lambs in the United States in the summer than on January 1st. However, in the summer the vast majority of sheep and lambs are either on range or pasture. Hence, January 1st was chosen for reporting since sheep and lamb feedlots have the greatest population at that time.

Cereal grains make up the bulk of lamb fattening ration but some roughage is desirable. Bedding is found only in the housed facilities.

Open Lot - Open lots include completely exposed dirt lot operations as well as partial confinement (e.g. sheltered feeding areas) where the open area is a corral. The wastes from these operations include both manure and runoff. Breeding flocks in open lots are stocked at a rate of from 1.9 to 19 meter sq. (20 to 200 ft. sq.) per animal. The stocking rate for lambs is about 1.4 to 9.3 meter sq. (15 to 100 ft. sq.) per animal.

Housed - Housed lamb production represents the most modern and concentrated lamb feeding operation. Wastes from such an operation are either solid (scraped) or liquid (pumped) depending on the chosen waste management scheme.

Turkeys

The two major methods of production consist of open lots with about 78% of the production capacity and housed production for the remaining 22%.

Open Lot - The open lot consists of a brooder house where the turkey poults are kept for the first eight weeks after hatching and outdoor confinement areas where the birds are fed to a finished market weight. The latter period averages nine weeks for hens and fifteen weeks for toms. Normally open lots grow one flock of birds per year. Some open lots utilize the brooder house to produce a second flock, in which case these birds are finished in confinement.

The wastes produced in the brooder house consist of the manure excreted by the birds and the litter material which is used to cover the floor; both are removed from the house by mechanical means between groups of birds. The wastes produced in the outdoor confinements or range area are generally not of sufficient mended value of 620 birds per hectare (250 birds per acre) up to 1240 birds per hectare (500 birds per acre). Good management practices consist of either rotating range areas and/or moving the feeders and waterers to prevent the accumulation of wastes in any one area in order to prevent the vegetation from being completely killed. This is also advantageous for disease and parasite control. The surfaces of range areas are plowed and planted in cover crops during idle periods. The wastes deposited on open range land may have a pollutional discharge due to runoff from incident rainfall.

Housed - Production of slaughter birds consist of poult growing for the first eight weeks after hatching in a brood house and then feeding to finish market weight in confinement rearing houses. The finishing houses are similar to brood houses with the exception that more space is allowed for each bird. Both the brood house and finishing house utilize litter on the floor and wastes are removed periodically by mechanical means.

The breeding portion of the industry is usually a separate farm and supplies chicks to open and housed operations. The breeding operation accounts for about 1/2% of the total number of turkeys on feed and consists of breeding flock maintained in enclosed facilities. The waste produced in this operation is from mature birds maintained on litter. mechanically removed periodically from the breeding houses.

Ducks

Duck raising facilities may be considered as being in two major groupings; wet and dry lots. The primary difference between the two is the amount of water used. In feedlots, the primary purpose for allowing ducks free access to swimming water is for improvement in the quality of the feathers (used as down). However, the quality of down is apparently not materially affected by growing in total dry lot facilities. Many of the larger producers have integrated facilities. That is, breeding, hatching, growing and slaughtering facilities are located on the same complex with the waste treatment plant usually designed to handle the entire waste load of the facility.

Wet - The largest group (80% of the population) are the "wet" lots in which the ducks have access to water runs. Local surface and groundwater is channeled to supply the birds swimming areas ("runs") and to facilitate a controlled discharge of waste water for treatment and disposal. The slopes leading to the waters edge collect fecal material which is washed into the water during rainstorms. These runs may be combined with some shelter facilities. For the last few weeks of the growing period, the birds are completely raised on the run and adjacent land. The amount of water provided in these "wet" lot ranges from 38 to 132 liters/duck/day (10 to 35 gallons/duck/day).

Dry - A second category of feedlot is the "dry" lot with the Midwest being the area tending more toward this totally environmentally controlled type of facility. The main difference from a wet lot is the reduced amount of water used in the raising of the duck. Dry lot facilities are usually constructed with flushing troughs placed under a wire floor portion of the building. Feeders and waterers are also in this area providing for collection of some of the manure. The remainder of the floor is solid covered with litter. Flushing results in the dilution of the manure and movement of the slurry into the processing plant. Water usage for a dry lot generally ranges up to 15 liters/duck/day (4 gallons/duck/day).

Horses

Of the approximately 7,500,000 horses in the country, by far the largest number (75%) fall into the "pleasure" category. For the most part, these are backyard horses used for occassional riding. Of this number, approximately half are located in suburban areas with the balance housed in rural areas.

The suburban horse is stalled an average of one-quarter of the time, the rest being spent out-of-doors. Some local ordinances restrict the number of horses allowed on a parcel of land with the minimum usually being one horse/acre. The amount of bedding used varies considerably from 4.5 - 18.2 kilograms/day/animal (10 - 40 pounds/day/animal). Bedding material is usually straw but sawdust and wood shavings are occasionally used. The purpose of the bedding is two-fold. It acts as an absorbent for the moisture excreted by the animal, and it acts as a cusioning agent for the animal when it lies down. The manure produced per day per animal is composed of 15.0 - 22.3 kilograms (33 - 50 pounds) of fecal waste at 75 - 80% moisture, 3.6 - 4.5 kilograms (8 - 10 pounds) of urine at 90% moisture and varying amounts of bedding. Good management practice dictates frequent stall cleaning, usually daily.

The second half of the "pleasure" horse population is housed in rural areas. As such, the amount of stalling will be less since more open roaming land is available. The amount of bedding used and manure production in the stall areas will, in general, be less than that for the suburban horse population. Certain special circumstances such as resort ranches or riding clubs are likely to have corral/stable facilities functionally similar to any other feedlot.

The remainder of the horses in the country (25% of the total) are considered "commercial". This may be broken into two groups. One of these is "general farm animals" comprising 85% of this category. These are used for general work around ranches and are stalled only a small percentage of the time. Bedding provided is slightly greater than for the pleasure horse averaging 9.1 - 18.2 kilograms/day/animal (20 - 40 pounds/day/animal) rather than 4.5 - 18.2 kilograms/day/animal (10 - 40 pounds/day animal). This is due to the "equipmentlike" nature of the animal that results in better care. In addition, bedding material is more readily available on facilities such as these, and the wastes are more easily disposed of leading to a more generous use of bedding. Excrement production for these animals is the same as the others discussed above.

For purposes of grouping, except for resort ranches, riding clubs or similar facilities, all three types of horses discussed so far may be placed in one group. In varying degrees they deliver their excrement directly to the natural eco-system, thereby obviating the need for processing. In the case of the individual owning a few backyard horses, the possibility of restrictions beyond the local level seems very slight.

The remaining category of "commercial" horses are of the racing class. These animals are carefully tended. Except for those times on the track or in training they may be considered continually stalled. These stalls are cleaned daily with fresh straw bedding averaging 22.7 kg/day/animal (50 lb/day/animal) provided. Tradition and fear of damage to the feet have slowed any change even in bedding material. Together with resort ranches or riding clubs, this is the only type of horse which can be considered to be maintained under feedlot conditions.

CATEGORIZATION

The following factors were considered in establishing categories for all the animal groups.

a. Animal type
b. Treatability of wastes
c. Location and climate
d. Size and age of facilities and equipment
e. Raw materials used
f. Product produced
g. Production process employed
h. Product or waste impact of any group or subgroup
i. Characteristics of waste produced.

Animal type is of course a significant factor and was used as the first level of categorization. In all cases, the treatability of wastes was not a factor for categorization since, except as discussed later for the category of ducks, all the wastes are so concentrated that there are no known practical technologies available to treat the waste to a degree which will allow an effluent to be discharged directly to navigable waterways. Location and climate have a material effect upon pollution control methodology for any given operation or segment of the industry. However, the impact of either location or climate is so highly variable as to prove to be unreliable in defining or substantiating any subcategories. The size of facilities was also not considered a significant factor since the pollutional potential is the same per unit of animal production for all sized facilities. Moreover, the essential requirements governing waste management and control are closely related for all facility sizes. The age of facilities is likewise not a significant factor; any effect of age is predominately reflected in the type of production facility, and this is taken into consideration through the production process factor.

Beef Cattle

Raw materials used in each case are feed, water and, in some cases, bedding. Since, except for bedding, these materials are common in all cases, they cannot be used as a basis for categorization. The difference of bedding being used in limited circumstances is not considered significant since any effect it has on a category shows up in the waste characteristics and is considered at that point. The product produced is also not considered a discriminator for categorization since the product produced in each case is beef cattle for slaughter. The production process employed is a significant factor in categorization since different types of facilities show materially different process features and frequently lend themselves to different means of pollution abatement. The production impact of certain types of facilities does not judify their being separated into individual categories. In this case they are placed in other categories which are most nearly similar. Waste characteristics are considered as a pertinent factor in that this factor incorporates specific differences in the amount and nature of waste constituents particularly related to rainfall runoff (open lots) and relatively undiluted solids (housed lots).

Figure 10 shows the structure of the confined beef cattle industry by type of production process employed. The capacity of each type of facility as of January 1973 in terms of number of animals on feed at any one time is indicated. In addition, the type of wastes generated by each facility is also shown in generic terms. Detailed definitions of the wastes are given in Section V.

The industry is divided into two categories for the purpose of effluent limitations. The major factor in this case is the production process employed, open lot versus housed facilities. These open lot methods each have similar wastes, giving further cause for such grouping. The paved lot is somewhat different as a production method but does not have the product impact in terms of animal capacity to justify a separate group. The housed facility category is barely numerically significant but represents a very different production process. The wastes from the various segments of the housed operations are similar, but significantly different from the wastes from an open feedlot. The use of bedding in the solid floor facilities represents a minor difference and since 350,000 head raised on bedding is only a small percentage of the total 14,000,000 head, there is not justification for a separate category.

Dairy Cattle

Raw materials used are similar to those discussed for beef and the rationale for not being a basis for categorization is the same. The same argument holds for product produced since throughout the diary industry it is milk. As with beef, the production process employed is considered a significant factor in categorization as are the waste characteristics.

Figure 11 shows the structure of the dairy industry by type of manufacturing process employed. The capacity of each type of facility as of January 1971 in terms of number of animals in production at any one time is indicated. In addition, type of wastes produced by each facility is shown in generic terms.

The dairy industry is divided into three categories for the purpose of effluent limitations. The major factor is the production process employed; stall barn, free stall barn and cowyard with milking center. The differences in waste outputs between the stall barns and the free stall barns is not significant; however, the numerical significance of each category is such as to further justify their separation. Within the free stall barn category, the subcategories of liquid storage,

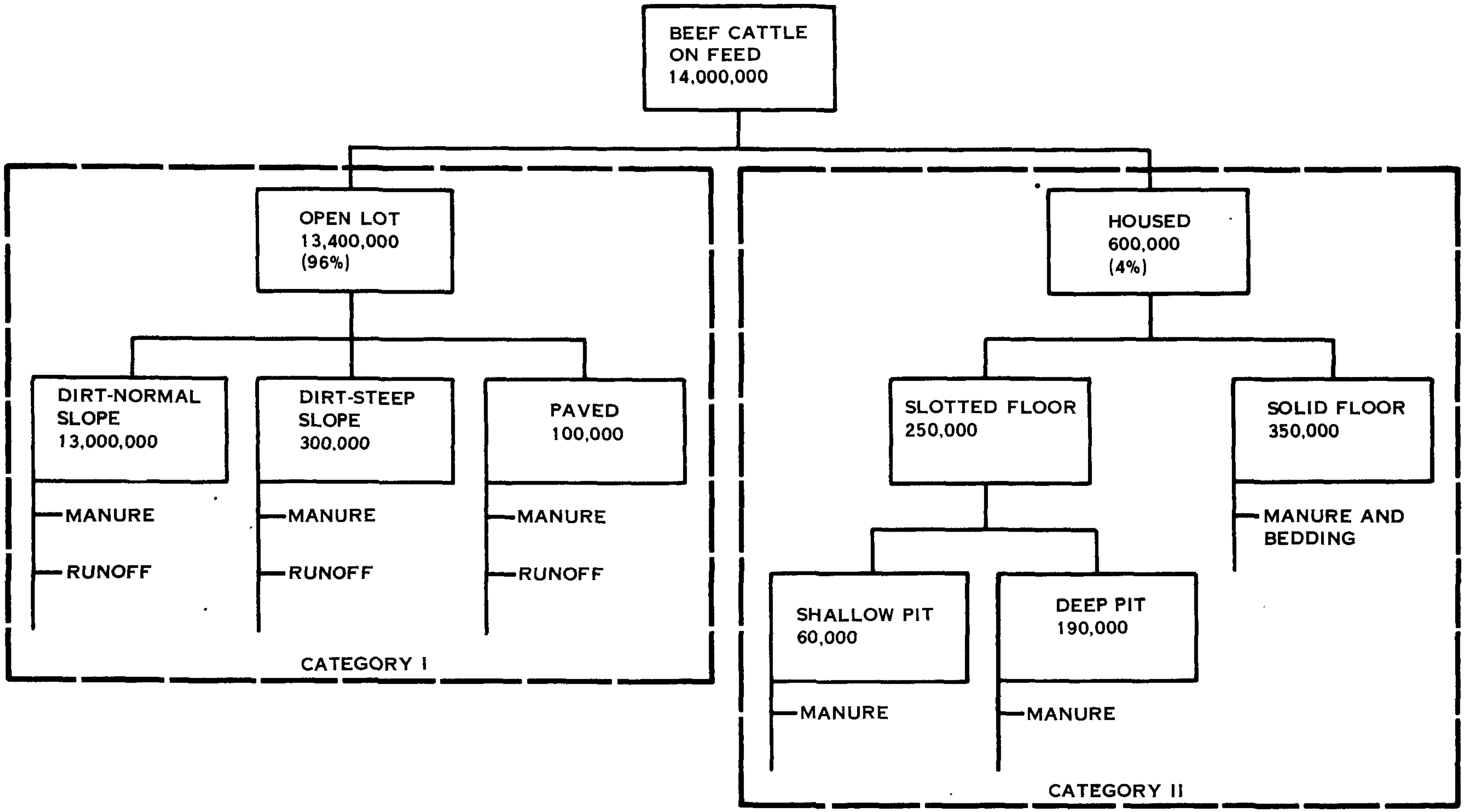


FIGURE 10. BEEF CATTLE INDUSTRY STRUCTURE

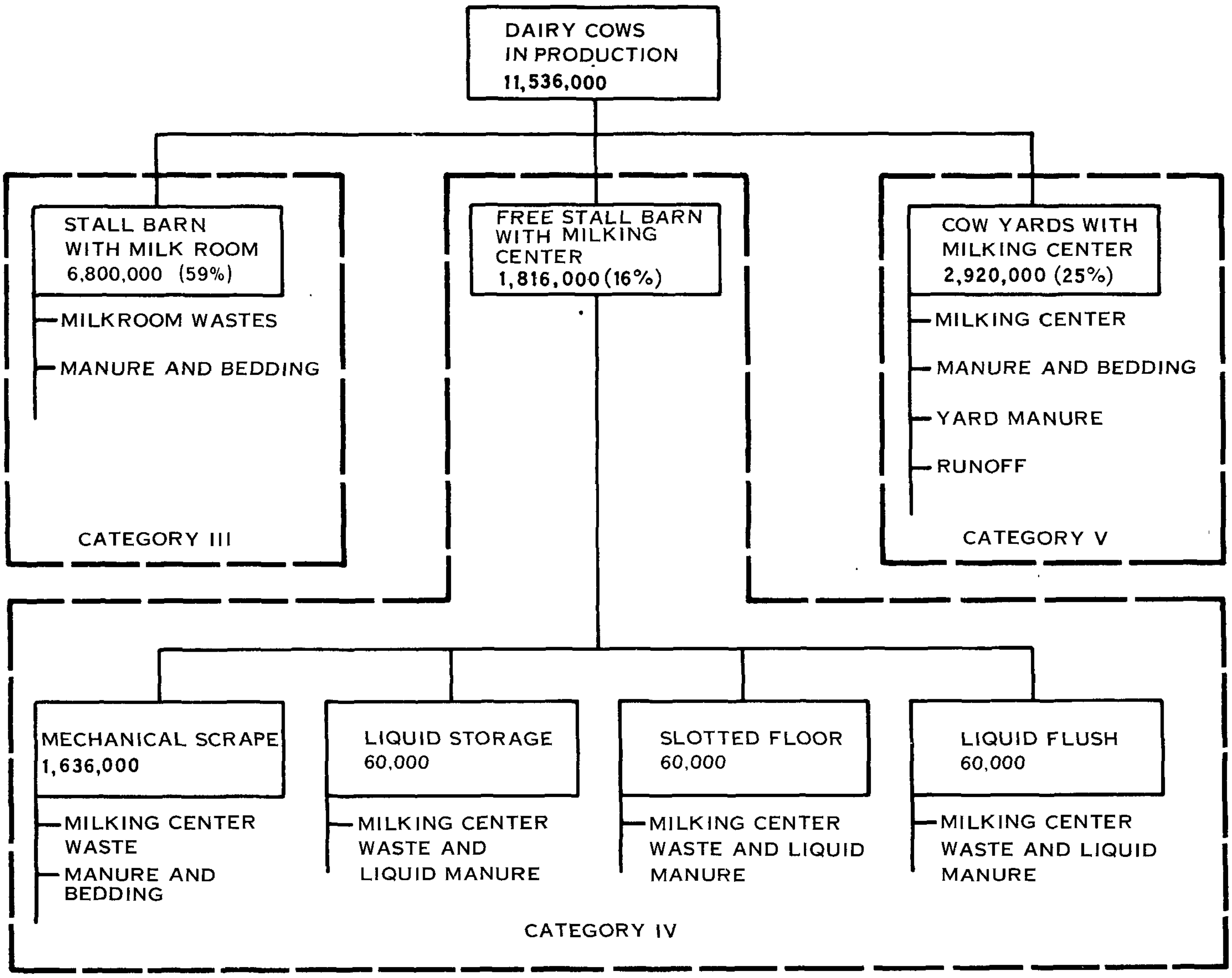


FIGURE 11. DAIRY CATTLE INDUSTRY STRUCTURE

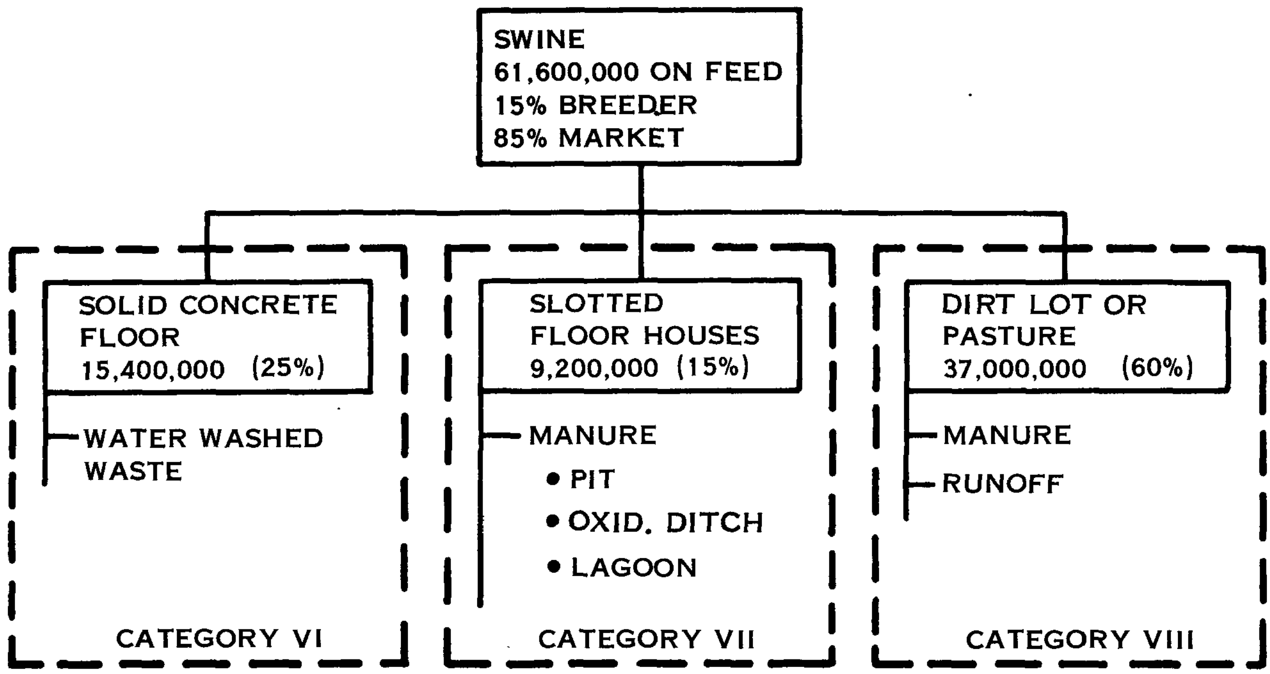


FIGURE 12. SWINE INDUSTRY STRUCTURE

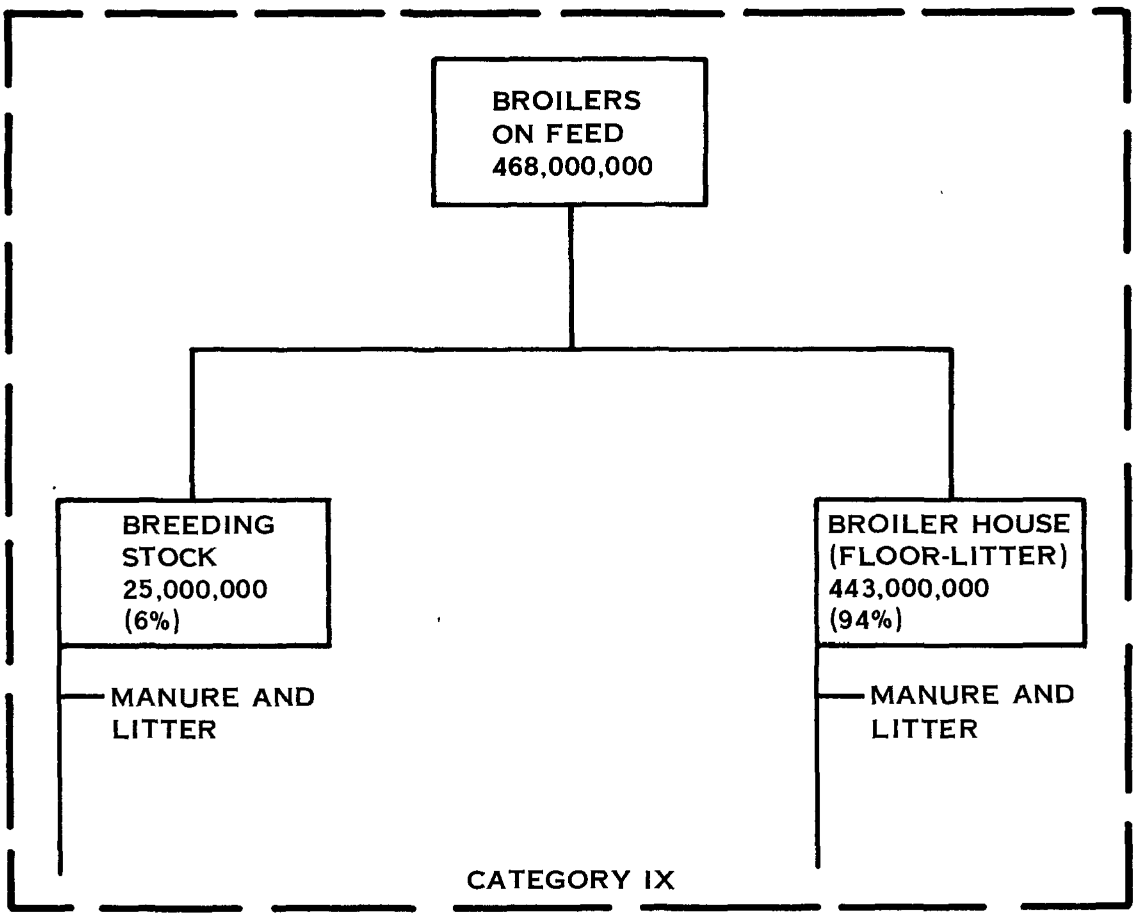


FIGURE 13. BROILER INDUSTRY STRUCTURE

slotted floor and liquid flush are significantly different from the subcategory of mechanical scrape but they are not numerically significant enough to justify a separate category. Cowyards with milking centers are not only numerically significant but also have significantly different waste outputs and thus are placed in a separate category.

Swine

Raw materials used in each case are feed and water. Since these materials are common in all cases, they cannot be used as a basis for categorization. Product produced is also not considered a discriminator for categorization since the product produced in each case is swine for slaughter. The production process employed and waste characteristics are a significant factor in categorization as in the preceding animal types.

Figure 12 shows the structure of the swine industry by type of manufacturing process employed. The capacity of each type of facility in terms of number of animals on feed at any one time is indicated. In addition, the type of wastes produced by each facility is shown in generic terms.

The industry is divided into three categories for the purpose of effluent limitations. The major factor is the production process employed; dirt lots, solid concrete floor lots and slotted floor houses. Each category in this case in numerically significant and also has significantly different waste outputs.

Chickens

Raw materials used in each case are feed, water and, in some cases, litter. Since, except for litter these materials are common in all cases they cannot be used as a basis for categorization. The difference of litter being used in some circumstances is not considered significant since any effect it has on a category shows up in the waste characteristics and is considered at that point. Product produced is a significant discriminator for categorization since it is broilers for slaughter in one case and eggs in the other. Hence the chicken industry is broadly categorized into two major segments, broilers and layers.

Broilers - Figure 13 shows the structure of this industry by type of manufacturing process employed. The capacity of each type of facility in terms of number of animals on feed at any one time is indicated. In addition, the type of wastes produced by each facility is shown in generic terms.

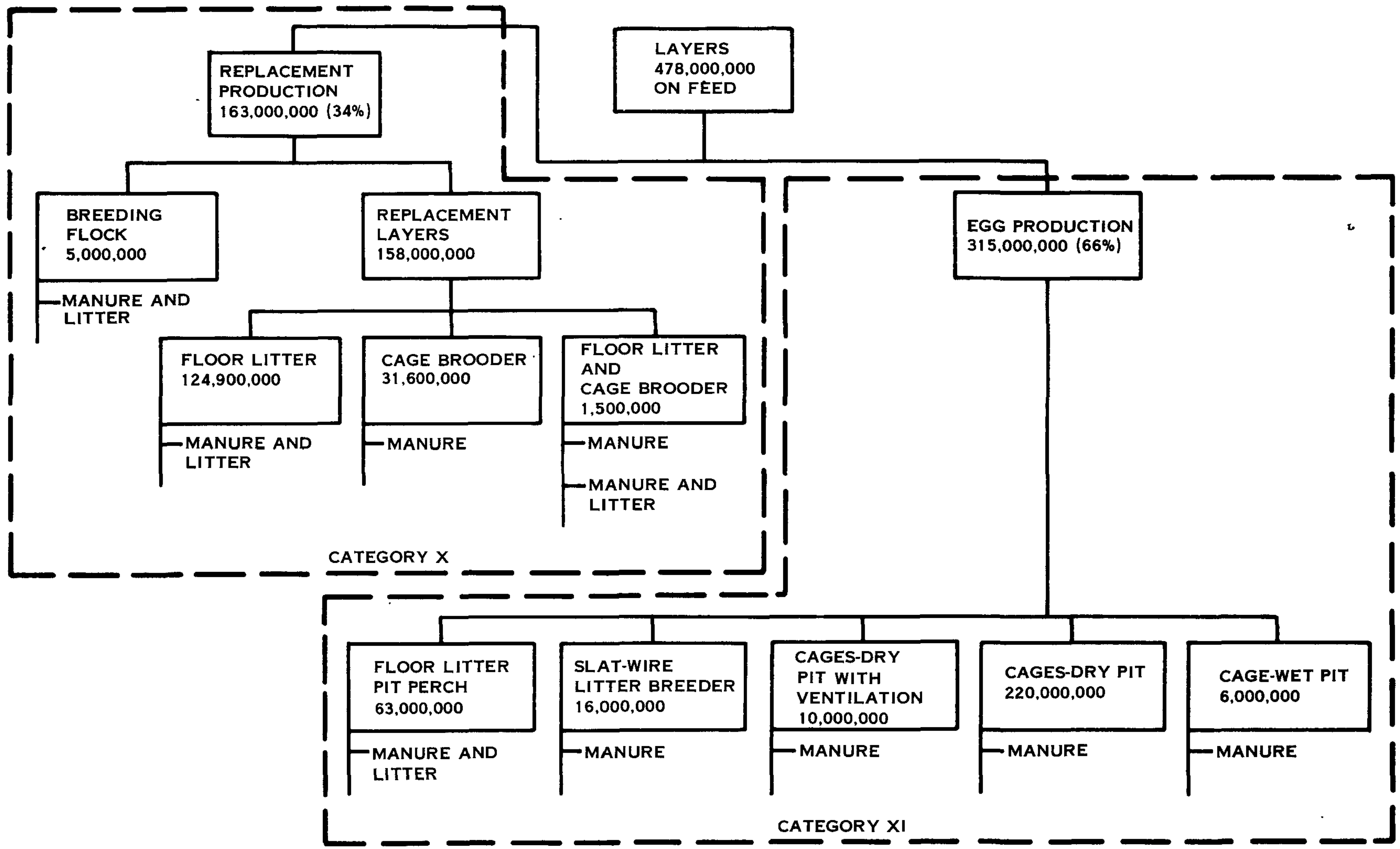


FIGURE 14. LAYER INDUSTRY STRUCTURE

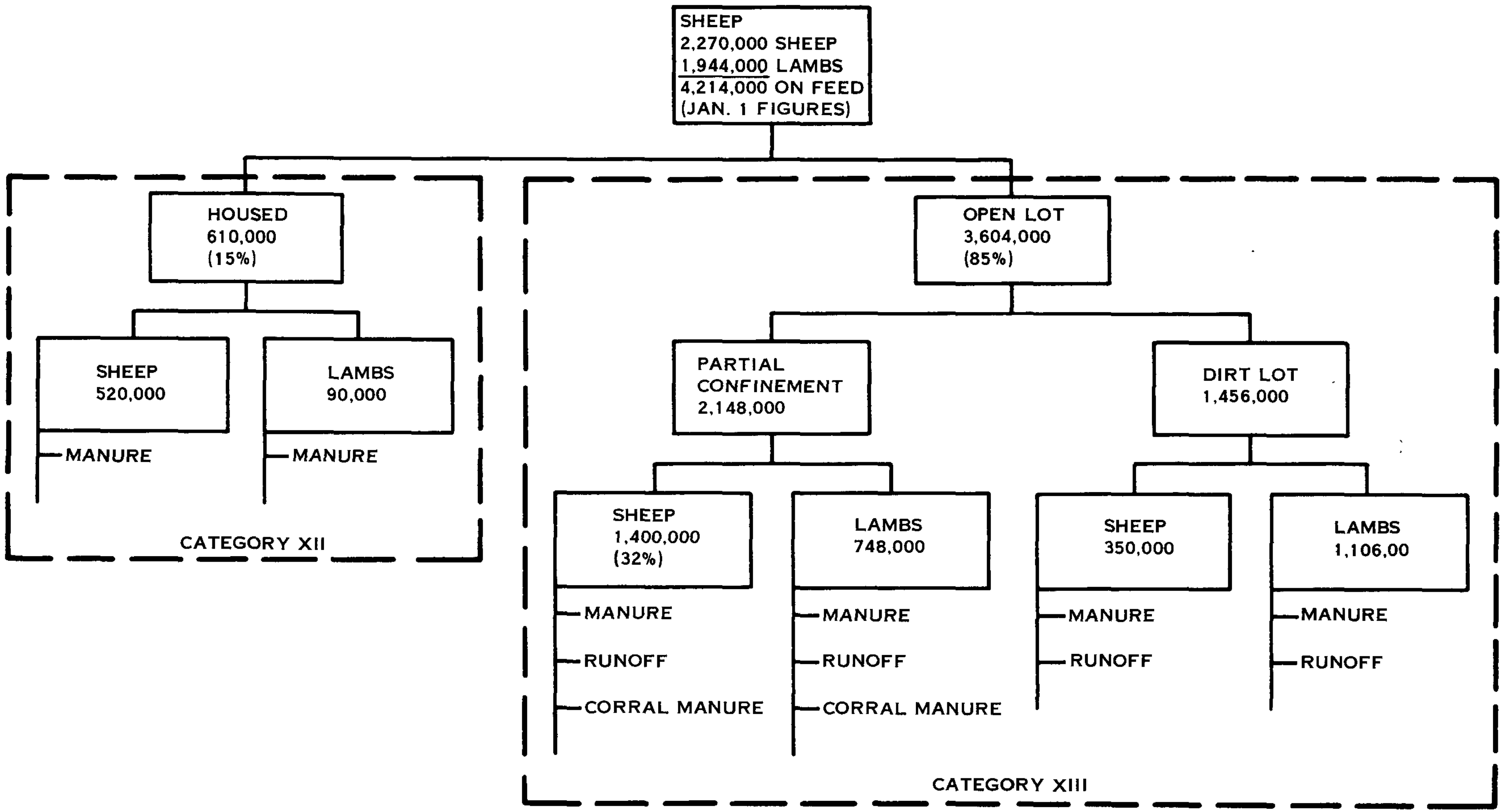


FIGURE 15. SHEEP INDUSTRY STRUCTURE

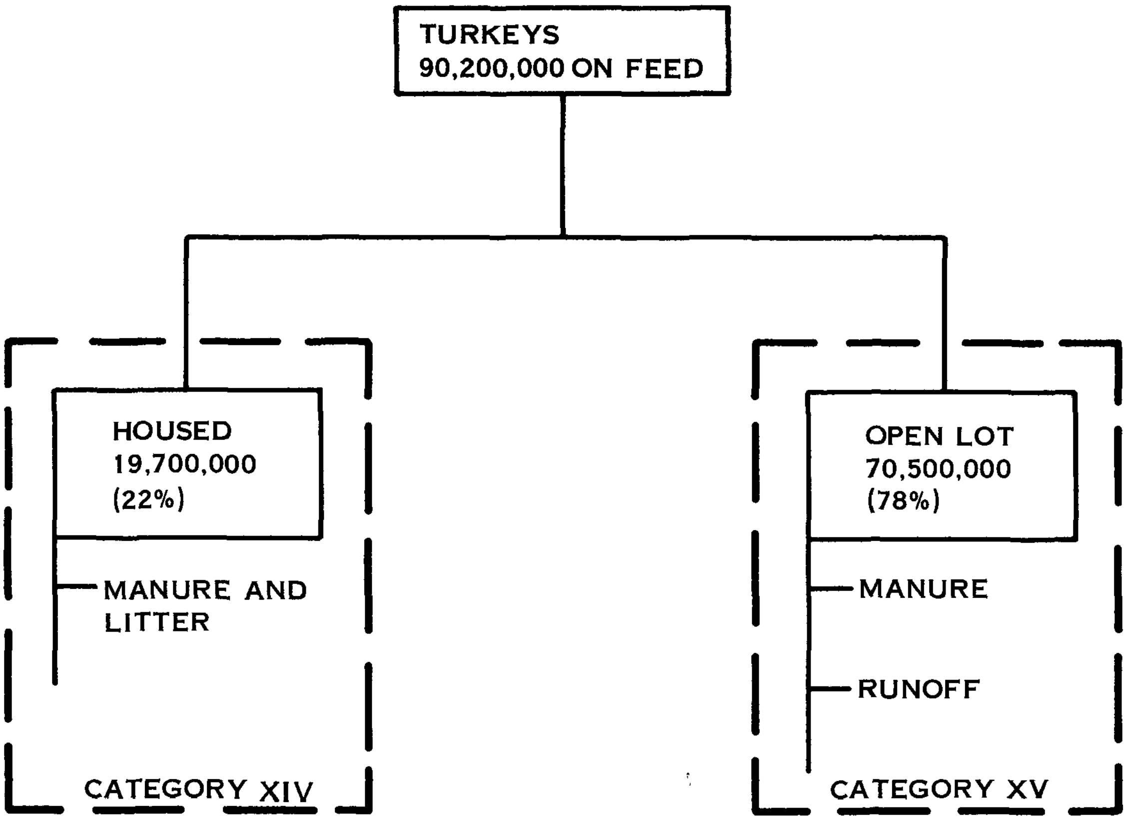


FIGURE 16. TURKEY INDUSTRY STRUCTURE

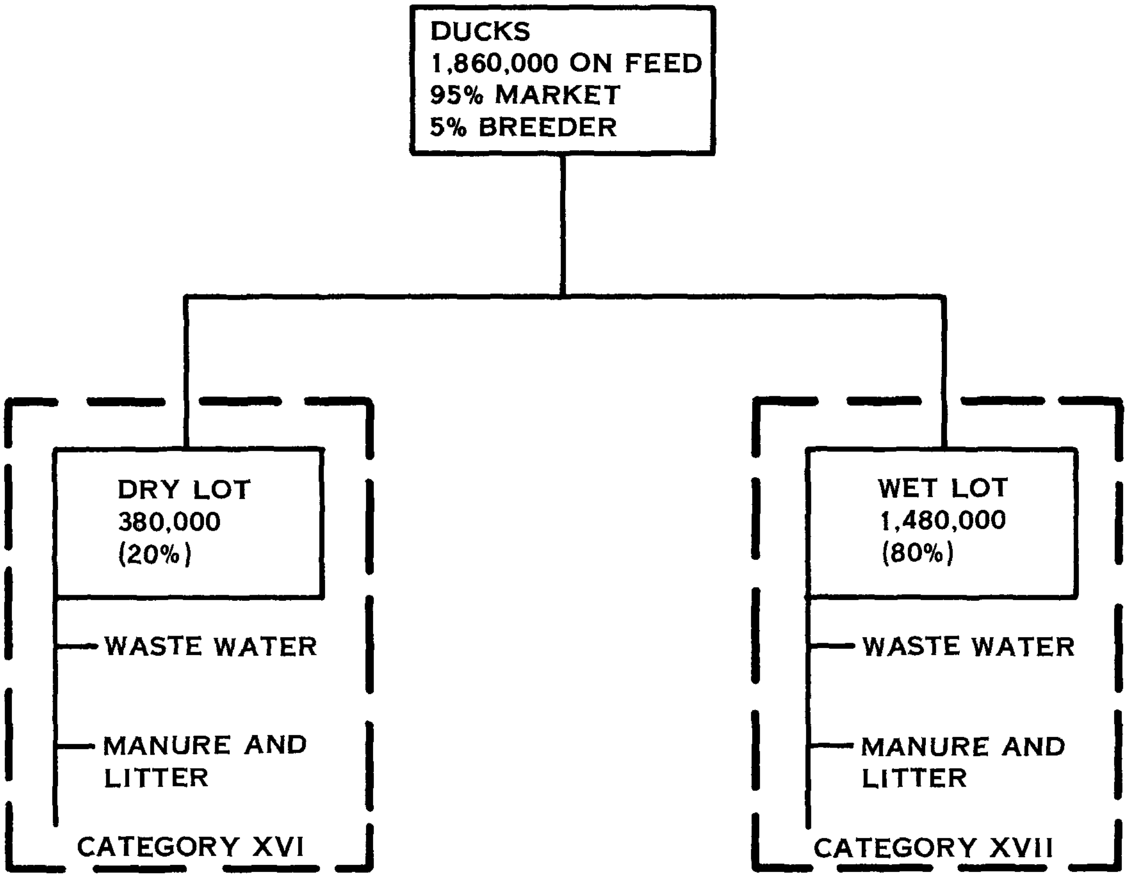


FIGURE 17. DUCK INDUSTRY STRUCTURE

The industry is grouped as one category for the purposes of effluent limitations. In this case there is no significant difference in the type of production process employed or in the type of wastes generated.

Layers - Figure 14 shows the structure of this industry by type of manufacturing process employed. The capacity of each type of facility in terms of number of animals on feed at any one time is indicated. In addition, the type of wastes produced by each facility is shown in generic terms.

The layer segment is divided into two categories for the purpose of effluent limitations. The major factor is the production process employed; replacement production and egg production. The subcategory of cage brooder in the category of replacement production does have a different type of waste output but it is not numerically significant enough to justify separate categorization. Likewise the differences in production process employed and type of waste outputs encountered in the egg production category are minor and do not justify further sub-categorization.

Sheep

Raw materials used in each case are feed, water and, in some cases, bedding, and the rationale for not being a basis for categorization is the same as for beef and dairy cattle. Product produced is also not considered a discriminator for categorization since the product produced in each case is lambs for slaughter. As with the previous animal types, the production process employed and the waste characteristics are considered to be a significant factor in categorization.

Figure 15 shows the structure of the sheep industry by type of production process employed. The capacity of each type of facility in terms of number of animals on feed on January 1 is indicated. In additon, the type of wastes produced by each facility is shown in generic terms.

The industry is divided into two cateogries. The main factor for this categorization is the production process employed; open lot facilities and housed facilities. In the housed category there is no significant difference in waste outputs of the subcategories to justify further division into two categories. In the open lot category the same logic holds true. In addition, the production process employed in both partial confinement and dirt lots are essentially similar.

Turkeys

Raw materials used in each case are similar to those used for chickens and the rationale for not being a basis for categorization is the same. Product produced is also not considered a discriminator for categorization since the product produced in each case is turkeys for slaughter. After considering all factors, production process employed and waste characteristics are considered to be a significant factor in categorization as in the preceding animal types. As a result, industry is divided into two categories for the purpose of effluent limitations; housed facilities and open lots.

Figure 16 shows the structure of the turkey industry by type of production process employed. The capacity of each type of facility in terms of animals on feed at any one time is indicated. In addition, the type of wastes produced by each facility is shown in generic terms.

Ducks

Raw materials used in each case are similar to those used for chickens and the rationale for not being a basis for categorization is the same. Product produced is also not considered to be a valid reason for categorization since the product produced in each case is ducks for slaughter. The production process employed and the waste characteristics are considered to be significant factors in categorization.

Figure 17 shows the structure of the duck industry by type of production process. The capacity of each type of facility in terms of animals on feed at any one time is indicated. In addtion, the type of wastes produced by each facility is shown in generic terms.

The industry is divided into two categories for the purpose of effluent limitations; dry lots and wet lots. Both categories are numerically significant and the wastes are significantly different in terms of water content and waste concentrations.

Horses

Only one category (horse stables) is recommended and since this category involves only one type of stabling the factors for categorization do not enter into the rationale. The other uses of horses as shown in Figure 18 represent very low concentrations of animals and allow the direct recycling of wastes to the land without, in general, causing any pollution problems. If these other uses of horses result in pollution problems, they can be best handled individually at the local level.

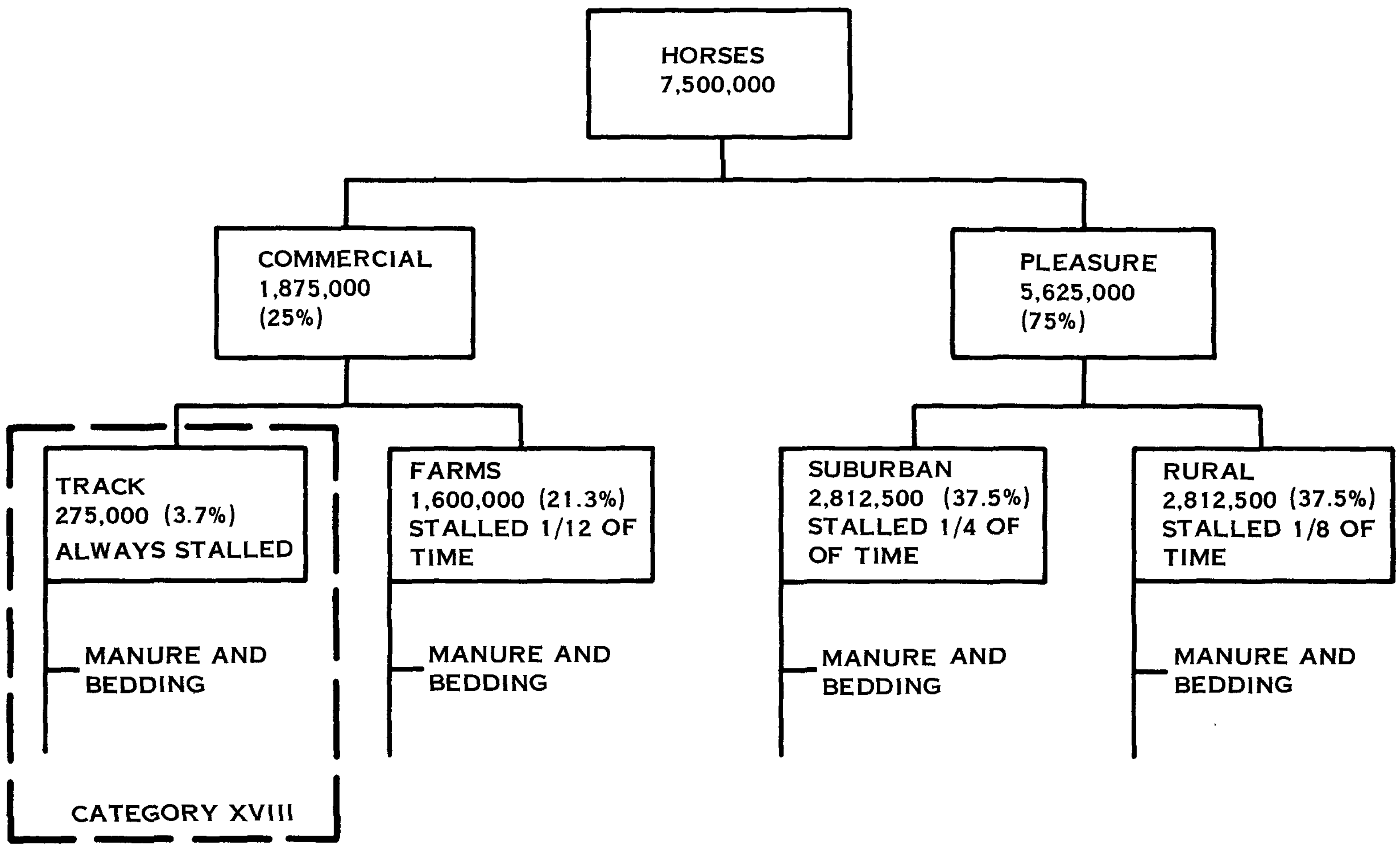


FIGURE 18. HORSE INDUSTRY STRUCTURE

SECTION V

WASTE CHARACTERIZATION

INTRODUCTION

Animal feedlot wastes generally includes the following components:

1. Bedding or litter (if used) and animal hair or feathers
2. Water and milking center wastes
3. Spilled feed
4. Undigested or partially digested food or feed additives
5. Digestive juices
6. Biological products of metabolism
7. Microorganisms from the digestive tract
8. Cells and cell debris from the digestive tract wall.
9. Residual soil and sand

The greatest influences on waste characteristics are animal type, type of facility used and diet. The latter two considerations are usually the only factors which lead to any substantial variation in waste characteristics for any given animal type. For example, bedding materials used in certain facilities, or amount of roughage used in various feeds will affect the character of waste loads. In the case of diet, variations encountered in manure constituents for one particular type of animal are not usually significant although solids content can be increased due to high roughage feeds. Some of the trace elements and all of the pharmaceuticals present in the wastes are a result of additives in the diet obtained from other than natural sources (i.e., other than crops used for feed).

Explanation of Tabular Data

This section details the waste outputs of the industry categories defined in Section IV. The information for each category includes:

1. Brief narrative description and explanation of waste characteristics
2. Industry waste identification figures
3. Generalized category flow diagrams
4. Detail waste characteristic tables.

The narrative in each case provides a brief explanation of types of wastes involved and also describes the assumptions and methods of estimation used where adequate waste data were not available. In some cases, data were so sparse that reasonable estimates could not be made as shown by the entry of "No data" in the tables. To the extent practicable, however, data are shown or are estimated by compositing as many specific sources of information as could be gathered and reviewed (with final review by consultants) to show expected characteristics for the entire industry and segments thereof on a national basis. The industry waste identification figures are similar to the industry structure figures shown in Section III; however, they also provide reference to detailed waste characteristic tables. Generalized flow diagrams are included for each category which show the origin of the wastes. The waste characteristic tables define the waste outputs of the industry in detail, and in some cases, the same table suffices for more than one category. The data used by the consultants in establishing the waste characteristics tables has been assembled from the literature and from the results of unpublished investigations. These data represent information originally generated over a substantial period of time from animals being produced or raised on a variety of diets and management practices. The available information has a high degree of variability and in many instances the conditions of animal breed, size, and diet, location as well as sample collection and analysis technique were not available. Therefore, it was necessary for the consultants to utilize a significant amount of engineering judgment in the preparation of some of these tables.

The characteristics reported under the heading of average, represented ; consultants best judgment of the values typical of the animal type, size, and conditions of management as indicated on the table heading. Characteristics reported under the heading of maximum and minimum represented the reasonable extremes to be encountered for each parameter and therefore they are not representative of the characteristics or integrity of a single sample. Where no conclusive test data were available the characteristics had been estimated and are so indicated by the use of an "e" following the estimated number. If the estimated number has been based upon test data tabulated elsewhere in these charts, it is generally shown with an "e" and a reduced number of significant figures. In some cases the maximum value reported is based upon data for fresh voided waste while the minimum and average values were not available and these were therefore estimated and reported with an "e". Where data were available for waste characteristics in "pounds per day per animal" and concentrations in "milligrams per liter", both are reported. In many instances one waste characteristic has been calculated from the other, and in other cases both values have been estimated separately. The values shown as "pounds per head per inch of runoff" have in general been calculated from measured concentrations in the runoff from animal pens, or are based upon estimated percentages of the deposited waste which will wash away each year and the national average annual runoff. This information is based upon a very limited existing amount of runoff documentation and defines the runoff waste load for the particular set of conditions present at the time of documentation including; the size and intensity of the rainfall event, the past history of rainfall events, the history of pen cleaning, temperatures, slope of lots, animal density, animal weight, etc. These data do not necessarily represent the waste load which will runoff for a different set of circumstances and conditions. In cases where only a portion of the time is spent in confinement housing the values are reported on a per day basis taking into consideration the percentage of confinement. This percentage is indicated on the table where applicable and corresponding reductions are made in the wastes collected outside of the confinement area.

BEEF CATTLE

Category I

As shown in Figure 19, Category I includes dirt-flat to moderate slope, dirt-steep slope, and paved open lots. All of these facilities require scraping to remove accumulated wastes denoted "manure" on Figure 19 and the flow diagram, Figure 20. In addition, rain falling on the waste-covered surface carries away a portion of wastes as runoff. The characteristics of the scraped manure are given by Tables 1 and 2. The characteristics of the manure depend on whether it is removed frequently or infrequently. Frequently removed manure undergoes little or no biodegradation and is essentially the same as freshly deposited manure. This type is defined by Table 1. Infrequently removed manure may undergo considereable biodegradation, and is defined by Table 2. These two tables represent the expected extremes for manure characteristics as removed from open lot surfaces.

The greater amount of runoff from dirt-steep slope surfaces over that from flat to moderate slope surfaces is due simply to the increased slope. Runoff from paved lots may vary from dirt lots since paved lots tend to dry out faster, thus preventing biodegradation and the movement of soluble pollutants such as nitrates down into the manure pack. Runoff from these three types of open lots is defined in Tables 3, 4 and 5.

Category II

A generalized flow diagram for Category II is shown in Figure 21. The shallow pit system is normally operated on a basis of frequent (usually daily) cleaning. As a result, the waste output is essentially fresh manure and, therefore, is defined by Table 1.

Deep pits are generally used for long term storage and may not be cleaned more than twice each year. No actual test data are available which defines the waste output of such a system. The values for this system, shown in Table 6 are based on the following assumptions:

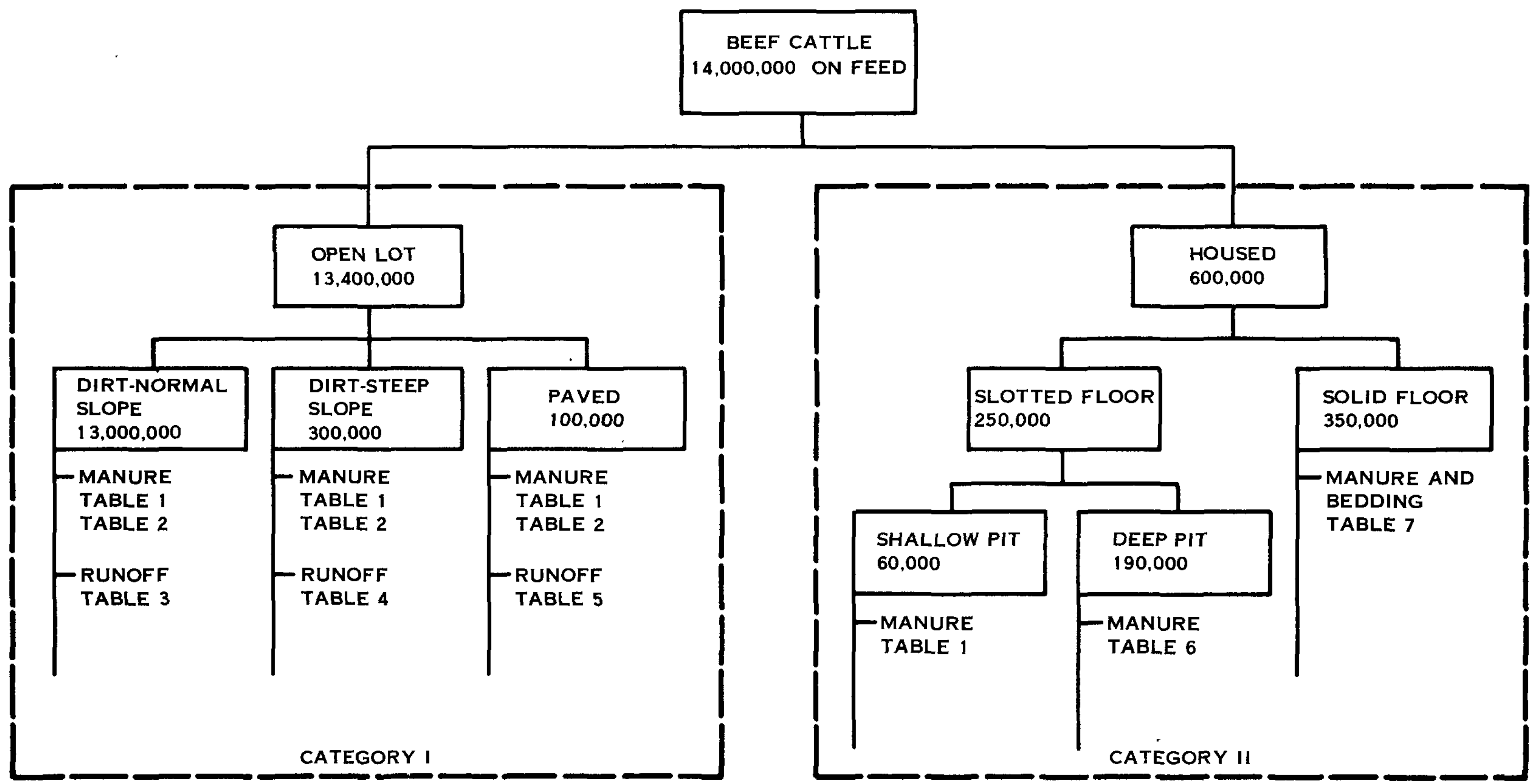
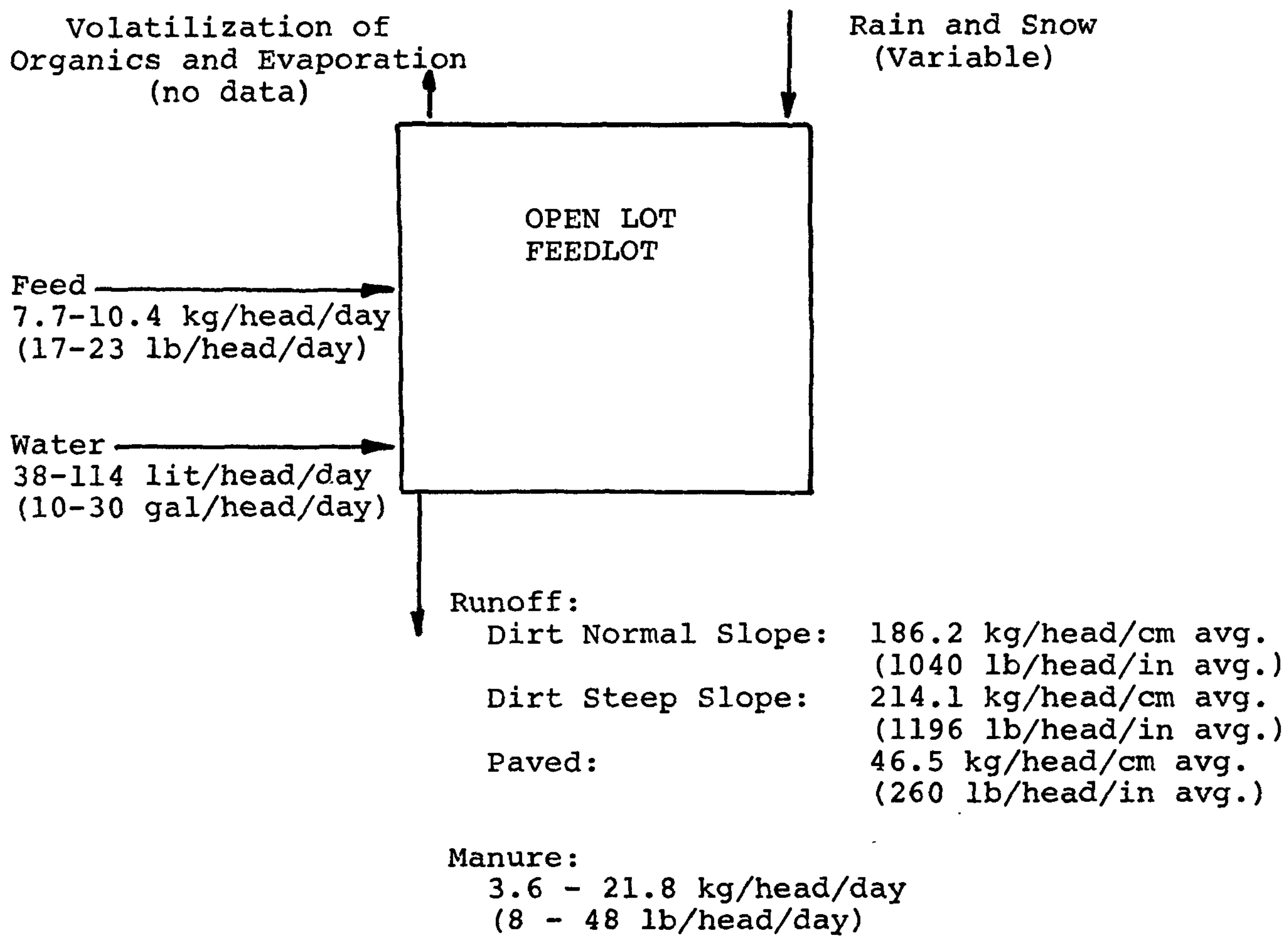


FIGURE 19. BEEF CATTLE INDUSTRY WASTE IDENTIFICATION

1. No less than ten percent of all input moisture would be evaporated in a storage period of 120 - 150 days.

2. No less than ten percent of the solids in the fresh manure would be liquified during same period.

3. About forty percent of the volatile solids would be degraded during a normal storage period.



BEEF CATTLE CATEGORY I FLOW DIAGRAM

FIGURE 20

ANIMAL TYPE: Beef Cattle
ANIMAL WEIGHT: 360 kg Average (800 lbs Average)
TYPE OF WASTE:
Fresh Manure and Slotted Floor/Shallow Pit Manure

Parameter	kg/head/day (lb/head/day)		
	Minimum	Average	Maximum
Total (wet solids)	18.2 (40.0)	21.8 (48.0)	29.1 (64.0)
Moisture	14.5 (32.0)	18.5 (40.8)	25.3 (55.7)
Dry Solids	1.9 (4.3)	3.3 (7.2)	5.81 (12.8)
Volatile Solids	1.4 (3.0)	2.6 (5.8)	3.2 (7.0)
pH	7.2	7.3	7.6
BOD_5	0.4 (0.8)	0.45 (1.0)	0.73 (1.6)
COD	0.73 (1.6)	1.6 (3.5)	2.0 (4.4)
Ash	0.59 (1.3)	0.77 (1.7)	1.3 (2.8)
Total Nitrogen	0.073 (0.16)	0.12 (0.263)	0.14 (0.307)
Ammonia Nitrogen	0.03 (0.07)	0.04 (0.08)	0.04 (0.09)
Nitrate Nitrogen	0.01 (0.03)	0.017 (0.038)	0.02 (0.04)
Total Phosphorus	0.03 (0.06)	0.031 (0.068)	0.03 (0.07)
Total Potassium	0.073 (0.016)	0.0831 (0.183)	0.091 (0.20)
Magnesium	0.018 (0.039)	0.0192 (0.0192)	0.020 (0.020)

TABLE 1

ANIMAL TYPE: Beef Cattle
ANIMAL WEIGHT: 360 kg Average (800 lbs Average)
TYPE OF WASTE:
Fresh Manure and Slotted Floor/Shallow Pit Manure

Parameter	kg/head/day (lb/head/day)		
	Minimum	Average	Maximum
Sodium	0.02 (0.05)	0.0365 (0.0803)	0.082 (0.18)
Diethylstilbestrol	-	-	Trace

TABLE 1 (Continued)

ANIMAL TYPE: Beef Cattle
ANIMAL WEIGHT: 360 kg Average (800 lbs. Average)
TYPE OF WASTE: Biodegraded Manure

Parameter	kg/head/day (lb/head/day)		
	Minimum	Average	Maximum
Total (wet solids)	1.5 (3.3)	3.6 (8.0)	7.81 (17.2)
Moisture	0.45 (1.0)	1.03 (2.26)	3.9 (8.6)
Dry Solids	1.0 (2.3)	2.61 (5.74)	3.9 (8.6)
Volatile Solids	0.82 (1.8)	1.80 (3.96)	2.9 (6.4)
pH	5.1	7.6	9.4
BOD_5	0.2 (0.5)	0.31 (0.68)	0.4 (0.9)
COD	0.91 (2.0)	1.09 (2.40)	1.8 (4.0)
Ash	0.23 (0.50)	0.808 (1.78)	1.8 (3.9)
Total Nitrogen	0.03 (0.07)	0.082 (0.18)	0.11 (0.25)
Ammonia Nitrogen	0 (0)	0.03 (0.07)	0.064 (0.14)
Nitrate Nitrogen	0 (0)	0.01 (0.03)	0.045 (0.045)
Total Phosphorus	0.02 (0.05)	0.039 (0.086)	0.050 (0.11)
Total Potassium	0.03 (0.07)	0.059 (0.13)	0.086 (0.19)
Magnesium	0.009 (0.02)	0.0192 (0.0423)	0.03 (0.06)
Sodium	0.01 (0.03)	0.0365 (0.0803)	0.059 (0.13)

TABLE 2

ANIMAL TYPE: Beef Cattle
ANIMAL WEIGHT: 360 kg Average (800 lbs. Average)
TYPE OF WASTE: Dirt-Moderate Slope-Runoff
AREA: 18.6 meter square/head (200 feet square/head)

Parameter	kg/head/cm runoff (lb/head/inch runoff)			mg/l		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Total (wet solids)	-	186.16 (1040.0)	-	-	-	-
Moisture	183.40 (1024.4)	184.67 (1031.7)	185.16 (1034.4)	985,000	992,000	994,000
Dry Solids	1.11 6.24	1.49 (8.32)	2.79 (15.0)	6,000	8,000	15,000
Volatile Solids	0.707 (3.95)	0.745 (4.16)	1.49 (8.32)	3,800	4,000	8,000
Suspended Solids	0.186 (1.04)	0.47 (2.6)	0.931 (5.20)	1,000	2,500	5,000
pH	5.1	7.6	9.4			
BOD5	0.186 (1.04)	0.279 (1.56)	1.12 (6.23)	1,000	1,500	5,000
COD	0.558 (3.12)	0.652 (3.64)	5.58 (31.2)	3,000	3,500	20,000
Ash	0.372 (2.08)	0.782 (4.37)	1.4 (7.8)	2,000	4,200	7,500
Total Nitrogen	0.004 (0.02)	0.029 (0.16)	0.204 (0.14)	20	150	1,100
Ammonia Nitrogen	0	0.01 (0.06)	0.093 (0.52)	0	60	500
Nitrate Nitrogen	0	0.005 (0.03)	0.022 (0.123)	0	25	120
Total Phosphorus	0.002 (0.01)	0.01 (0.08)	0.039 (0.22)	14	80	200

TABLE 3

ANIMAL TYPE: Beef Cattle
ANIMAL WEIGHT: 360 kg Average (800 lbs. Average)
TYPE OF WASTE: Dirt-Moderate Slope-Runoff
AREA: 18.6 meter square/head (200 feet squre/head)

	kg/head/cm runoff (lb/head/inch runoff)			mg/l		
Parameter	Minimum	Average	Maximum	Minimum	Average	Maximum
Total Potassium	0.004 (0.02)	0.063 (0.35)	0.2 (0.9)	20	340	900
Magnesium	0.01 (0.07)	0.018 (0.10)	0.021 (0.12)	70	95	120
Sodium	0.01 (0.07)	0.043 (0.24)	0.1 (0.7)	65	230	700

TABLE 3 (Continued)

ANIMAL TYPE: Beef Cattle
ANIMAL WEIGHT: 360 kg Average (800 lbs. Average)
TYPE OF WASTE: Dirt-Steep Slope-Runoff
AREA: 18.6 meter square/head (200 feet square/head)

Parameter	kg/head/cm runoff (lb/head/inch runoff)			mg/l		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Total (wet solids)	-	214.08 (1196.0)	-	-	-	-
Moisture	210.0 (1175.0)	212.29 (1186.0)	213.01 (1190.0)	982,750	990,800	990,800
Dry Solids	1.67 (9.33)	1.71 (9.57)	3.20 (17.9)	9,200	9,200	17,250
Volatile Solids	0.813 (4.54)	0.856 (4.78)	1.71 (9.57)	4,370	4,600	9,200
Suspended Solids	0.215 (1.20)	0.535 (2.99)	1.07 (5.98)	1,150	2,875	5,750
pH	5.1	7.6	9.4			
BOD_5	0.215 (1.20)	0.320 (1.79)	1.29 (7.18)	1,150	1,725	5,750
COD	0.643 (3.59)	0.750 (4.19)	6.43 (35.9)	3,450	4,025	23,000
Ash	0.428 (2.39)	0.900 (5.03)	1.61 (8.97)	2,300	4,830	8,625
Total Nitrogen	0.0041 (0.023)	0.0329 (0.184)	0.234 (1.31)	23	173	1,265
Ammonia Nitrogen	0	0.012 (0.069)	0.107 (0.598)	0	69	575
Nitrate Nitrogen	0	0.00474 (0.0265)	0.00618 (0.0345)	0	29	138
Total Phosphorus	0.00206 (0.0115)	0.0185 (0.104)	0.0453 (0.253)	16	92	230

TABLE 4

ANIMAL TYPE: Beef Cattle
ANIMAL WEIGHT: 360 kg Average (800 lbs. Average)
TYPE OF WASTE: Dirt-Steep Slope-Runoff
AREA: 18.6 meter square/head (200 feet square/head)

Parameter	kg/head/cm runoff (lb/head/inch runoff)			mg/l		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Total Potassium	0.00412 (0.0230)	0.0721 (0.403)	0.186 (1.04)	23	391	1,035
Magnesium	0.0144 (0.0805)	0.0206 (0.115)	0.0247 (0.138)	81	109	138
Sodium	0.0144 (0.0805)	0.0494 (0.276)	0.144 (0.805)	75	265	805

TABLE 4 (Continued)

ANIMAL TYPE: Beef Cattle
ANIMAL WEIGHT: 360 kg Average (800 lbs. Average)
TYPE OF WASTE: Paved Lot Runoff
AREA: 4.6 meter square/head (50 feet square/head)

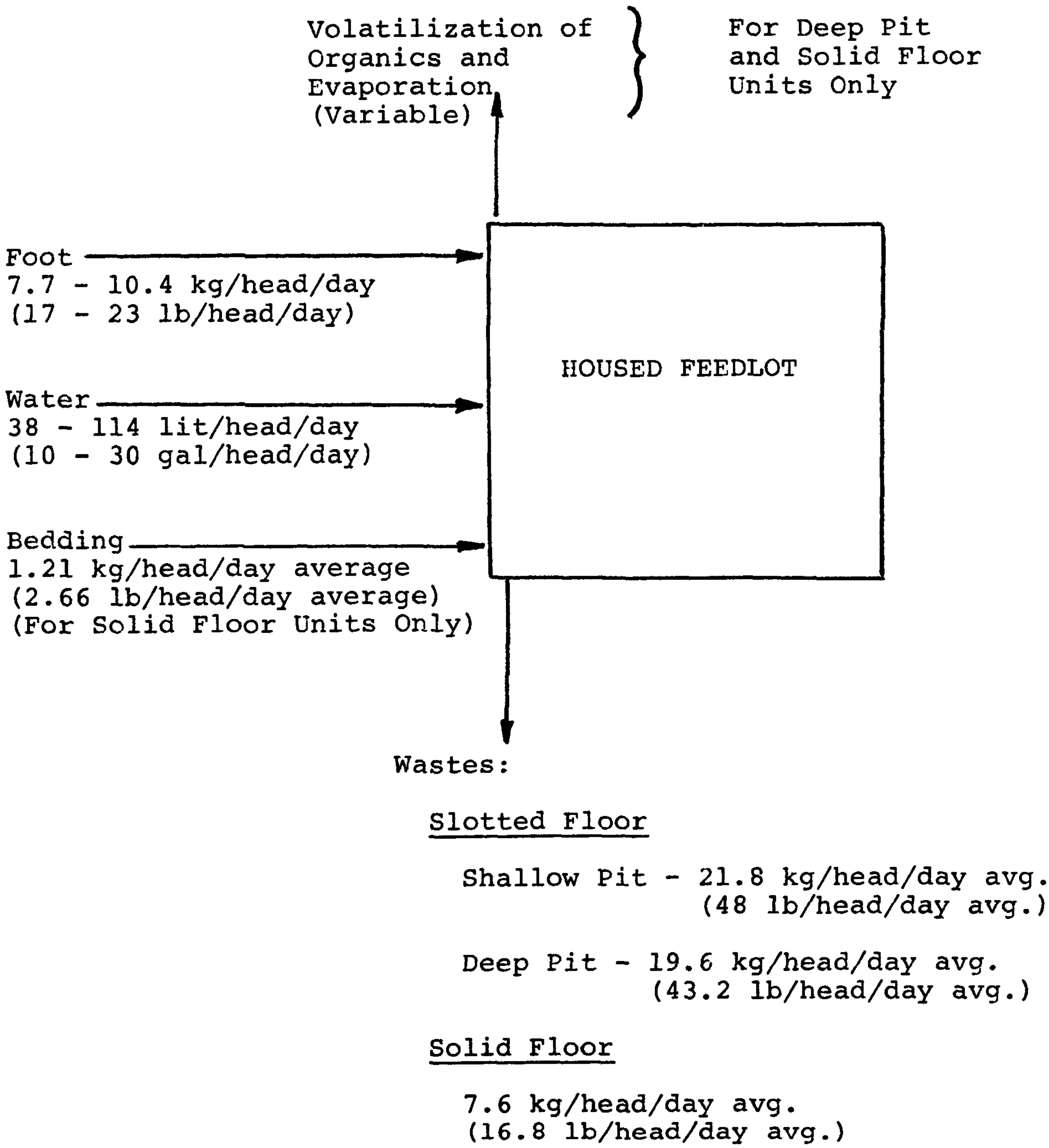
Parameter	kg/head/inch runoff (lb/head/inch runoff)			mg/l		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Total (wet solids)	-	46.54 (260.0)	-	-	-	-
Moisture	45.795 (255.88)	45.982 (255.84)	45.61 (254.8)	980,000	984,000	988,000
Dry Solids	0.569 (3.18)	0.745 (4.16)	0.93 (5.2)	12,000	20,000	160,000
Volatile Solids	0.279 (1.56)	0.387 (2.16)	5.93 (3.12)	6,000	8,300	12,000
Suspended Solids	0.093 (0.52)	0.279 (1.56)	0.47 (2.6)	2,000	6,000	10,000
pH	5.5	6.6	7.5			
BOD5	0.093 (0.52)	0.15 (0.83)	0.558 (3.12)	2,000	3,200	12,000
COD	0.23 (13.)	0.331 (1.85)	1.86 (10.4)	5,000	7,100	40,000
Ash	0.186 (1.04)	0.358 (2.00)	0.70 (3.9)	4,000	7,700	15,000
Total Nitrogen	0.02 (0.1)	0.052 (0.29)	0.073 (0.41)	370	1,100	1,580
Ammonia Nitrogen	0.0047 (0.026)	0.01 (0.08)	0.023 (0.13)	100	325	500
Nitrate Nitrogen	0	0.02 (0.09)	0.0558 (0.312)	0	360	1,200
Total Phosphorus	0.002 (0.01)	0.005 (0.03)	0.01 (0.08)	20	110	305

TABLE 5

ANIMAL TYPE: Beef Cattle
ANIMAL WEIGHT: 360 kg Average (800 lbs. Average)
TYPE OF WASTE: Paved Lot Runoff
AREA: 4.6 meter square/head (50 feet square/head)

Parameter	kg/head/inch runoff (lb/head/inch runoff)			mg/l		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Total Potassium	0.002 (0.01)	0.02 (0.09)	0.075 (0.42)	30	350	1,600
Magnesium	0.004 (0.02)	0.005 (0.03)	0.007 (0.04)	80	100	140
Sodium	0.005 (0.03)	0.021 (0.12)	0.045 (0.25)	120	450	950

TABLE 5 (Continued)



BEEF CATTLE CATEGORY II FLOW DIAGRAM

FIGURE 21

ANIMAL TYPE: Beef Cattle
ANIMAL WEIGHT: 360 kg Average (800 lbs. Average)
TYPE OF WASTE: Slotted Floor - Deep Pit Manure

e = estimate

Parameter	kg/head/day (lb/head/day)		
	Minimum	Average	Maximum
Total (wet solids)	No Data	19.6e (43.2e)	29.1e (64.0e)
Moisture	No Data	16.7e (36.7e)	25.3e (55.7e)
Dry Solids	1.0e (2.3e)	3.0e (6.5e)	5.81e (12.8e)
Volatile Solids	0.82e (1.8e)	1.6e (3.5e)	3.2e (7.0e)
ph	5.1e	5.8e	7.6e
BOD_5	0.2e (0.5e)	0.3e (0.6e)	0.73e (1.6e)
COD	0.91e (2.0e)	1.1e (2.4e)	2.0e (4.4e)
Ash	0.2e (0.5e)	0.95e (2.1e)	1.3e (2.8e)
Total Nitrogen	0.03e (0.07e)	0.11e (0.25e)	0.1e (0.3e)
Ammonia Nitrogen	0e	0.04e (0.09e)	0.05e (0.12e)
Nitrate Nitrogen	No Data	No Data	0.02e (0.04e)
Total Phosphorus	0.02e (0.05e)	0.03e (0.07e)	0.03e (0.07e)

TABLE 6

ANIMAL TYPE: Beef Cattle
ANIMAL WEIGHT: 360 kg Average (800 lbs. Average)
TYPE OF WASTE: Slotted Floor - Deep Pit Manure

e = estimate

Parameter	kg/head/day (lb.head/day)		
	Minimum	Average	Maximum
Total Potassium	0.03e (0.07e)	0.08e (0.19e)	0.09e (0.02e)
Magnesium	0.009e (0.02e)	0.02e (0.04e)	0.020e (0.045e)
Sodium	0.01e (0.03e)	0.04e (0.09e)	0.082e (0.18e)
Diethylstilbestrol	0e	0e	Trace

TABLE 6 (Continued)

ANIMAL TYPE: Beef Cattle
ANIMAL WEIGHT: 360 kg Average (800 lbs. Average)
TYPE OF WASTE: Housed-Solid Floor Manure and Bedding

e = estimate

Parameter	kg/head/day (lb/head/day)		
	Minimum	Average	Maximum
Total (wet solids)	5.77e (12.7e)	7.63e (16.8e)	20.2e (44.4e)
Moisture	2.6e (5.7e)	3.8e (8.4e)	16.5e (36.4e)
Dry Solids	3.2e (7.0e)	3.8e (8.4e)	9.08e (20.0e)
Volatile Solids	1.6e (3.5e)	1.8e (4.0e)	2.5e (5.5e)
pH	No Data	7.3e	No Data
BOD_5	No Data	0.4e (0.7e)	No Data
COD	No Data	1.1e (2.5e)	No Data
Ash	No Data	2.0e (4.4e)	No Data
Total Nitrogen	No Data	0.082e (0.18e)	No Data
Ammonia Nitrogen	No Data	0.03e (0.07e)	No Data
Nitrate Nitrogen	No Data	0.01e (0.03e)	No Data
Total Phosphorus	No Data	0.031 (0.068e)	No Data
Total Potassium	No Data	0.183e (0.183e)	No Data
Magnesium	No Data	0.019e (0.042e)	No Data
Sodium	No Data	0.04e (0.08e)	No Data

TABLE 7

4. Approximately forty percent of the BOD5 would be satisfied during the storage period.

5. Approximately one-third of the COD would be satisfied during the storage period.

6. Because of degradation, the concentration of ash would be increased about 25 percent.

7. Small losses of nitrogen (as ammonia) would occur during the digestion process.

8. No losses of phosphorus, potassium, magnesium, or sodium would occur, and the resulting concentrations would be increased slightly over concentrations found in fresh manure.

Maximum values were estimated on the basis of fresh manure. Minimum values were estimated on the basis of biodegraded manure (Table 2).

The waste output of a solid floor unit could not be completely documented because of the variability of bedding used. To estimate the characteristics given in Table 7 it was assumed that bedding amounts are based on absorbing moisture from the wastes such that an acceptable moisture content could be reached that would be comfortable for the cattle for walking. An average number for this is 1.21 kg (2.66 lbs.) of bedding per animal per day. Furthermore, it was assumed that a substantial quantity of moisture would evaporate, that the material added would be relatively inert, and that no substantial amounts of readily degradable organic pollutants would be added to the feedlot as bedding material. Amounts of inorganic materials (phosphorus, potassium, magnesium and sodium) are shown to be approximately equal to the concentrations in raw manure.

Data on maximum and minimum variations was not available for most of the characteristics.

DAIRY CATTLE

Category III

As shown in Figure 22, this category comprises only one method of production, stall barns with milkrooms, and is depicted in Figure 23. The collectable wastes from this system are the milkroom wastes, (Tables 8) from the washdown of the milking equipment, and manure and bedding (Table 9) which is mechanically removed from the stall area. Experimental data on milkroom wastes is extremely sparse. For this reason, only the average value is shown.

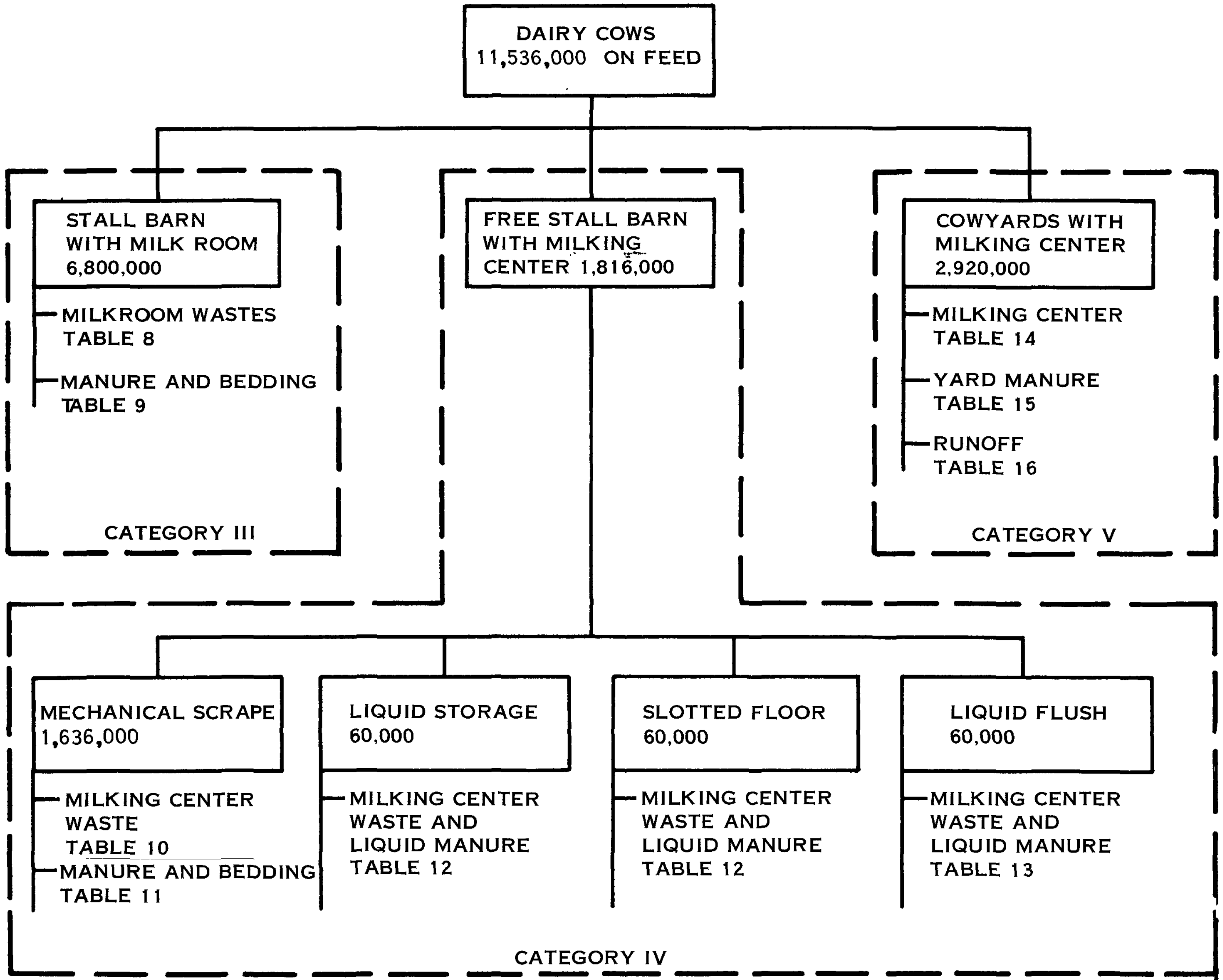
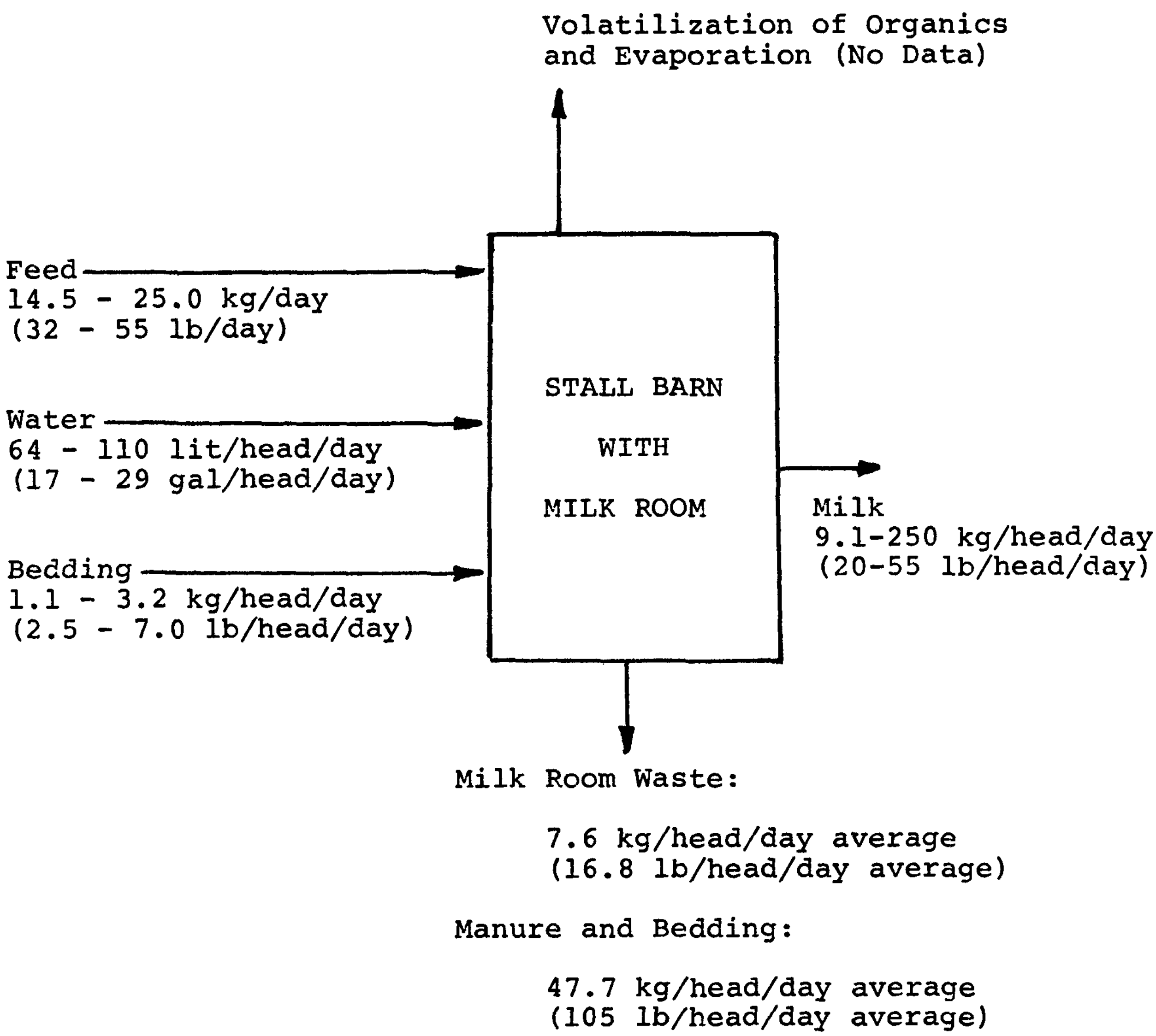


FIGURE 22. DAIRY CATTLE INDUSTRY WASTE IDENTIFICATION



DAIRY CATTLE CATEGORY III FLOW DIAGRAM

FIGURE 23

ANIMAL TYPE: Dairy Cattle
ANIMAL WEIGHT: 590 kg Average (1300 lbs. Average)
TYPE OF WASTE: Stall Barn - Milk Room Waste

Parameter	kg/head/day (lb/head/day)			mg/l		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Total (wet solids)	No Data	7.63 (16.8)	No Data	-	-	-
Moisture	"	7.54 (16.6)	"	No Data	988,000	No Data
Dry Solids	"	0.059 (0.13)	"	"	7,740	"
Volatile Solids	"	No Data	"	"	No Data	"
Suspended Solids	"	0.005 (0.01)	"	"	595	"
pH	"	8.0	"	-	-	-
BOD5	"	0.005 (0.01)	"	No Data	595	No Data
COD	"	No Data	"	"	No Data	"
Ash	"	"	"	"	"	"
Total Nitrogen	"	0.00077 (0.0017)	"	"	101	"
Ammonia Nitrogen	"	0.000039 (0.000085)	"	"	5	"
Nitrate Nitrogen	"	No Data	"	"	No Data	"
Total Phosphorus	"	0.000064 (0.00014)	"	"	8	"
Total Potassium	"	No Data	"	"	No Data	"
Magnesium	"	"	"	"	"	"
Sodium	"	"	"	"	"	"

TABLE 8

ANIMAL TYPE: Dairy Cattle
ANIMAL WEIGHT: 590 kg Average (1300 lbs. Average)
TYPE OF WASTE: Stall Barn, Manure and Bedding
PERCENT CONFINED: 46%

Parameter	kg/head/day (lb/head/day)		
	Minimum	Average	Maximum
Total (wet solids)	18.8 (41.4)	21.9 (48.3)	26.5 (58.4)
Moisture	14.2 (31.3)	(17.8 (39.1)	24.0 (52.9)
Dry Solids	2.1 (4.6)	4.2 (9.2)	7.31 (16.1)
Volatile Solids	1.73 (3.82)	3.55 (7.82)	6.67 (14.7)
pH	5	7	9
BOD5	0.0396 (0.873)	0.459 (1.01)	0.627 (1.38)
COD	1.67 (3.68)	2.92 (6.44)	6.27 (13.8)
Ash	0.146 (0.322)	0.355 (0.782)	0.731 (1.61)
Total Nitrogen	0.0749 (0.165)	(0.115 (0.253)	0.167 (0.368)
Ammonia Nitrogen	0.021 (0.046)	0.0708 (0.156)	0.125 (0.276)
Nitrate Nitrogen	0	0.042 (0.092)	0.0835 (0.184)
Total Phosphorus	0.0167 (0.368)	0.021 (0.046)	0.0835 (0.184)
Total Potassium	0.021 (0.046)	0.0731 (0.161)	0.136 (0.299)
Magnesium	0.021 (0.046)	0.0251 (0.0552)	0.0292 (0.0644)
Sodium	No Data	No Data	No Data

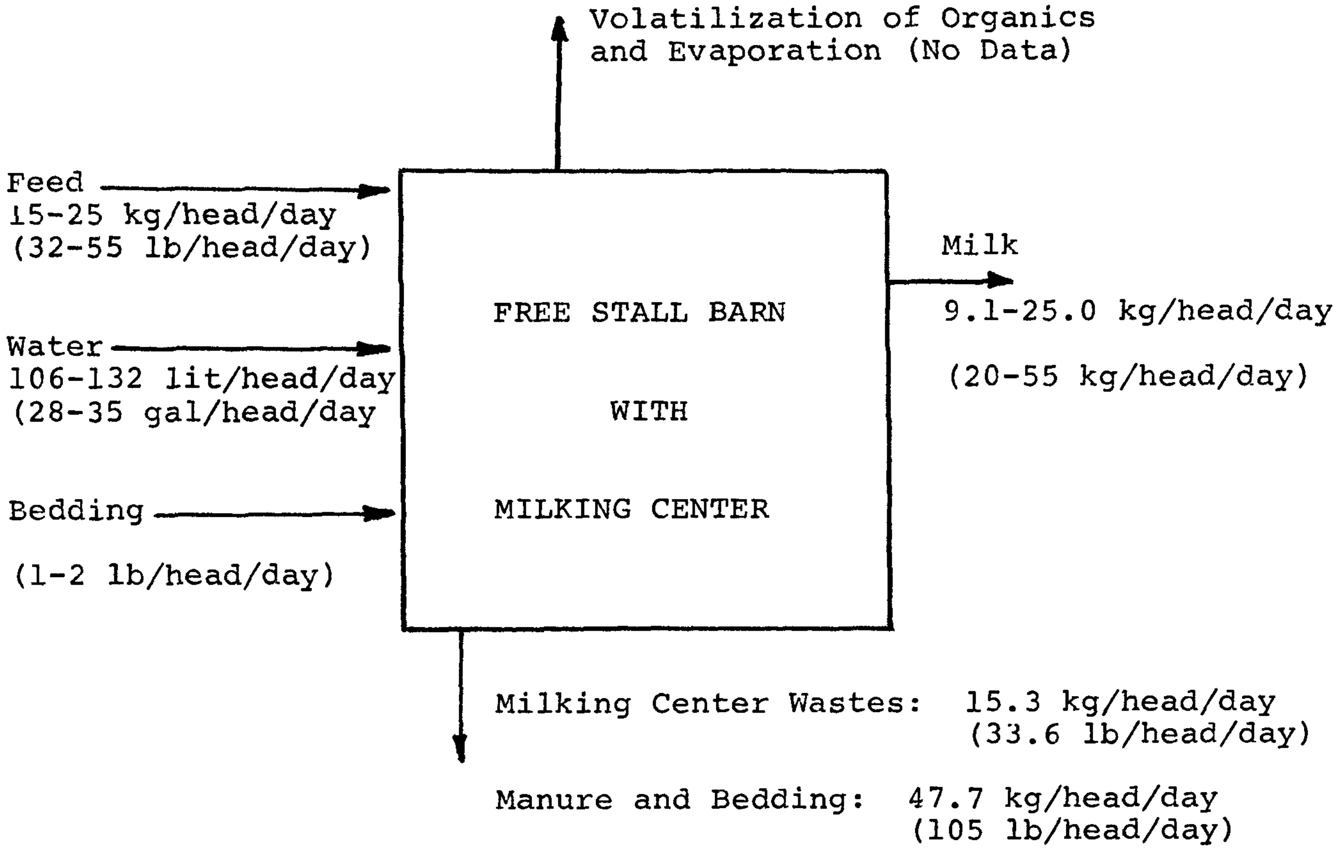
TABLE 9

Category IV

This category, as seen in Figure 22, includes four types of free stall barn systems:

1. Mechanical Scrape
2. Liquid Storage
3. Slotted Floor
4. Liquid Flush

Figure 24 is a flow diagram for the most common free stall system, mechanical scrape.



DAIRY CATTLE CATEGORY IV FLOW DIAGRAM

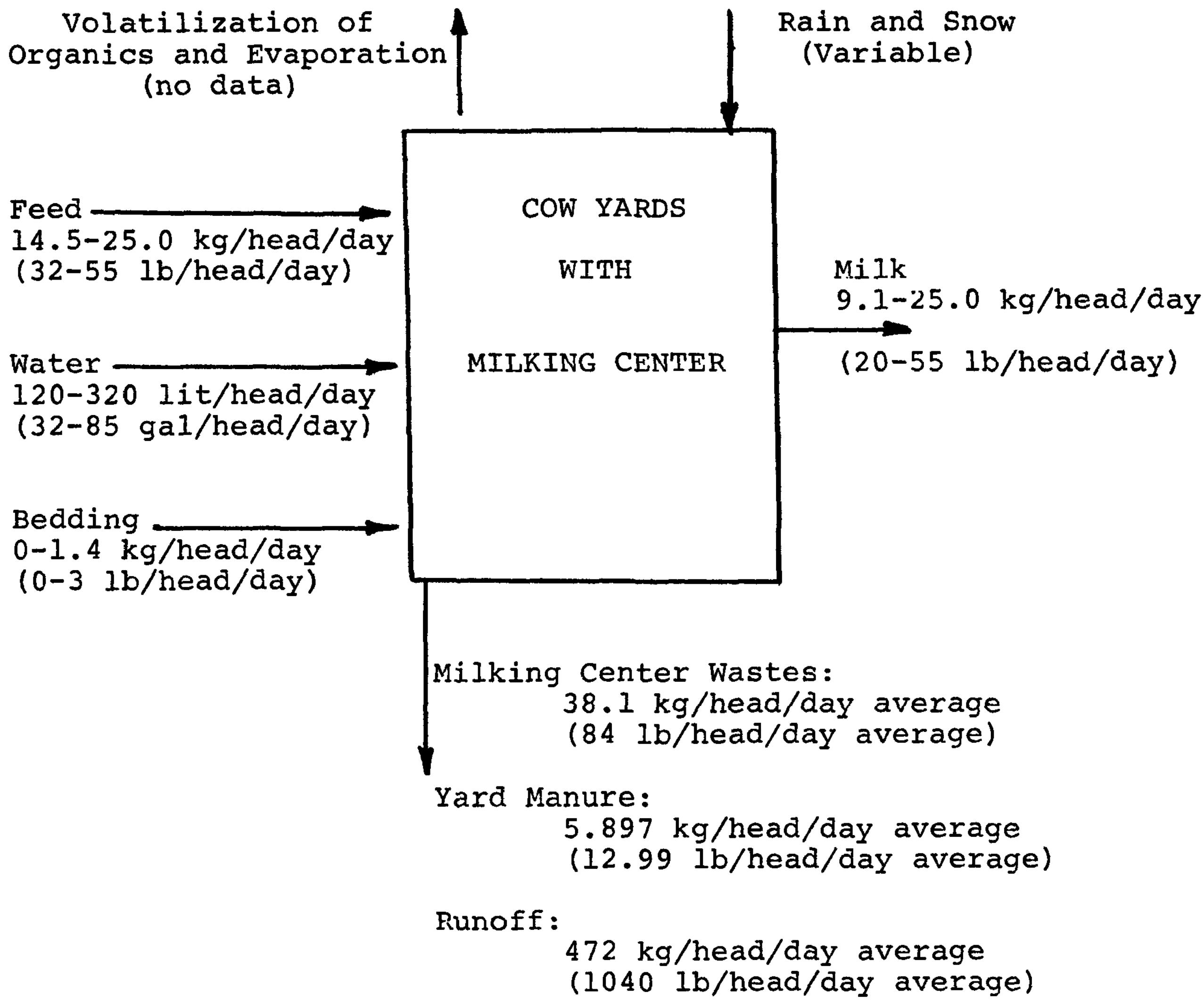
FIGURE 24

The wastes for the mechanical scrape system are shown in Tables 10 and 11. As with the previous category, the data for milking center wastes is sparse and only the average value is indicated (even this value is uncertain).

Table 12 provides rough estimates of the average values for the liquid storage and slotted floor waste systems based on the wastes of Table 10 and limited data on the characteristics of fresh manure. Table 13 is based on Table 10, fresh manure and an increased water usage. Real data are insufficient for estimating minimum and maximum values for Tables 12 and 13.

Category V

Cow yards with milking centers are depicted in Figure 25 and have three types of waste streams as shown in Tables 14, 15 and 16. As in the previous cases, milking center wastes are very rough estimates of only the average values because of a lack of data. Yard manure is the waste scraped from the floor of the cow yard and is estimated on the basis of the biodegraded wastes of beef feedlots since actual data is not available. Runoff from the cow yard is likewise estimated on the basis of beef feedlot runoff. In these cases, only certain average values can be estimated.



DAIRY CATTLE CATEGORY V FLOW DIAGRAM

FIGURE 25

ANIMAL TYPE: Dairy Cattle
ANIMAL WEIGHT: 590 kg Average (1300 lbs. Average)
TYPE OF WASTE: Free Stall Barn - Milking Center Waste

Parameter	kg/head/day (lb/head/day)			mg/l		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Total (wet solids)	No Data	15.3 (33.6)	No Data	-	-	-
Moisture	"	15.2 (33.4)	"	No Data	995,000	No Data
Dry Solids	"	0.077 (0.17)	"	"	5,060	"
Volatile Solids	"	No Data	"	"	No Data	"
Suspended Solids	"	0.04 (0.08)	"	"	2,380	"
pH	"	8.0	"	"	No Data	"
BOD_5	"	0.059 (0.13)	"	No Data	3,870	No Data
COD	"	No Data	"	"	No Data	"
Ash	"	No Data	"	"	No Data	"
Total Nitrogen	"	0.0068 (0.015)	"	"	446	"
Ammonia Nitrogen	"	0.0020 (0.0044)	"	"	131	"
Nitrate Nitrogen	"	No Data	"	"	No Data	"
Total Phosphorus	"	0.0009 (0.002)	"	"	60	"
Total Potassium	"	No Data	"	"	No Data	"
Magnesium	"	"	"	"	"	"
Sodium	"	"	"	"	"	"

TABLE 10

ANIMAL TYPE: Dairy Cattle
ANIMAL WEIGHT: 590 kg Average (1300 lbs. Average)
TYPE OF WASTE: Free Stall Barn - Manure and Bedding
PERCENT CONFINED: 90%

Parameter	kg/head/day (lb/head/day)		
	Minimum	Average	Maximum
Total (wet solids)	36.7 (80.9)	42.9 (94.5)	52.2 (115)
Moisture	27.8 (61.3)	34.7 (76.4)	47.2 (104)
Dry Solids	4.1 (9.0)	8.2 (18)	14.3 (31.5)
Volatile Solids	3.39 (7.47)	6.95 (15.3)	13.1 (28.8)
pH	5	7	9
BOD_5	0.776 (1.71)	0.899 (1.98)	1.23 (2.71)
COD	3.27 (7.20)	5.72 (12.6)	12.3 (27.1)
Ash	0.286 (0.629)	0.695 (1.53)	1.43 (3.15)
Total Nitrogen	0.143 (0.314)	0.225 (0.495)	0.327 (0.720)
Ammonia Nitrogen	0.041 (0.090)	0.138 (0.305)	0.245 (0.540)
Nitrate Nitrogen	0	0.082 (0.18)	0.16 (0.36)
Total Phosphorus	0.033 (0.072)	0.041 (0.090)	0.16 (0.36)
Total Potassium	0.0695 (0.153)	0.143 (0.315)	0.266 (0.585)
Magnesium	0.041 (0.090)	0.0490 (0.108)	0.0572 (0.126)
Sodium	No Data	No Data	No Data

TABLE 11

ANIMAL TYPE: Dairy Cattle
ANIMAL WEIGHT: 590 kg Average (1300 Average)
TYPE OF WASTE: Free Stall Barn-Liquid Storage and Slotted Floor
PERCENT CONFINED: 100%

Parameter	kg/head/day (lb/head/day)		
	Minimum	Average	Maximum
Total (wet solids)	No Data	43.5 (95.8)	No Data
Moisture	"	38.3 (84.4)	"
Dry Solids	"	5.162 (11.37)	"
Volatile Solids	"	No Data	"
pH	"	"	"
BOD_5	"	0.885 (1.95)	"
COD	"	No Data	"
Ash	"	"	"
Total Nitrogen	"	0.228 (0.503)	"
Ammonia Nitrogen	"	0.0627 (0.304)	"
Nitrate Nitrogen	"	"	"
Total Phosphorus	"	"	"
Total Potassium	"	"	"
Magnesium	"	"	"
Sodium	"	"	"

TABLE 12

ANIMAL TYPE: Dairy Cattle
ANIMAL WEIGHT: 590 kg Average (1300 lbs. Average)
TYPE OF WASTE: Free Stall Barn - Liquid Flush
PERCENT CONFINED: 100%

e = estimate

Parameter	kg/head/day (lb/head/day)		
	Minimum	Average	Maximum
Total (wet Solids)	No Data	284.6e (626.0e)	No Data
Moisture	"	279.2e (615.0e)	"
Dry Solids	"	5.162 (11.37)	"
Volatile Solids	"	No Data	"
pH	"	"	"
BOD_5	"	0.885 (1.95)	"
COD	"	No Data	"
Ash	"	"	"
Total Nitrogen	"	0.228 (0.503)	"
Ammonia Nitrogen	"	0.138 (0.304)	"
Nitrate Nitrogen	"	No Data	"
Total Phosphorus	"	"	"
Total Potassium	"	"	"
Magnesium	"	"	"
Sodium	"	"	"

TABLE 13

ANIMAL TYPE: Dairy Cattle
ANIMAL WEIGHT: 590 kg Average (1300 lbs. Average)
TYPE OF WASTE: Cow Yard - Milking Center Waste

Parameter	kg/head/day (lb/head/day)			mg/l		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Total (wet solids)	No Data	38.1 (84.0)	No Data	-	-	-
Moisture	"	37.8 (83.2)	"	No Data	990,500	No Data
Dry Solids	"	0.4 (0.8)	"	"	9,530	"
Volatile Solids	"	No Data	"	"	No Data	"
Suspended Solids	"	0.10 (0.22)	"	"	2,620	"
pH	"	8.0	"			
BOD_5	"	0.17 (0.38)	"	No Data	4,530	No Data
COD	"	No Data	"	"	No Data	"
Ash	"	"	"	"	"	"
Total Nitrogen	"	0.068 (0.15)	"	"	1,790	"
Ammonia Nitrogen	"	0.02 (0.05)	"	"	596	"
Nitrate Nitrogen	"	No Data	"	"	No Data	"
Total Phosphorus	"	0.0068 (0.015)	"	"	179	"
Total Potassium	"	No Data	"	"	No Data	"
Magnesium	"	"	"	"	"	"
Sodium	"	"	"	"	"	"

TABLE 14

ANIMAL TYPE: Dairy Cattle
ANIMAL WEIGHT: 590 kg Average (1300 lbs. Average)
TYPE OF WASTE: Cow Yard - Yard Manure

e = estimate

Parameter	kg/head/day (lb/head/day)		
	Minimum	Average	Maximum
Total (wet solids)	No Data	5.897e (12.99e)	No Data
Moisture	"	1.67e (3.67e)	"
Dry Solids	"	4.23e (9.32e)	"
Volatile Solids	"	2.92e (6.43e)	"
pH	"	No Data	"
BOD_5	"	0.499e (1.10e)	"
COD	"	1.77e (3.90e)	"
Ash	"	1.31e (2.89e)	"
Total Nitrogen	"	0.133e (0.292e)	"
Ammonia Nitrogen	"	No Data	"
Nitrate Nitrogen	"	"	"
Total Phosphorus	"	0.063e (0.140e)	" "
Total Potassium	"	0.095e (0.211e)	"
Magnesium	"	No Data	"
Sodium	"	"	"

TABLE 15

ANIMAL TYPE: Dairy Cattle
ANIMAL WEIGHT: 590 kg Average (1300 lbs. Average)
TYPE OF WASTE: Cow Yard - Runoff
AREA 18.6 meter square/head (200 feet square/head)

e = estimate

Parameter	kg/head/cm Runoff (lb/head/inch runoff)			mg/l		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Total (wet solids)	No Data	186e (1040e)	No Data	-	-	-
Moisture	"	184.67e (10317e)	"	No Data	992,000e	No Data
Dry Solids	"	1.49e (8.32e)	"	"	8,000e	"
Volatile Solids	"	0.707e (3.95e)	"	"	4,000e	"
Suspended Solids	"	No Data	"	"	No Data	"
pH	"	"	"			
BOD_5	"	0.279e (1.56e)	"	No Data	1,500e	No Data
COD	"	0.652e (3.64e)	"	"	3,500e	"
Ash	"	0.782e (4.37e)	"	"	No Data	"
Total Nitrogen	"	0.029e (0.16e)	"	"	150e	"
Ammonia Nitrogen	"	No Data	"	"	No Data	"
Nitrate Nitrogen	"	"	"	"	"	"
Total Phosphorus	"	0.01e (0.08e)	"	"	80e	"
Total Potassium	"	0.063e (0.35e)	"	"	340e	"
Magnesium	"	No Data	"	"	No Data	"
Sodium	"	"	"	"	"	"

TABLE 16

SWINE

Figure 26 identifies the types of wastes for each of the swine categories.

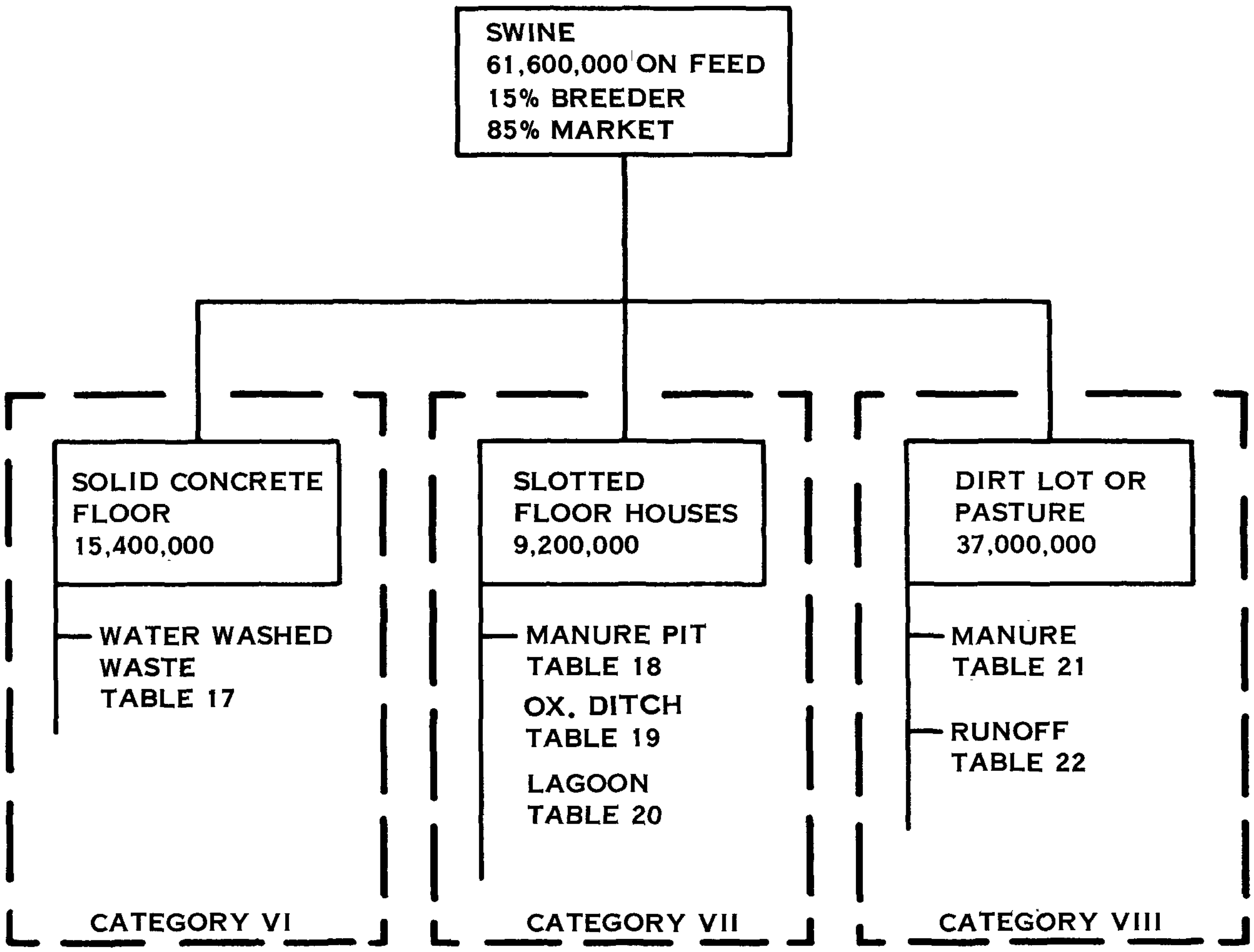
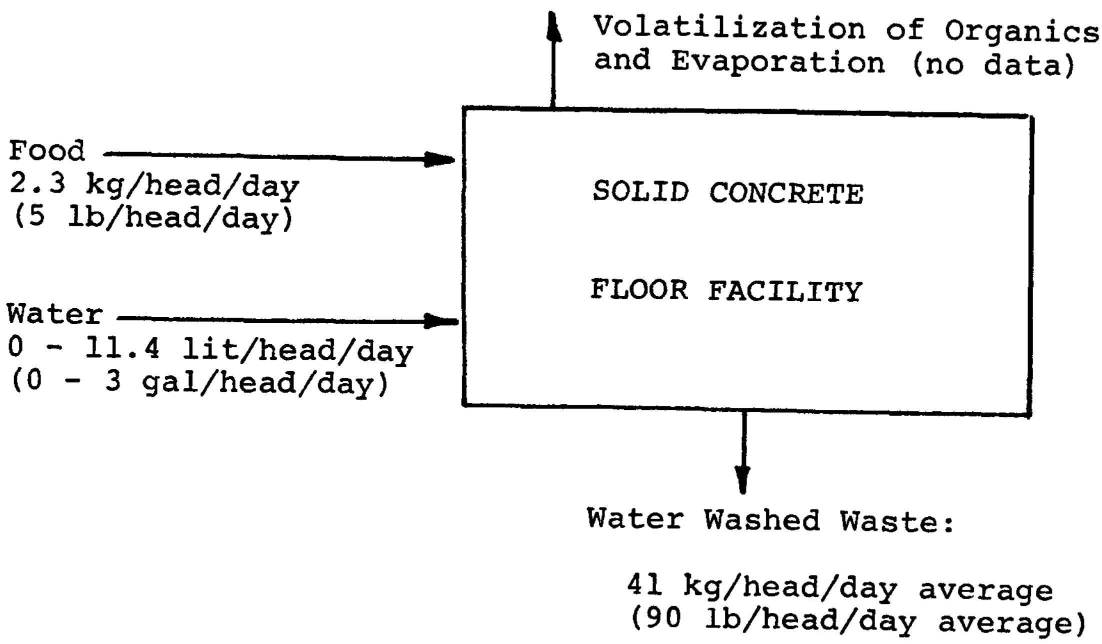


FIGURE 26. SWINE INDUSTRY WASTE IDENTIFICATION

Category VI

As shown in Figure 27, the only waste emanating from the solid concrete floor units is water washed waste, which has been hosed from the floor. It is defined in Table 17. Estimates were made for the amount of water used and amount of biodegradation which would occur.



SWINE CATEGORY VI FLOW DIAGRAM

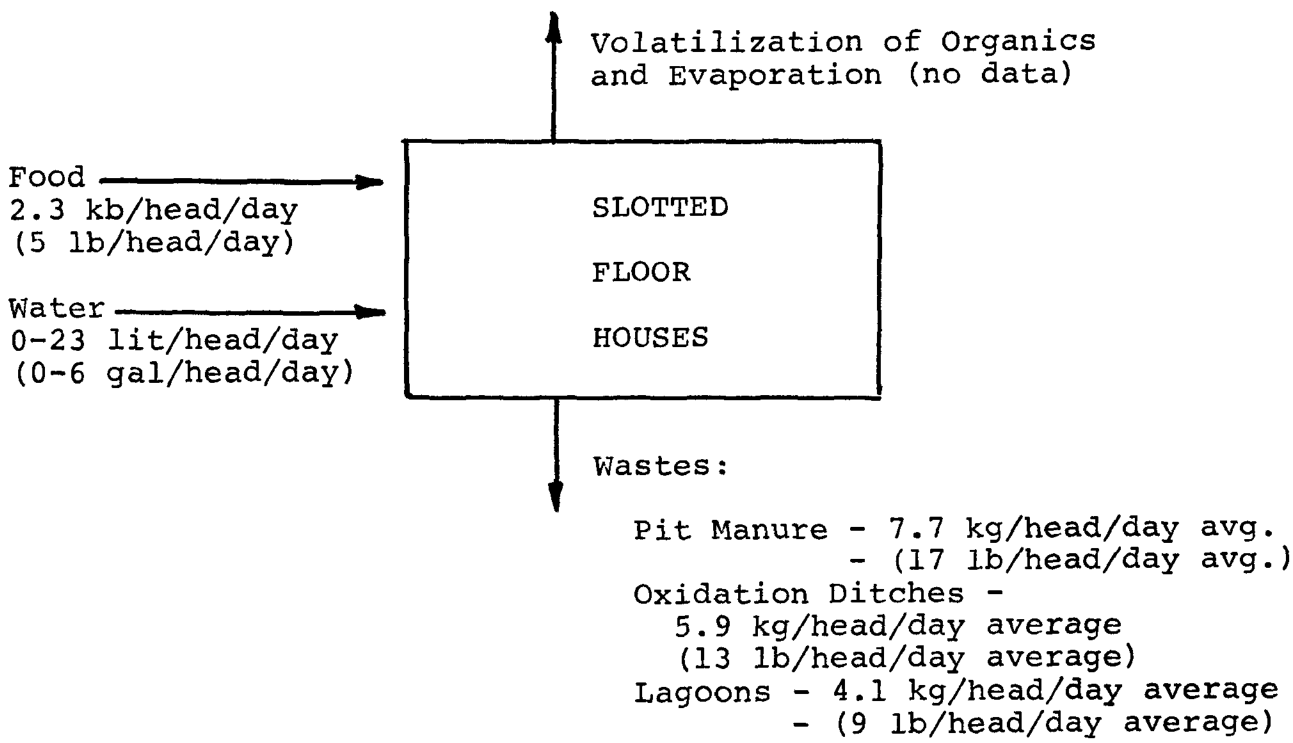
FIGURE 27

Category VII

Slotted floor units depicted in Figure 28 have one of the following options built into the system:

a. Pit Storage (Table 18)
b. Oxidation Ditch (Table 19)
c. Lagoon (Table 20)

For the pit system the maximum value is based on freshly voided manure. The average value assumes 20% biodegradation of the degradable constituents while the minimum value assumes 40% biodegradation. Biodegradation of volatile solids in the oxidation ditch were assumed to be a minimum of 50%, an average of 80% and a maximum of 90%. These values are estimated since data on oxidation ditches which includes a complete material balance is not available. Lagoon values are estimated on the basis that in the minimum case there is no overflow of liquid from the lagoon. The flow and biodegradation for the average and maximum values are estimates. The smallest volatile solids reduction is assumed to be 60%.



SWINE CATEGORY VII FLOW DIAGRAM

FIGURE 28

ANIMAL TYPE: Swine
ANIMAL WEIGHT: 45 kg Average (100 lb. Average)
TYPE OF WASTE: Solid Floor Waterwashed Waste

e = estimate

Parameter	kg/head/day (lb/head/day)			mg/l		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Total (wet solids)	20e (50e)	40e (90e)	50e (110e)	-	-	-
Moisture	20e (50e)	40e (90e)	50e (110e)	987,000e	995,000e	997,000e
Dry Solids	0.1e (0.3e)	0.2e (0.5e)	0.29 (0.64e)	3,000e	5,500e	13,000e
Volatile Solids	0.11e (0.25e)	0.2e (0.4e)	0.21 (0.47)	2,500e	4,500e	9,500e
Suspended Solids	0.1e (0.3e)	0.2e (0.5e)	0.29 (0.64)	3,000e	5,500e	13,000e
pH	6	7	8			
BOD_5	0.068e (0.15e)	0.09e (0.2e)	0.13 (0.28)	3,500e	12,000e	35,000e
COD	0.16e (0.35e)	0.25e (0.55e)	0.32 (0.71)	3,000e	6,000e	14,000e
Ash	0.02e (0.05e)	0.05 (0.1e)	0.077 (0.17e)	450e	1,000e	3,500e
Total Nitrogen	0.011e (0.025e)	0.02e (0.04e)	0.022 (0.048e)	250e	450e	1,000e
Ammonia Nitrogen	0.0068e (0.015e)	0.011e (0.025e)	0.012 (0.027)	150e	300e	600e
Nitrate Nitrogen	0	0	0	0	0	0
Total Phosphorus	0.0064 (0.014)	0.0064 (0.014)	0.0064 (0.014)	150e	150e	300e
Total Potassium	0.0095 (0.021)	0.0095 (0.021)	0.0095 (0.021)	200e	250e	400e

TABLE 17

ANIMAL TYPE: Swine
ANIMAL WEIGHT: 45 kg Average (100 lb Average)
TYPE OF WASTE: Solid Floor Waterwashed Waste

e = estimate

Parameter	kg/head/day (lb/head/day)			mg/l		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Magnesium	2.0×10^{-3} (4.5×10^{-3})	2.0×10^{-3} (4.5×10^{-3})	2.0×10^{-3} (4.5×10^{-3})	40e	50e	100e
Sodium	$2x10^{-3}$ ($4x10^{-3}$)	$2x10^{-3}$ ($4x10^{-3}$)	$2x10^{-3}$ ($4x10^{-3}$)	35e	45e	80e
Chlortetracycline	0	$4x10^{-5}$ ($8x10^{-5}$)	$0.5x10^{-4}$ ($1x10^{-4}$)			
Copper	$3x10^{-5}$ ($6x10^{-5}$)	$3x10^{-5}$ $6x10^{-5}$)	$4x10^{-4}$ ($8x10^{-4}$)	0.5e	le	15e

TABLE 17 (Continued)

ANIMAL TYPE: Swine
ANIMAL WEIGHT: 45 kg Average (100 lbs. Average)
TYPE OF WASTE: Slotted Floor - Pit Manure

e = estimate

Parameter	kg/head/day (lb/head/day)			mg/l		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Total (wet solids)	4e (9e)	7.7e (17e)	19e (42e)	-	-	-
Moisture	3.9 (8.5)	7.49e (16.5e)	18.8e (41.5e)	923,000e	970,000e	990,000e
Dry Solids	0.2e (0.4e)	0.2e (0.5e)	0.29 (0.64e)	9,500e	30,000e	77,000e
Volatile Solids	0.1e (0.3e)	0.2e (0.4e)	0.21 (0.47e)	7,000e	25,000e	56,000e
Suspended Solids	0.05e (0.1e)	0.068e (0.15e)	0.09 (0.2)	2,500e	9,000e	25,000e
pH	6	7.5	9			
BOD_5	0.068e (0.15e)	0.09e (0.2e)	0.13 (0.28)	3,500e	12,000e	35,000e
COD	0.2e (0.4e)	0.25e (0.55e)	0.32 (0.71)	9,500e	35,000e	85,000e
Ash	0.02e (0.05e)	0.05e (0.1e)	0.077 (0.17)	1,200e	6,000e	20,000e
Total Nitrogen	0.01e (0.03e)	0.02e (0.04e)	0.022 (0.048)	700e	2,500e	5,800e
Ammonia Nitrogen	0.009e (0.02e)	0.011e (0.025e)	0.012 (0.027e)	450e	1,500e	3,300e
Nitrate Nitrogen	0	0	0	0	0	0
Total Phosphorus	0.0064 (0.014)	0.0064 (0.014)	0.0064 (0.014)	350e	850e	1,700e
Total Potassium	0.0095 (0.021)	0.0095 (0.021)	0.0095 (0.021)	500e	1,300e	2,500e

TABLE 18

ANIMAL TYPE: Swine
ANIMAL WEIGHT: 45 kg Average (100 lbs. Average)
TYPE OF WASTE: Slotted Floor - Pit Manure

e = estimate

Parameter	kg/head/day (lb/head/day)			mg/l		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Magnesium	2.0×10^{-3} (4.5×10^{-3})	2.0×10^{-3} (4.5×10^{-3})	2.0×10^{-3} (4.5×10^{-3})	100e	250e	550e
Sodium	$2x10^{-3}$ ($4x10^{-3}$)	$2x10^{-3}$ ($4x10^{-3}$)	$2x10^{-3}$ ($4x10^{-3}$)	100e	250e	500e
Chlortetracycline	0	$4x10^{-5}$ (8×10^{-5})	$0.5x10^{-4}$ (1×10^{-5})	0	5e	10e
Copper	$3x10^{-5}$ ($6x10^{-5}$)	$3x10^{-5}$ ($6x10^{-5}$)	$4x10^{-4}$ ($8x10^{-4}$)	1e	5e	10e

TABLE 18 (Continued)

ANIMAL TYPE: Swine
ANIMAL WEIGHT: 45 kg Average (100 lbs. Average)
TYPE OF WASTE: Oxidation Ditch Mixed Liquor

e = estimate

Parameter	kg/head/day (lb/head/day)			mg/l		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Total (wet solids)	2e (4e)	5.9e (13e)	7.7e (17e)	-	-	-
Moisture	1.6e (3.5e)	5.68e (12.5e)	7.49e (16.5e)	900,000e	985,000e	991,000e
Dry Solids	0.068e (0.15e)	0.09e (0.2e)	0.1e (0.3e)	9,000e	15,000e	100,000e
Volatile Solids	0.02e (0.05e)	0.04e (0.09e)	0.11e (0.25e)	3,000e	7,000e	75,000e
Suspended Solids	0.068e (0.15e)	0.09e (0.2e)	0.1e (0.3e)	9,000e	15,000e	100,000e
pH	6	8	9			
BOD_5	0.0068e (0.015e)	0.01e (0.03e)	0.068e (0.15e)	900e	2,500e	45,000e
COD	0.03e (0.07e)	0.09e (0.2e)	0.1e (0.3e)	4,000e	15,000e	100,000e
Ash	0.02e (0.05e)	0.050e (0.11e)	0.068e (0.15e)	3,000e	9,000e	45,000e
Total Nitrogen	0.0009e (0.002e)	0.005e (0.01e)	0.011e (0.025e)	100e	800e	7,500e
Ammonia Nitrogen	0	0.001e (0.003e)	0.005e (0.01e)	0e	250e	3,000e
Nitrate Nitrogen	0.0005e (0.001e)	0.001e (0.003e)	0.009e (0.02e)	50e	250e	6,000e
Total Phosphorus	0.0064 (0.014)	0.0064 (0.014)	0.0064 (0.014)	850e	1,000e	4,500e
Total Potassium	0.0095 (0.021)	0.0095 (0.021)	0.0095 (0.021)	1,300e	1,700e	6,500e

TABLE 19

ANIMAL TYPE: Swine
ANIMAL WEIGHT: 45 kg Average (100 lbs. Average)
TYPE OF WASTE: Oxidation Ditch Mixed Liquor

e = estimate

Parameter	kb/head/day (lb/head/day)			mg/l		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Magnesium	2.5×10^{-3} (4.5×10^{-3})	2.5×10^{-3} 4.5×10^{-3})	2.5×10^{-3} 4.5×10^{-3})	250e	350e	1,400e
Sodium	2×10^{-3} (4×10^{-3})	2×10^{-3} (4×10^{-3})	2×10^{-3} (4×10^{-3})	250e	300e	1,200e
Chlortetracycline	0	0	0.5×10^{-4} (1×10^{-4})	0	0	30e
Copper	3×10^{-5} (6×10^{-5})	3×10^{-5} (6×10^{-5})	4×10^{-4} (8×10^{-4})	5e	35e	250e

TABLE 19 (Continued)

ANIMAL TYPE: Swine
ANIMAL WEIGHT: 45 kg Average (100 lbs. Average)
TYPE OF WASTE: Unaerated Lagoon Effluent

e = estimate

Parameter	kg/head/day (lb/head/day)			mg/l		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Total (wet solids)	0e	4e (9e)	54e (120e)	-	-	-
Moisture	0e	3.9e (8.5e)	52.2e (115e)	970,000e	991,000e	1,000,000e
Dry Solids	0e	0.068e (0.15e)	0.11e (0.25e)	0e	9,000e	30,000e
Volatile Solids	0e	0.03e (0.07e)	0.091e (0.20e)	0e	9,000e	30,000e
Suspended Solids	0e	0.068e (0.15e)	0.11e (0.25e)	0e	9,000e	30,000e
pH	6	7	8.5			
BOD5	0e (0.04e)	0.02e (0.15e)	0.068e	0e	2,500e	20,000e
COD	0e	0.05e (0.1e)	0.1e (0.3e)	0e	6,000e	40,000e
Ash	0e	0.04e (0.08e)	0.05e (0.1e)	0e	5,000e	12,000e
Total Nitrogen	0e	0.009e (0.02e)	0.01e (0.03e)	0e	1,200e	3,600e
Ammonia Nitrogen	0e	0.0068e (0.015e)	0.011e (0.025e)	0e	900e	3,000e
Nitrate Nitrogen	0	0	0	0	0	0
Total Phosphorus	0e (0.007e)	0.003e (0.013e)	0.0059e	0e	400e	1,500e
Total Potassium	0e (0.01e)	0.005e (0.02e)	0.009e	0e	600e	2,500e

TABLE 20

ANIMAL TYPE: Swine
ANIMAL WEIGHT: 45 kg Average (100 lbs. Average)
TYPE OF WASTE: Unaerated Lagoon Effluent

e = estimate

Parameter	kg/head/day (lb/head/day)			mg/l		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Magnesium	0e	0.9×10^{-3}e (2×10^{-3}e)	2×10^{-3}e (4×10^{-3}e)	0e	100e	500e
Sodium	0e	0.9×10^{-3}e (2×10^{-3}e)	2×10^{-3}e (4×10^{-3}e)	0e	100e	500e
Chlortetracycline	0	0	0	0	0	0
Copper	0e	0.5×10^{-5} (1×10^{-5})	0.5×10^{-4} (1×10^{-4})	0e	5e	10e

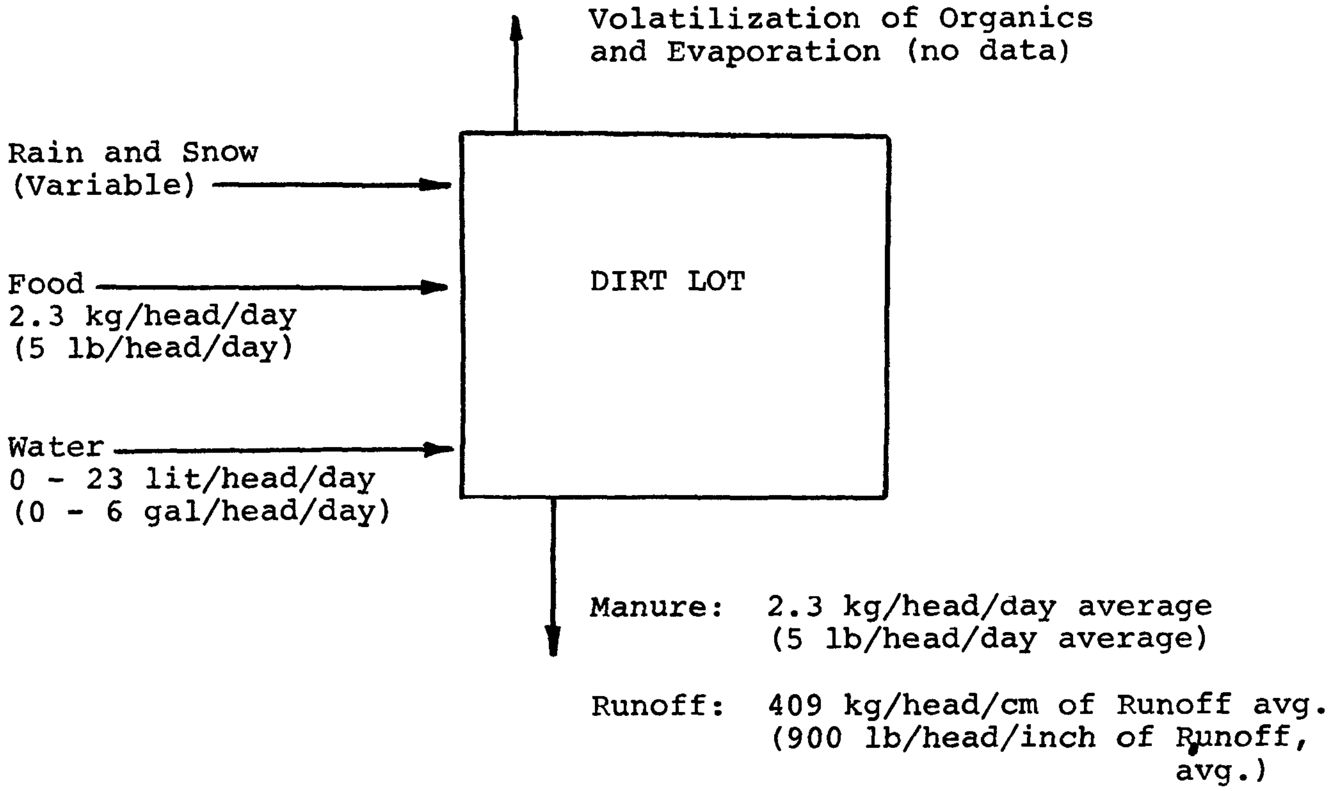
TABLE 20 (Continued)

Category VIII

As depicted in Figure 29, dirt lots have two types of wastes:

a. Manure (scraped from the surface)
b. Runoff.

The maximum value for the manure (Table 21) is based on swine



SWINE CATEGORY VIII FLOW DIAGRAM

FIGURE 29

manure as voided. The average is based on 50% biodegradation of volatile solids. The minimum values of zero are based on a stocking density low enough not to require scraping of the surface. Runoff (Table 22) is based on 10% of the wastes being washed away at most, 5% on the average and none for very low stocking densities and dry climates.

CHICKENS

Category IX

As discussed in Section IV, the entire broiler industry is in one category. Both the breeding flocks and the growing birds are kept on litter. Litter is a highly variable item both in terms of quantity and quality. The following is a list of some of the materials used as litter:

pine straw
peanut hulls
pine shavings
chopped pine straw
rice hulls
pine stump chips
pine bark and chips
pine bark
corn cobs
pine sawdust
clay

Obviously these materials vary considerably in their composition. The amount of litter used is likewise quite variable depending on the type of litter, its ability to absorb moisture and its availability. In breeding flock houses the litter usage is approximately 0.9 kg (2 lbs.) of litter per bird per year. In the broiler house the value is about 2.7 kg (6 lbs) of litter per bird per year. These values are highly dependent on individual management. Another variable is the biodegradation of the wastes. Virtually no data is available along this line. Because of the lack of test data available and because the type

ANIMAL TYPE: Swine
ANIMAL WEIGHT: 45 kg Average (100 lbs. Average)
TYPE OF WASTE: Manure

e = estimate

Parameter	kg/head/day (lb/head/day)		
	Minimum	Average	Maximum
Total (wet solids)	0	2e (5e)	4 (9)
Moisture	0	2e (4e)	4 (8)
Dry Solids	0	0.15e (0.32e)	0.29 (0.64)
Volatile Solids	0	0.10e (0.23e)	0.21 (0.47)
pH	-	-	-
BOD_5	0	0.064e (0.14e)	0.13 (0.28)
COD	0	0.16e (0.35e)	0.32 (0.71)
Ash	0	0.04e (0.09e)	0.077 (0.17)
Total Nitrogen	0	0.011e (0.024e)	0.022 (0.048)
Ammonia Nitrogen	0	0.0064e (0.014e)	0.012 (0.027)
Nitrate Nitrogen	0	0	0
Total Phosphorus	0	0.0064 (0.014)	0.0064 (0.014)
Total Potassium	0	0.0095 (0.021)	0.0095 (0.021)
Magnesium	0	2.0×10^{-3} (4.5×10^{-3})	2.0×10^{-3} (4.5×10^{-3})

TABLE 21

ANIMAL TYPE: Swine
ANIMAL WEIGHT: 45 kg Average (100 lbs. Average)
TYPE OF WASTE: Manure

e = estimate

Parameter	kg/head/day (lb/head/day)		
	Minimum	Average	Maximum
Sodium	0	$2x10^{-3}$ ($4x10^{-3}$)	$2x10^{-3}$ ($4x10^{-3}$)
Chlortetracycline	0	0 ($1x10^{-4}$)	$0.5x10^{-4}$
Copper	0	$3x10^{-5}$ ($6x10^{-5}$)	($4x10^{-4}$ ($8x10^{-4}$)

TABLE 21 (Continued)

ANIMAL TYPE: Swine
ANIMAL WEIGHT: 45 kg Average (100 lbs. Average)
TYPE OF WASTE: Dirt Lot Runoff
AREA: 124 - 618 head/hectare (50 - 250 head/acre)

e = estimate

Parameter	kg/head/cm runoff (lb/head/inch runoff)			mg/l		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Total (wet solids)	0e	161e (900e)	806 (4500e)	-	-	-
Moisture	0e	161e (900e)	806e (4500e)	997,400e	999,700e	1,000,000e
Dry Solids	0e	0.21e (1.2e)	0.41e (2.3e)	0e	260e	2,600e
Volatile Solids	0e	0.16e (0.09e)	0.30e (1.7e)	0e	200e	2,000e
Suspended Solids	0e	0.21e (1.2e)	0.41e (2.3e)	0e	260e	2,600e
pH	6e	7e	8e			
BOD_5	0e	0.09e (0.5e)	0.18e (1.0e)	0e	100e	1,000e
COD	0e	0.23e (1.3e)	0.47e (2.6e)	0e	300e	3,000e
Ash	0e	0.05e (0.3e)	0.11e (0.6e)	0e	20e	200e
Total Nitrogen	0e	0.016e (0.09e)	0.032e (0.18e)	0e	20e	200e
Ammonia Nitrogen	0e	0.007e (0.04e)	0.18e (1.0e)	0e	10e	100e
Nitrate Nitrogen	0e	0.005e (0.03e)	0.032e (0.18e)	0e	5e	200e
Total Phosphorus	0e	0.004e (0.02e)	0.009e (0.05e)	0e	5e	50e
Total Potassium	0e	0.007e (0.04e)	0.014e (0.08e)	0e	10e	100e

TABLE 22

ANIMAL TYPE: Swine
ANIMAL WEIGHT: 45 kg Average (100 lbs. Average)
TYPE OF WASTE: Dirt Lot Runoff
AREA: 124 - 618 head/hectare (50 - 250 head/acre)

e = estimate

Parameter	kg/head/cm runoff (lb/head/inch runoff)			mg/l		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Magnesium	0e	1.4×10^{-3} (8×10^{-3})	2.9×10^{-3} (16×10^{-3})	0e	2e	20e
Sodium	0e	1.3×10^{-3} (7×10^{-3})	2.7×10^{-3} (15×10^{-3})	0e	2e	20e
Chlortetracycline	0e	0e	0e	0e	0e	0e
Copper	0e	0.2×10^{-4} (1×10^{-4})	0.5×10^{-3} (3×10^{-3})	0e	0.05e	3e

TABLE 22 (Continued)

ANIMAL TYPE: Chicken
ANIMAL WEIGHT: 1 kg (1 lb.) (Normalized Value
TYPE OF WASTE: Fresh Manure

Parameter	kg/kg/ or bird/day (lb/lb of bird/day)		
	Minimum	Average	Maximum
Total (wet solids)	No Data	0.059	No Data
Moisture	"	0.0416	"
Dry Solids	"	0.0174	"
Volatile Solids	"	0.0129	"
pH	"	No Data	"
BOD_5	"	0.0044	"
COD	"	0.0157	"
Ash	"	No Data	"
Total Nitrogen	"	0.0115	"
Ammonia Nitrogen	"	No Data	"
Nitrate Nitrogen	"	No Data	"
Total Phosphorus	"	0.0098	"
Total Potassium	"	0.011	"
Magnesium	"	0.0003	"
Sodium	"	0.0003	"

TABLE 23

of litter cannot be readily determined, no detailed waste definition can be presented. Instead a table (Table 23) of the known characteristics of fresh chicken manure is included with no estimation made for litter, biodegradation or evaporation. For purposes of generality the values are reported in kg/kg of bird/day (lb/lb of bird/day).

Categories X and XI

As developed in Section IV, the layer industry comprises two categories. The same difficulties in defining waste loads for broilers apply to laying chickens. In addition, the laying chicken industry includes types of housing in both categories which do not use litter. There is no definitive data as to the waste outputs of such systems nor is there sufficient information about management techniques which would allow estimation of the waste loads. Cages over dry pits with or without ventilation involve drying and possibly biodegradation of the wastes to an unknown extent. Cages over wet pits involve the added complication of water addition which is also not documented by test data. Because of these reasons waste characteristics for laying hens and the respective breeding flocks cannot be estimated. The waste characteristics of fresh manure given in Table 23 are also applicable to layers.

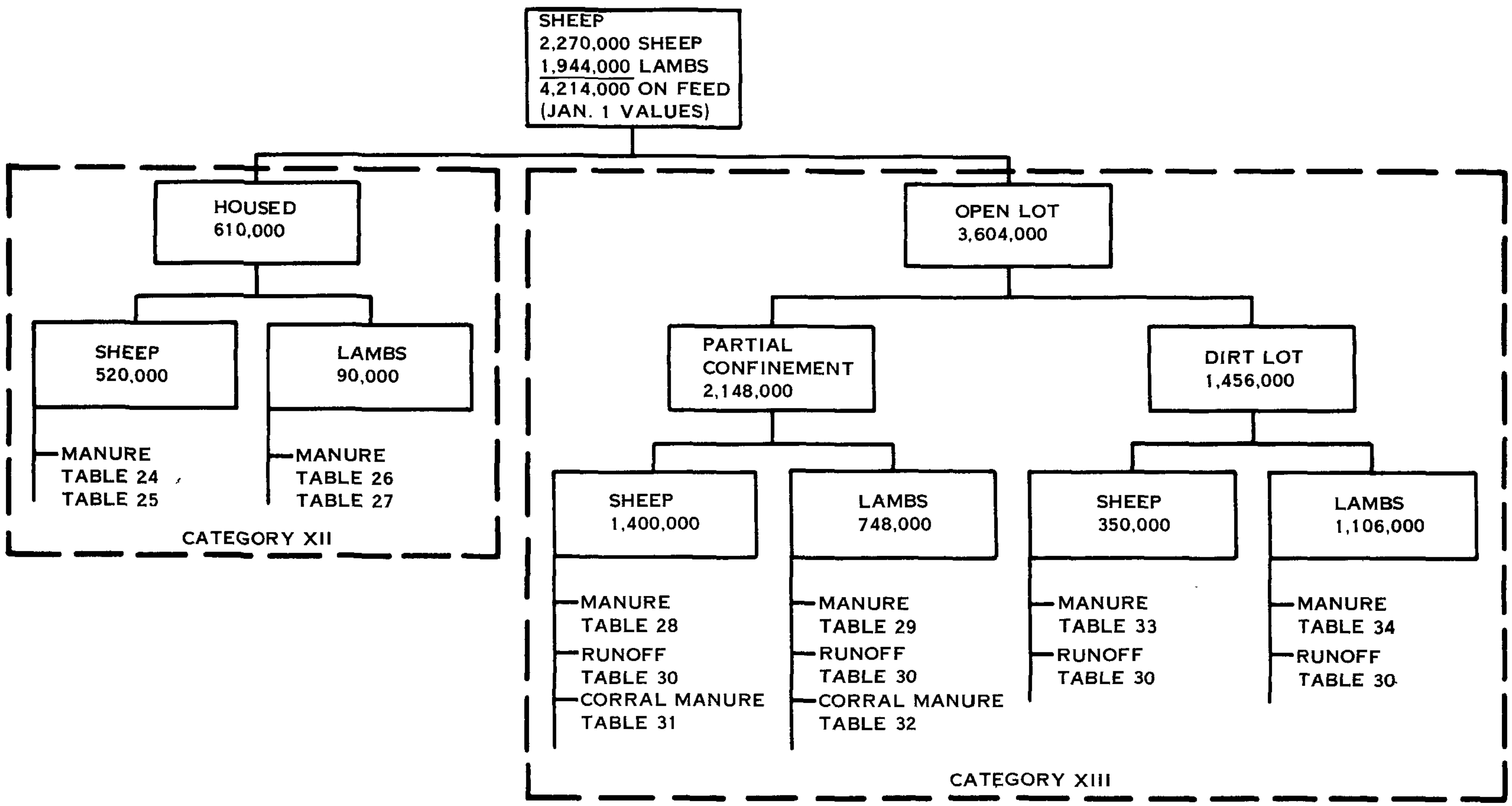


FIGURE 31. SHEEP AND LAMB INDUSTRY WASTE IDENTIFICATION

SHEEP

A substantial amount of the sheep waste characteristics are estimated. The basis of these estimates are:

a. Documented data on the characteristics of fresh manure

b. Reported values of total quantities and moisture content of wastes removed from open lots.

c. Literature values of the maximum and minimum values of Nitrogen, Phosphorus and Potassium as well as average BOD's and COD's for wastes removed from open lots.

d. Estimates of bedding used in housed facilities.

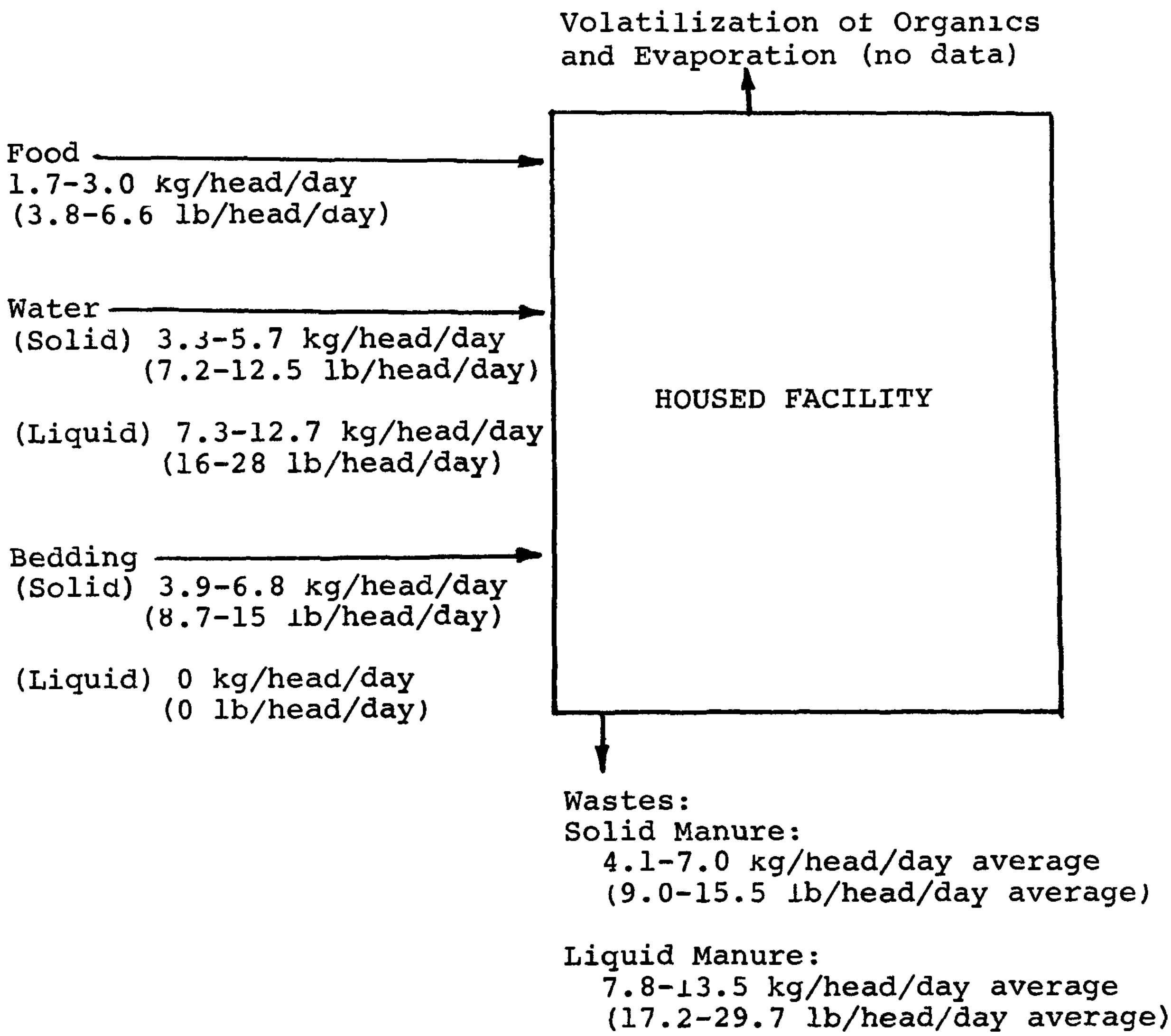
e. Estimates of water added in liquid handling systems.

f. Estimates of expected biodegradation of the wastes.

g. Maximum and minimum values of the constituents of runoff reported in the literature.

h. Average weights of 68 kg (150 lb.) for sheep and 39.4 kg (86.7 lb.) for lambs.

Figure 31 identifies the wastes from each of the sheep industry categories.



SHEEP AND LAMBS CATEGORY XII FLOW DIAGRAM

FIGURE 32

Category XII

As seen in Figure 32, two types of waste streams generated from housed facilities depending on whether solid or liquid handling systems are used. In the solid handling system manure and bedding (usually straw) is removed mechanically from the facility. The waste characteristics for sheep and lambs are given in Table 24 and 26 respectively. In liquid handling systems water is added to the manure to produce a pumpable slurry and no bedding is used. Tables 25 and 27 detail the applicable waste characteristics.

Category XIII

In partial confinement operations, shown in Figure 33, manure and bedding from the confinement house is essentially the same as that from full confinement buildings except that not all the waste is left in the confinement building. Fifty per cent (50%) confinement is assumed as an average; consequently, half the waste is left in confinement and half outside (see Tables 28 and 29). Runoff from the corral area due to rainfall and snowmelt is defined by Table 30 which applies for both sheep and lambs. The manure which builds up on the corral surface must be scraped off periodically and is shown in Table 31 for sheep and Table 32 for lambs (compensated for 50% confinement). Dirt lots have the same type of waste characteristics as the partial confinement operations except that there is not manure from a housed facility. The applicable waste tables are:

a. Tables 33 and 34 for manure scraped from pens.

b. Table 30 for runoff'

ANIMAL TYPE: Sheep
ANIMAL WEIGHT: 68 kg Average (150 lbs. Average)
TYPE OF WASTE: Housed-Manure (Solid)

e = estimate

Parameter	kg/head/day (lb/head/day)		
	Minimum	Average	Maximum
Total (wet solids)	3.84e (8.46e)	7.02e (15.48e)	8.917e (19.64e)
Moisture	2.96e (6.52e)	5.09e (11.23e)	6.138e (13.52e)
Dry Solids	0.881e (1.94e)	1.93e (4.25e)	2.78e (6.12e)
Volatile Solids	0.0708e (1.56e)	1.57e (3.45e)	2.34e (5.15e)
pH	6.5e	6.9e	7.4e
BOD_5	0.0495e (0.109e)	0.16e (0.35e)	0.12e (0.27e)
COD	0.708e (1.56e)	2.2e (4.8e)	4.20e (9.25e)
Ash	0.22e (0.48e)	0.36e (0.80e)	0.44e (0.97e)
Total Nitrogen	0.039e (0.085e)	0.0631e (0.139e)	0.25e (0.55e)
Ammonia Nitrogen	0.000039e (0.000085e)	0.00563e (0.0124e)	0.025e (0.055e)
Nitrate Nitrogen	0e	0.0032e (0.0070e)	0.020e (0.044e)
Total Phosphorus	0.0024e (0.0054e)	0.018e (0.039e)	0.0622e (0.137e)
Total Potassium	0.0095e (0.021e)	0.079e (0.174e)	0.024e (0.52e)
Magnesium	0.0035e (0.0078e)	0.0095e (0.021e)	0.016e (0.036e)
Sodium	0.0013e (0.0029e)	0.011e (0.025e)	0.024e (0.053e)

TABLE 24

ANIMAL TYPE: Sheep
ANIMAL WEIGHT: 68 kg Average (150 lbs. Average)
TYPE OF WASTE: Housed-Manure (Liquid)

e = estimate

Parameter	kg/head/day (lb/head/day)			mg/l		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Total (wet solids)	3.47e (7.64e)	13.46e (29.65e)	25.6e (56.3e)	-	-	-
Moisture	2.96e (6.53e)	12.35e (27.21e)	24.0e (52.8e)	850,000e	906,000e	937,000e
Dry Solids	0.504e (1.11e)	2.44e (2.44e)	3.53e (3.53e)	63,000e	84,000e	150,000e
Volatile Solids	0.39e (0.87e)	0.917e (2.02e)	1.36e (3.00e)	49,000e	68,000e	126,000e
Suspended Solids	0.15e (0.33e)	0.434e (1.00e)	0.795e (1.75e)	19,000e	34,000e	75,000e
pH	6.5e	6.9e	7.4e			
BOD_5	0.032e (0.070e)	0.091e (0.20e)	0.16e (0.35e)	3,900e	6,800e	15,000e
COD	0.39e (0.87e)	1.3e (2.8e)	2.5e (5.4e)	49,000e	95,000e	225,000e
Ash	0.11e (0.24e)	0.21e (0.46e)	0.24e (0.53e)	14,000e	16,000e	24,000e
Total Nitrogen	0.00050e (0.0011e)	0.011e (0.025e)	0.0649e (0.143e)	60e	810e	6,000e
Ammonia Nitrogen	0.00025e (0.00055e)	0.0040e (0.0089e)	0.020e (0.045e)	30e	300e	1,000e
Nitrate Nitrogen	0e	(0.00027e) (0.00059e)	(0.0025e) (0.0056e)	0e	20e	100e
Total Phosphorus	0.00036e (0.00080e)	0.0059e (0.013e)	0.035e (0.076e)	94e	420e	1,350e
Total Potassium	0.0020e (0.0043e)	0.027e (0.060e)	0.15e (0.32e)	500e	1,900e	5,600e

TABLE 25

ANIMAL TYPE: Sheep
ANIMAL WEIGHT: 68 kg Average (150 Average)
TYPE OF WASTE: Housed-Manure (Liquid)

e = estimate

Parameter	kg/head/day (lb/head/day)			mg/l		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Magnesium	0.0020e (0.0045e)	0.0059e (0.013e)	0.010e (0.023e)	280e	480e	980e
Sodium	0.000749e (0.00165e)	0.00676e (0.0149e)	0.01e (0.03e)	110e	540e	1,280e

TABLE 24

ANIMAL TYPE: Lambs
ANIMAL WEIGHT: 39.4 kg Average (86.7 lbs. Average)
TYPE OF WASTE: Housed-Manure (Solid)

e = estimate

Parameter	kg/head/day (lb/head/day)		
	Minimum	Average	Maximum
Total (wet solids)	2.23e (4.91e)	4.08e (8.98e)	5.18e (11.4e)
Moisture	1.72e (3.78e)	2.96e (6.51e)	3.56e (7.84e)
Dry Solids	0.513e (1.13e)	1.12e (2.47e)	1.61e (3.55e)
Volatile Solids	(0.41e) (0.90e)	(0.908e) (2.00e)	(1.36e) (2.99e)
pH	6.5e	6.9e	7.4e
BOD_5	0.029e (0.063e)	0.0922e (0.203e)	0.0713e (0.157e)
COD	0.41e (0.90e)	1.26e (2.78e)	2.44e (5.37e)
Ash	0.13e (0.28e)	0.21e (0.46e)	0.25e (0.56e)
Total Nitrogen	0.022e (0.049e)	0.037e (0.081e)	0.15e (0.32e)
Ammonia Nitrogen	0.000022e (0.000049e)	0.0033e (0.0072e)	0.015e (0.032e)
Nitrate Nitrogen	0e	0.0008e (0.004e)	0.012e (0.026e)
Total Phosphorus	0.0014e (0.0031e)	0.010e (0.023e)	0.036e (0.079e)
Total Potassium	0.0054e (0.012e)	0.0459e (0.101e)	0.1e (0.3e)
Magnesium	0.0020e (0.0045e)	0.0055e (0.012e)	0.0095e (0.021e)
Sodium	0.00073e (0.0016e)	0.00658e (0.0145e)	0.014e (0.031e)

TABLE 26

ANIMAL TYPE: Lambs
ANIMAL WEIGHT: 39.4 kg Average (86.7 lbs. Average)
TYPE OF WASTE: Housed-Manure (Liquid)

e = estimate

Parameter	Minimum	Average	Maximum	Minimum	Average	Maximum
Total (wet solids)	2.01e (4.43e)	7.81e (17.2e)	14.8e (32.7e)	-	-	-
Moisture	1.72e (3.79e)	7.17e (15.8e)	13.9e (30.6e)	850,000e	916,000e	937,000e
Dry Solids	0.29e (0.64e)	0.645e (1.42e)	0.931e (2.05e)	63,000e	84,000e	150,000e
Volatile Solids	0.229e (0.505e)	0.531e (1.17e)	0.790e (1.74e)	49,000e	68,000e	126,000e
Suspended Solids	0.26e (0.58e)	0.463e (1.02e)	0.867e (1.91e)	19,000e	34,000e	75,000e
pH	6.5e	6.9e	7.4e			
BOD_5	0.019e (0.041e)	0.0527e (0.116e)	0.0922e (0.203e)	3,900e	6,800e	15,000e
COD	0.229e (0.505e)	0.740e (1.63e)	1.42e (3.13e)	49,000e	95,000e	225,000e
Ash	0.0631e (0.139e)	0.121e (0.267e)	0.139e (0.307e)	14,000e	16,000e	24,000e
Total Nitrogen	0.00029e (0.00064e)	0.0068e (0.015e)	0.038e (0.083e)	60e	810e	6,000e
Ammonia Nitrogen	0.00015e (0.00032e)	0.0024e (0.0052e)	0.012e (0.026e)	30e	300e	1,000e
Nitrate Nitrogen	0e	0.00015e (0.00034e)	0.0015e (0.0032e	0e	20e	100e
Total Phosphorus	0.00021e (0.00046e)	0.0034e (0.0075e)	0.020e (0.044e)	94e	420e	1,350e

TABLE 27

ANIMAL TYPE: Lambs
ANIMAL WEIGHT: 39.4 kg Average (86.7 lbs. Average)
TYPE OF WASTE: Housed-Manure (Liquid)

e = estimate

Parameter	kg/head/day (lb/head/day)			mg/l		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Total Potassium	0.0010e (0.0023e)	0.016e (0.035e)	0.0844e (0.186e)	500e	1,900e	5,600e
Magnesium	0.0012e (0.0026e)	0.0034e (0.0075e)	0.0059e (0.013e)	280e	480e	980e
Sodium	0.00044e (0.00096e)	0.0039e (0.0086e)	0.00790e (0.0174e	110e	540e	128e

TABLE 27 (Continued)

ANIMAL TYPE: Sheep
ANIMAL WEIGHT: 68 kg Average (150 lbs. Average)
TYPE OF WASTE: Partial Confinement Manure
PERCENT CONFINED: 50%

e = estimate

Parameter	kg/head/day (lb/head/day)		
	Minimum	Average	Maximum
Total (wet solids)	1.92e (4.23e)	3.51e (7.74e)	4.46e (9.82e)
Moisture	1.48e (3.26e)	2.55e (5.62e)	3.07e (6.76e)
Dry Solids	0.44e (0.97e)	0.967e (2.13e)	1.39e (3.06e)
Volatile Solids	0.35e (0.78e)	0.785e (1.73e)	1.17e (2.58e)
pH	6.5e	6.9e	7.4e
BOD_5	0.025e (0.055e)	0.0795e (0.175e)	0.0613e (0.135e)
COD	0.35e (0.78e)	1.1e (2.4e)	2.10e (4.63e)
Ash	0.11e (0.24e)	0.2e (0.4e)	0.220e (0.485e)
Total Nitrogen	0.020e (0.043e)	0.0316e (0.0695e)	0.125e (0.275e)
Ammonia Nitrogen	0.000020e (0.000043e)	0.0028e (0.0062e)	0.0125e (0.0275e)
Nitrate Nitrogen	0e	0.0016e (0.0035e)	0.010e (0.022e)
Total Phosphorus	0.0012e (0.0027e)	0.00885e (0.0195e)	0.0141e (0.0685e)
Total Potassium	0.00477e (0.0105e)	0.039e (0.087e)	0.12e (0.26e)
Magnesium	0.0018e (0.0039e)	0.0047e (0.0105e)	0.0082e (0.018e)
Sodium	0.000658e (0.00145e)	0.00568e (0.0125e)	0.0120e (0.0265e)

TABLE 28

ANIMAL TYPE: Lambs
ANIMAL WEIGHT: 39.4 kg Average (86.7 lbs. Average)
TYPE OF WASTE: Partial Confinement - Manure
PERCENT CONFINED: 50%

e = estimate

Parameter	kg/head/day (lb/head/day)		
	Minimum	Average	Maximum
Total (wet solids)	1.11e (2.45e)	2.04e (4.49e)	2.58e (5.69e)
Moisture	0.858e (1.89e)	1.47e (3.23e)	1.78e (3.92e)
Dry Solids	0.256e (0.563e)	0.563e (1.24e)	0.804e (1.77e)
Volatile Solids	0.205e (0.452e)	0.454e (1.00e)	0.676e (1.49e)
pH	6.5e	6.9e	7.4e
BOD_5	0.015e (0.032e)	0.0463e (0.102e)	0.0355e (0.0783e)
COD	0.205e (0.452e)	0.631e (1.39e)	1.22e (2.69e)
Ash	0.0631e (0.139e)	0.105e (0.232e)	0.128e (0.281e)
Total Nitrogen	0.011e (0.025e)	0.0183e (0.0403e)	0.0722e (0.159e)
Ammonia Nitrogen	0.000011e (0.000025e)	0.0016e (0.0036e)	0.00722e (0.0159e)
Nitrate Nitrogen	0e	0.000922e (0.00203e)	0.00581e (0.0128e)
Total Phosphorus	0.000713e (0.0157e)	0.00513e (0.0113e)	0.0173e (0.382e)
Total Potassium	0.0028e (0.0061e)	0.0229e (0.0505e)	0.0686e (0.151e)
Magnesium	0.0010e (0.0023e)	0.0028e (0.0061e)	0.00472e (0.0104e)
Sodium	0.00038e (0.00084e)	0.0033e (0.0073e)	0.00699e (0.0154e)

TABLE 29

ANIMAL TYPE: Sheep and Lambs
ANIMAL WEIGHT: 68 and 39.4 kg Average Respectively
(150 and 86 lbs. Average Respectively)
TYPE OF WASTE: Open Lot - Runoff
AREA: 2.8 meter square/head (Sheep)
(30 feet square/head) (Sheep)

1.4 meter square/head (Lambs)
(15 feet square/head) (Lambs)

e = estimate

	kg/head/cm runoff (lb/head/inch runoff)			mg/l		
Parameter	Minimum	Average	Maximum	Minimum	Average	Maximum
Total (wet solids)	27.9 (156)	27.9 (156)	27.9 (156)			
Moisture	26.5 (148)	27.6e (154e)	27.9 (156)	950,000	987,000e	987,600
Dry Solids	0.07 (0.4)	0.43 (2.4)	1.4 (7.8)	2,400	12,500e	50,000
Volatile Solids	0.029 (0.16)	0.18e (0.98e)	0.39 (2.2)	1,000	6,200e	14,000
Suspended Solids	0.030 (0.17)	0.13e (0.70e)	0.38 (2.1)	1,100	4,500e	13,500
pH	5.8	6.9e	8.0			
BOD_5	0.011 (0.062)	0.084e (0.47e)	0.335 (1.87)	400	3,000e	12,000
COD	(0.036) (0.20)	(0.279e) (1.56e)	(2.18) (12.2)	1,300	10,000e	78,000
Ash	0.039 (0.22)	0.17e (0.97e)	0.474 (2.65)	1,400	6,200e	17,000
Total Nitrogen	(0.0014) (0.0078)	(0.029e) (0.16e)	(0.16) (0.90)	50	1,000e	5,000

TABLE 30

ANIMAL TYPE: Sheep and Lambs
ANIMAL WEIGHT: 68 and 39.4 kg Average Respectively
(150 and 86.7 lbs. Average Respectively)
TYPE OF WASTE: Open Lot - Runoff
AREA: 2.8 meter square/head (Sheep)
(30 feet square/head) (Sheep)

1.4 meter square/head (Lambs)
(15 feet square/head) (Lambs)

e = estimate

Parameter	kg/head/cm runoff (lb/head/inch runoff)			mg/l		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Ammonia Nitrogen	0	0.0029e (0.016e)	0.055 (0.31)	0	100e	2,000
Nitrate Nitrogen	0	0.00055e (0.0031e)	0.00224 (0.0125)	0	20e	80
Total Phosphorus	0.00014 (0.00078)	0.00224e (0.0125e)	0.021 (0.12	5	80e	750
Total Potassium	0.0011 (0.0062)	0.020e (0.11e)	0.057 (0.32)	40	700	2,100
Magnesium	0.0017 (0.0093)	0.0029e (0.016e)	0.011 (0.062)	60	100e	400
Sodium	0.0017 (0.0093)	0.014e (0.078e)	0.045 (0.25)	60	500e	1,600
Chloride	0.0055 (0.031)	0.013e (0.072e)	0.021 (0.12)	200	460e	780

TABLE 30 (Continued)

ANIMAL TYPE: Sheep
ANIMAL WEIGHT: 68 kg Average (150 lbs. Average)
TYPE OF WASTE: Partial Confinement-Corral Manure
PERCENT CONFINEMENT: 50%

e = estimate

Parameter	kg/head/day (lb/head/day)		
	Minimum	Average	Maximum
Total (wet solids)	0.477e (1.05e)	0.73e (1.6e)	0.922e (2.03e)
Moisture	0.184e (0.405e)	0.21e (0.47e)	0.24e (0.53e)
Dry Solids	0.24e (0.53e)	0.504e (1.11e)	0.735e (1.62e)
Volatile Solids	0.0477e (0.105e)	0.17e (0.37e)	0.37e (0.81e)
pH	6.5e	6.9e	7.5e
BOD_5	0.010e (0.023e)	0.024e (0.053e)	0.034e (0.075e)
COD	0.034e (0.075e)	0.17e (0.37e)	0.443e (0.975e)
Ash	0.19e (0.42e)	0.325e (0.715e)	0.37e (0.81e)
Total Nitrogen	0.00167e (0.00368e)	0.0116e (0.0255e)	0.0222e (0.0488e)
Ammonia Nitrogen	0.000017e (0.000037e)	0.000568e (0.00125e)	0.00207e (0.00455e)
Nitrate Nitrogen	0e	0.000050e (0.00011e)	0.0012e (0.0026e)
Total Phosphorus	0.00024e (0.00053e)	0.00215e (0.00473e)	0.0040e (0.0089e)
Total Potassium	0.00040e (0.00089e)	0.00749e (0.0165e)	0.012e (0.027e)
Magnesium	0.000717e (0.00158e)	0.00184e (0.00405e)	0.0037e (0.0081e)
Sodium	0.00038e (0.00083e)	0.00279e (0.00615e)	0.00627e (0.0138e)

TABLE 31

ANIMAL TYPE: Lambs
ANIMAL WEIGHT: 39.4 kg Average (86.7 lbs. Average)
TYPE OF WASTE: Partial Confinement - Corral Manure
PARTIAL CONFINEMENT: 50%

e = estimate

Parameter	kg/head/day (lb/head/day)		
	Minimum	Average	Maximum
Total (wet solids)	0.276e (0.609e)	0.421e (0.928e)	0.536e (1.18e)
Moisture	0.108e (0.273e)	0.14e (0.31e)	2.831e (6.235e)
Dry Solids	0.139e (0.307e)	0.292e (0.644e)	0.426e (0.939e)
Volatile Solids	0.028e (0.061e)	0.0976e (0.215e)	0.213e (0.470e)
pH	6.5e	6.9e	7.5e
BOD_5	0.00604e (0.0133e)	0.0139e (0.0307e)	0.0197e (0.0435e)
COD	0.0197e (0.0435e)	0.0976e (0.215e)	0.0257e (0.566e)
Ash	0.111e (0.244e)	0.188e (0.415e)	0.213e (0.470e)
Total Nitrogen	0.000967e (0.00213e)	0.00672e (0.0148e)	0.0128e (0.0283e)
Ammonia Nitrogen	0.0000095e (0.000021e)	0.000329e (0.000725e)	0.00119e (0.00263e)
Total Phosphorus	0.00014e (0.00031e)	0.0012e (0.0027e)	0.0024e (0.0052e)
Total Potassium	0.00024e (0.00052e)	0.0044e (0.0096e)	0.0073e (0.016e)
Magnesium	0.00042e (0.00092e)	0.0010e (0.0023e)	0.0021e (0.0047e)
Sodium	0.00022e (0.00048e)	0.0016e (0.0036e)	0.004e (0.008e)

TABLE 32

ANIMAL TYPE: Sheep
ANIMAL WEIGHT: 68 kg Average (150 lbs. Average)
TYPE OF WASTE: Dirt Lot - Manure

e = estimate

Parameter	kg/head/day (lb/head/day)		
	Minimum	Average	Maximum
Total (wet solids)	0.95e (2.1e)	1.43 (3.15)	1.84e (4.05e)
Moisture	0.37e (0.81e)	0.43e (0.94e)	0.477e (1.05e)
Dry Solids	0.477e (1.05e)	1.00e (2.21e)	1.47e (3.24e)
Volatile Solids	0.095e (0.21e)	0.34e (0.74e)	0.735e (1.62e)
pH	6.5e	6.9e	7.5e
BOD_5	0.020e (0.045e)	0.0477 (0.105)	0.068e (0.15e)
COD	0.068e (0.15e)	0.34 (0.74)	0.885e (1.95e)
Ash	0.38e (0.84e)	0.649e (1.43e)	0.735e (1.62e)
Total Nitrogen	0.00334 (0.00735)	0.023e (0.051e)	0.0443 (0.0975)
Ammonia Nitrogen	0.000034e (0.000074e)	0.0011e (0.0025e)	0.0041e (0.0091e)
Nitrate Nitrogen	0e	0.00022e (0.00010e)	0.0052e (0.0024e)
Total Phosphorus	0.000477 (0.0010e)	0.00429e (0.00945e)	0.00808 (0.0178)
Total Potassium	0.000808 (0.00178)	0.015e (0.033e)	0.025 (0.054)
Magnesium	0.00143e (0.00315e)	0.0037e (0.0081e)	0.00735e (0.0162e)
Sodium	0.000749e (0.00165e)	0.000558e (0.00123e)	0.0125e (0.0276e)

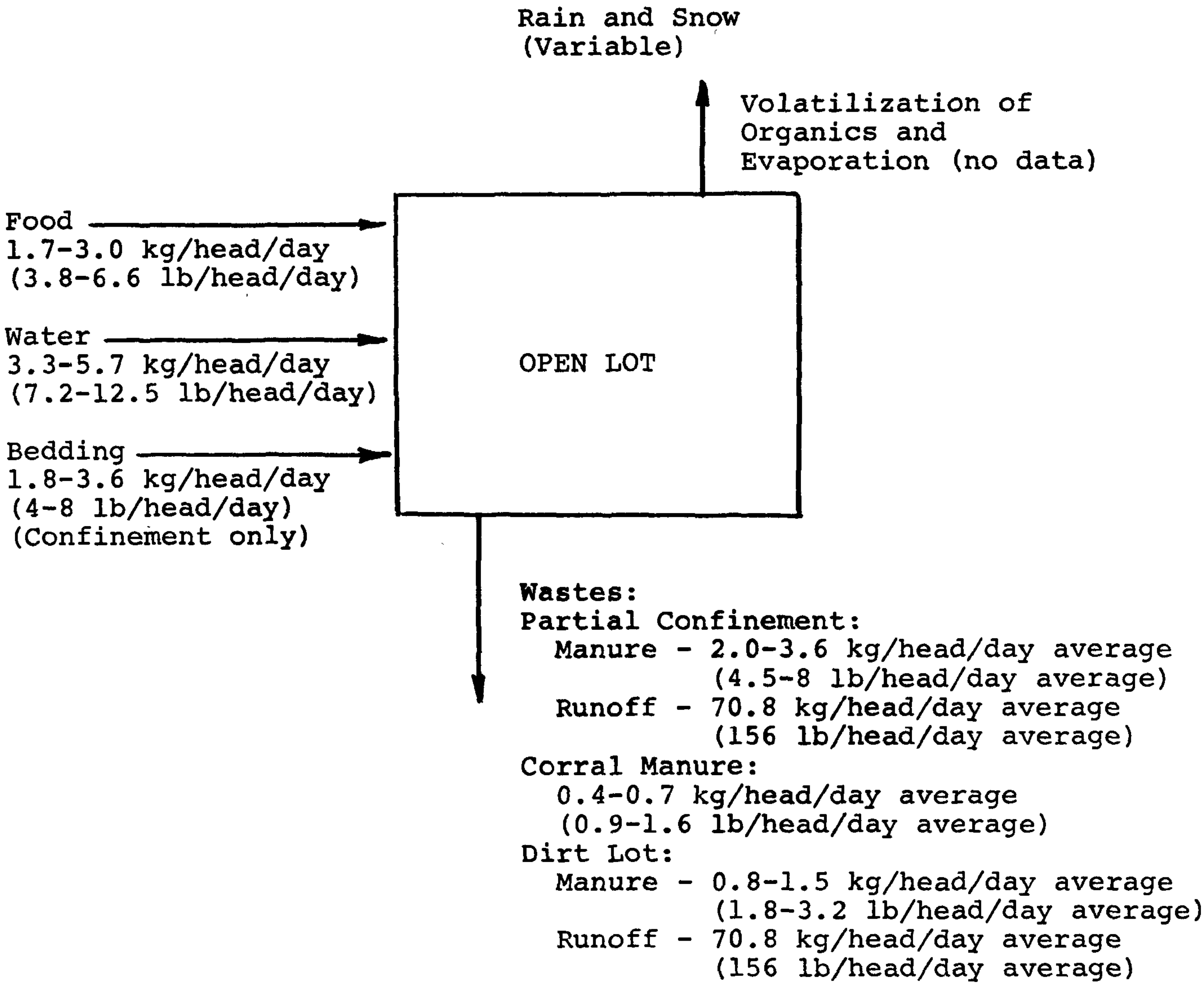
TABLE 33

ANIMAL TYPE: Lambs
ANIMAL WEIGHT: 39.4 kg Average (86.7 lbs. Average)
TYPE OF WASTE: Dirt Lot - Manure

e = estimate

Parameter	kg/head/day (lb/head/day)		
	Minimum	Average	Maximum
Total (wet solids)	0.554e (1.22e)	0.831 (1.83)	1.07e (2.35e)
Moisture	0.21e (0.47e)	0.25e (0.55e)	0.28e (0.61e)
Dry Solids	0.28e (0.61e)	0.581e (1.28e)	0.854e (1.88e)
Volatile Solids	0.054e (0.12e)	0.20e (0.43e)	0.43e (0.94e)
pH	6.5e	6.9e	7.5e
BOD_5	0.012e (0.026e)	0.028 (0.061)	0.039e (0.087e)
COD	0.039e (0.087e)	0.20 (0.43)	0.513e (1.13e)
Ash	0.22e (0.49e)	0.38e (0.83e)	0.43e (0.94e)
Total Nitrogen	0.0020 (0.0043)	0.01e (0.03e)	0.026 (0.057)
Ammonia Nitrogen	0.000020e (0.000043e)	0.00068e (0.0015e)	0.0024e (0.0053e)
Nitrate Nitrogen	0e	0.000059e (0.00013e)	0.001e (0.003e)
Total Phosphorus	0.00028 (0.00061)	0.0025e (0.0055e)	0.00468 (0.0103)
Total Potassium	0.000468 (0.00103)	0.0086e (0.019e)	0.014 (0.031)
Magnesium	0.00082e (0.0018e)	0.0021e (0.0047e)	0.0043e (0.0094e)
Sodium	0.00044e (0.00096e)	0.0032e (0.0071e)	0.0073e (0.016e)

TABLE 34



SHEEP AND LAMBS CATEGORY XIII FLOW DIAGRAM

FIGURE 33

Turkeys

Figure 34 identifies the wastes from each of the turkey categories.

Category XIV

The wastes from this category are a mixture of manure and litter. There are, however, two types of wastes, manure and litter from breeding birds and that from market birds. These two types are estimated in Tables 35 and 36 respectively. The data are estimated on the basis of a limited amount of data on fresh turkey waste and some data on laying hens. Biodegradation of the wastes, evaporation and litter usage are not considered due to the lack of actual test data.

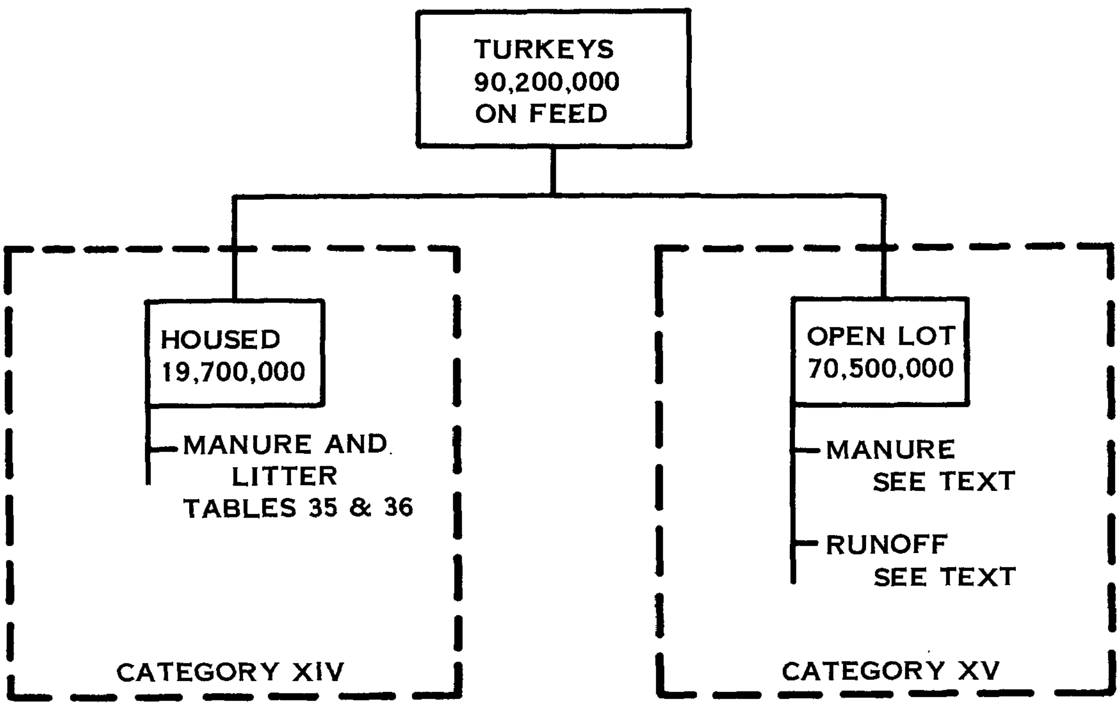


FIGURE 34. TURKEY INDUSTRY WASTE IDENTIFICATION

Category XV

In open lot operations where animal densities are high, removal of accumulated solids may be required. There is no data available on this type of waste. Similarly there is no runoff data available.

Manure and runoff characteristics are dependent on stocking density, vegetative cover and land use practices. Land use varies from about 10% to 30% of the year. This low usage is a result of the sensitivity of turkeys to disease. Since there is an undefined variability in open lot practices and since no actual manure or runoff data is available no tables of waste characteristics are included. This is not to say that manure and runoff are not present in some cases but that documentation of such wastes does not exist.

DUCKS

Figure 35 identifies the wastes for each duck category.

Category XVI

Dry lots operate with no water except for drinking and, in some cases, washing out the wastes. This type of system is relatively new and no test data on waste outputs are available. As a result, no waste characteristic tables are included for this category.

Category XVII

Some waste water characteristics have been measured for Long Island duck farms and are given in Table 37. The characteristics of solid manure and litter removed from the confinement house have not been measured. The degree of biodegradation and the amount of bedding used are unknown; consequently, a table defining this waste is not included.

HORSES

Category XVIII The wastes from this category are a mixture of manure and bedding. The quantities and variations of quantities are based on a survey of several racetracks conducted by the Thoroughbred Racing Association. Quantities for some specific constituents were from the literature. Inorganic salts were estimated on the basis of a similarity to the wastes of beef cattle. The characteristics are detailed in Table 38.

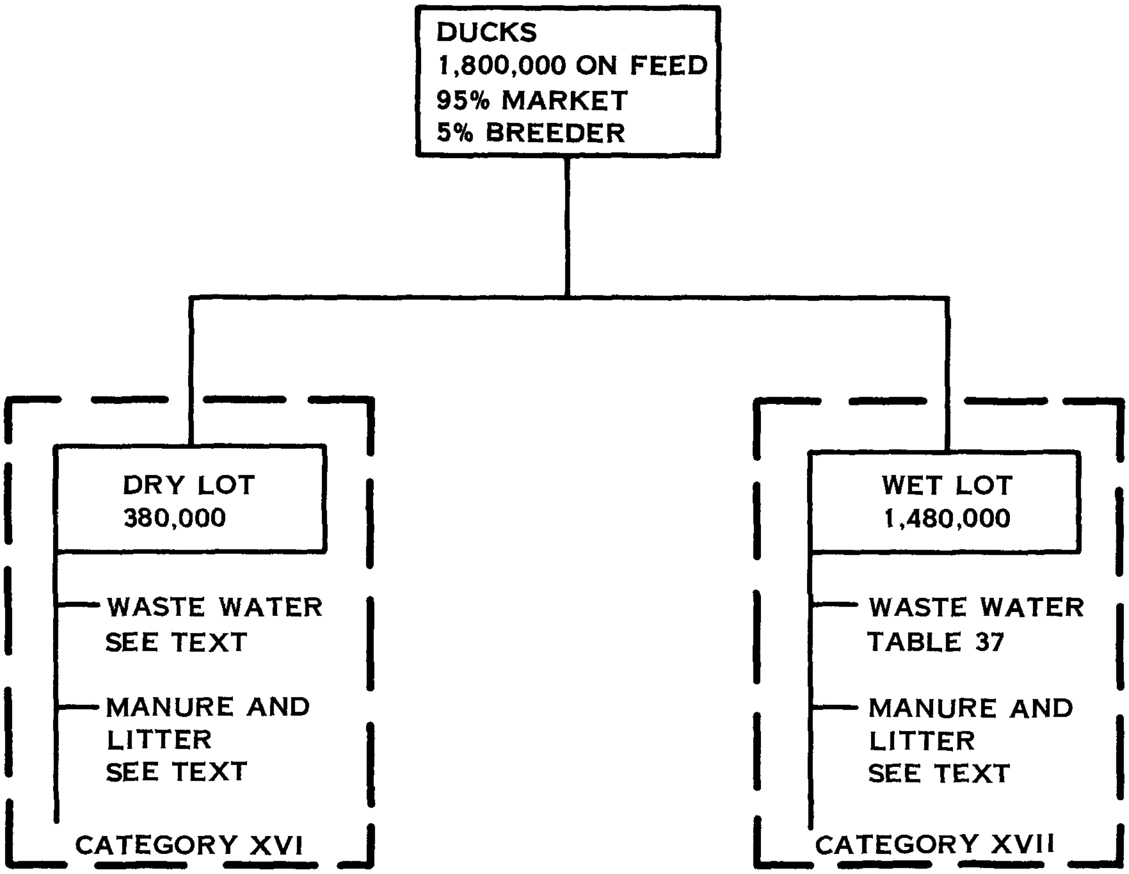


FIGURE 35. DUCK INDUSTRY WASTE IDENTIFICATION

ANIMAL TYPE: Turkeys
ANIMAL WEIGHT: 11.4 kg Average (25 lbs. Average)
TYPE OF WASTE: Breeding - Fresh Manure

e = estimate

Parameter	kg/head/day (lb/head/day)		
	Minimum	Average	Maximum
Total (wet solids)	No Data	0.681e (1.50e)	No Data
Moisture	"	0.5108e (1.125e)	"
Dry Solids	0.147e (0.323e)	0.170e (0.375e)	0.216e (0.476e)
Volatile Solids	0.0876e (0.193e)	0.110e (0.243e)	0.131e (0.288e)
pH	6.4e	6.7e	7.0e
BOD_5	0.015e (0.033e)	0.039e (0.85e)	0.0822e (0.181e)
COD	0.0844e (0.186e)	0.118e (0.259e)	0.147e (0.323e)
Ash	0.034e (0.075e)	0.040e (0.089e)	0.0477e (0.105e)
Total Nitrogen	0.0073e (0.016e)	0.0082e (0.018e)	0.0086e (0.019e)
Ammonia Nitrogen	0.001e (0.003e)	0.004e (0.008e)	0.0059e (0.013e)
Nitrate Nitrogen	No Data	No Data	No Data
Total Phosphorus	0.002e (0.005e)	0.0068e (0.015e)	0.011e (0.025e)
Total Potassium	0.001e (0.003e)	0.003e (0.006e)	0.004e (0.009e)
Magnesium	0.0001e (0.0003e)	0.0001e (0.0003e)	0.0001e (0.0003e)

TABLE 35

ANIMAL TYPE: Turkeys
ANIMAL WEIGHT: 11.4 kg Average (25 lbs. Average)
TYPE OF WASTE: Breeding - Fresh Manure

e = estimate

Parameter	kg/head/day (lb/head/day)		
	Minimum	Average	Maximum
Sodium	0.0054e (0.012e)	0.0054e (0.012e)	0.0054e (0.012e)
Arsenic	No Data	0.0003 (0.0007)	No Data

TABLE 35 (Continued)

ANIMAL TYPE: Turkeys
ANIMAL WEIGHT: 6.8 kg Average (15 lbs. Average)
TYPE OF WASTE: Growing - Fresh Mnaure

e = estimate

Parameter	kg/head/day (lb/head/day)		
	Minimum	Average	Maximum
Total (wet solids)	No Data	0.41e (0.90e)	No Data
Moisture	"	0.306e (0.675e)	"
Dry Solids	0.0881e (0.194e)	0.102e (0.225e)	0.130e (0.286e)
Volatile Solids	0.0527e (0.116e)	0.0663e (0.146e)	0.0785e (0.173e)
pH	6.4e	6.7e	7.0e
BOD_5	0.0091e (0.020e)	0.023e (0.051e)	0.0495e (0.109e)
COD	0.0508e (0.112e)	0.0708e (0.156e)	0.0881e (0.194e)
Ash	0.020e (0.045e)	0.025e (0.054e)	0.029e (0.063e)
Total Nitrogen	0.0045e (0.010e)	0.0050e (0.011e)	0.0054e (0.012e)
Ammonia Nitrogen	0.001e (0.002e)	0.002e (0.005e)	0.004e (0.008e)
Nitrate Nitrogen	No Data	No Data	No Data
Total Phosphorus	0.001e (0.003e)	0.004e (0.009e)	0.0068e (0.015e)
Total Potassium	0.001e (0.002e)	0.002e (0.004e)	0.003e (0.006e)

TABLE 36

ANIMAL TYPE: Turkeys
ANIMAL WEIGHT: 6.8 kg Average (15 lbs. Average)
TYPE OF WASTE: Growing - Fresh Manure

e = estimate

Parameter	kg/head/day (lb/head/day)		
	Minimum	Average	Maximum
Sodium	0.003e (0.007e)	0.003e (0.007e)	0.003e (0.007e)
Arsenic	No Data	0.0003e (0.0007e)	No Data

TABLE 36 (Continued)

ANIMAL TYPE: Ducks
ANIMAL WEIGHT: 1.6 kg Average (3.5 Average)
TYPE OF WASTE: Wet Lot Waste Water

Parameter	kg/head/day (lb/head/day)			mg/l		
	Minimum	Average	Maximum	Minimum	Average	Minimum
Total (wet solids)	18.2 (40)	No Data	454 (1000)	-	-	-
Moisture	18.2 (40)	"	454 (1000)	993,000	998,000	999,670
Dry Solids	0.012 (0.026)	0.044 (0.096)	0.15 (0.32)	330	1,010	6,340
Volatile Solids	No Data	No Data	No Data	No Data	No Data	No Data
Suspended Solids	0.005 (0.01)	0.0248 (0.0546)	0.108 (0.237)	17	337	4,630
pH	6.2	6.9	8.0			
BOD_5	0.0050	No Data	0.030	26	No Data	490
COD	0.0086 (0.019)	0.037 (0.082)	0.12 (0.26)	140	810	7,520
Ash	No Data	No Data	No Data	No Data	No Data	No Data
Total Nitrogen	0.0021 (0.0047)	"	0.0029 (0.0064)	7	"	50
Ammonia Nitrogen	No Data	"	No Data	No Data	"	No Data
Nitrate Nitrogen	"	"	"	"	"	"
Total Phosphorus	0.001 (0.003)	"	0.010 (0.022)	9	"	73
Total Potassium	No Data	"	No Data	No Data	"	No Data
Magnesium	"	"	"	"	"	"
Sodium	"	"	"	"	"	"

TABLE 37

ANIMAL TYPE: Horses
ANIMAL WEIGHT: 454 kg Average (1000 lbs. Average)
TYPE OF WASTE: Manure and Bedding

e = estimate

Parameter	kg/head/day (lb/head/day)		
	Minimum	Average	Maximum
Total (wet solids)	23.4 (51.5)	37.2 (82.0)	51.08 (112.5)
Moisture	15.0 (33.0)	20.0 (44.0)	24.5 (54.0)
Dry Solids	8.40 (18.5)	17.3 (38.0)	26.6 (58.5)
Volatile Solids	6.31e (13.9e)	12.9e (28.5e)	19.9e (43.8e)
pH	6.0e	7.0e	8.0e
BOD_5	0.16e (0.36e)	0.4e (0.8e)	0.663e (1.46e)
COD	0.899e (1.98e)	2.0e (4.5e)	3.65e (8.05e)
Ash	2.1e (4.6e)	4.3e (9.5e)	6.67e (14.7e)
Total Nitrogen	0.114e (0.252e)	0.261 (0.574)	0.463e (1.02e)
Ammonia Nitrogen	0.029e (0.063e)	0.068e (0.15e)	0.116e (0.256e)
Nitrate Nitrogen		NEGLIGIBLE	
Total Phosphorus	0.0197e (0.0433e)	0.045 (0.10)	0.0799e (0.176e)
Total Potassium	0.12 (0.26)	0.24 (0.52)	0.38 (0.84)
Magnesium	0.0157e (0.0345e)	0.04 (0.08)	0.0636e (0.141e)
Sodium	0.0126e (0.0278e)	0.03e (0.06e)	0.05108e (0.1125e)

TABLE 38

SECTION VI

SELECTION OF POLLUTANT PARAMETERS

DEFINITION OF POLLUTANT

This study deals with animal feedlot waste, which is one of many different types of agricultural wastes. In accordance with Section 502 of the "Federal Water Pollution Control Act Amendments of 1972", all agricultural wastes are defined as pollutants, hence animal feedlot wastes are pollutants in a legal sense.

In the context of this investigation the main parameters of water pollution to be considered are grouped as follows:

1. Total Solids content
2. Oxygen Demand
3. Color and Turbidity
4. Odor
5. Bacteriological
6. Total Dissolved Solids

There is no question that animal wastes can cause water pollution from any one or all of the groups listed. The exact degree of pollution, however, will be different for each set of circumstances. For instance, the ratios of the concentrations of animal waste constituents remain constant to a practical extent throughout the wide range of types of animal waste; however, in one in-stream situation phosphorus may be a limiting nutrient for excessive algae growth and nitrogen may be the limiting nutrient in another. These differences vary with the normal characteristics of the water in question and can only be specified by studying each situation individually. Moreover, even though the available data shows a number of specific pollutant parameters are contained in animal wastes, the degree of specificity is not absolute since waste flows (particularly runoff) have apparently not been sampled and analyzed for some types of animal feeding operations (e.g., turkeys, sheep, low density swine lots) as shown by the estimates provided in Section V. The following general discussion therefore centers upon those parameters for which data provides confidence in requiring control of discharges and (conversely) the lack of data highlights a need for concern that is not as completely well documented.

TOTAL SOLIDS CONTENT AND OXYGEN DEMAND

The primary solid constituents of animal waste are best described by the following terms which are not mutually exclusive, but which represent significant classifications from the pollutional standpoint.

1. Biological Material
2. Nitrogen
3. Phosphorus
4. Dissolved solids and trace constituents.

These represent specific pollutants since they supply nutrients, viable organisms and other contaminants to surface waters. Each group is described in more detail below.

<u>Biological Material</u>

Animal wastes contain both plant and animal biological materials. The composition of this biological material is as follows:

1. Undigested and partially digested feed.
2. Partially broken-down organic matter resulting from body metabolism.
3. Expired and viable micro-organisms from the digestive tract.
4. Cell wall material and other organic debris from the digestive tract.
5. Excess digestive juices.
6. Any other organisms which may have grown in the wastes after leaving the animal.

All of these components can biodegrade further and in so doing deplete the oxygen level of surface waters thus killing fish.

The most common standard measure of biodegradability or degree of oxygen depleting activity due to bacterial digestion of wastes is the fiveday biochemical oxygen demand, designated BOD5, expressed as either total kilograms (pounds) of oxygen required or parts per million (mg/l) oxygen concentration required. Another measure is chemical oxygen demand (COD) which provides an indication of the total amount of oxidizable carbon in a waste. It is also expressed as either kilograms (pounds) of oxygen required or parts per million oxygen concentration required. COD likewise gives an indication of the biological strength of a waste but it also incorporates depletion of chemically bound oxygen. This is evident since lignified cellulose (from partially digested animal forage feeds) has a high COD and a low BOD5 because, although it is biological in nature, it is not easily broken down by bacteria. In either case, both BOD and COD have been used extensively in characterizing animal wastes and feedlot runoff, and both parameters are found in such high concentration in these waste flows as to suggest immediate concern for the adverse impact upon waterbodies.

Another important aspect of the biological nature of animal wastes is the microorganism content. Potentially harmful microorganisms (e.g. pathogenic bacteria, viruses, parasites) are commonly found in raw animal wastes and have been shown to persist in some manure handling systems for some ill-defined periods of time. However, once voided from the animal, the manure fails to provide a viable environment for sustaining these microorganisms and no data appears to exist which shows microorganisms persist through runoff containment structures, land utilization or other sound waste handling system. However, the potential for contamination should not be dismissed and tests (involving coliform bacteria indicator organisms) do exist to check for contamination if any possible question arises.

Nitrogen

Another important pollutional waste constituent other than biological content is nitrogen. The three most common forms of nitrogen in wastes are organic, ammonia, and nitrate. Organic nitrogen compounds will break down into ammonia nitrogen, and nitrates which in turn will promote the growth of aquatic plants and bacteria thereby increasing the oxygen demand upon the receiving water body. In addition, unused ammonia nitrogen may be converted into additional nitrate nitrogen which, along with the original nitrates, may create high concentrations which are potentially hazardous.

Phosphorus

Phosphorus is also a significant component of animal wastes and can be directly linked to the eutrophication process of lakes and streams. As such, phosphorus must be considered to be a pollutant. When applied to soil, however, phosphorus usually does not exhibit a runoff potential because it usually becomes fixed by minerals adsorbed in the soil particles. In this case, movement to groundwater is essentially precluded and runoff can only occur if actual erosion of the soil is involved. When soil particles reach watercourses as sediment, however, the potential exists for the phosphorus to be chemically released into solution as an available nutrient.

Dissolved Solids and Trace Constituents

Inorganic salts such as potassium, calcium, sodium, magnesium, and organic materials such as pharmaceuticals and pesticides fall into this group. Some of these are required in trace amounts for the growth of aquatic plants; however, they are usually present in natural waters in sufficient quantities and therefore are not commonly limiting nutrients. There is no reliable data which shows the persistence of pharmaceuticals (e.g. growth hormones or antibiotics) in runoff or manure. Recognition of a potential is offered here in a precautionary context only since adverse effects on water quality may exist if the presence of these substances (copper, arsenicals, estrogens) in runoff is documented in the future. With respect to the mineral salts, usually measured as salinity or "total dissolved solids," high levels sometines found in animal wastes and runoff can aggravate salinity in watercourses, or adversely affect water supplies for drinking water (such as sodium which can be harmful to humans in high concentrations). Pesticides used for sanitation and animal dissease control are also potential contaiminants. Compounds such as toxaphene used in cattle dipping tanks are hazardous and may persist in small amounts in runoff from pen areas.

COLOR AND TURBIDITY

Color and turbidity may readily be caused by manure runoff into watercourses particularly lakes, ponds or sluggish streams where the influence of the runoff from areas other than the feedlot is not great. Both parameters particularly affect the aesthetic benefits of waterbodies and should therefore be controlled.

ODOR

The odor of animal waste is mainly a function of how it has been stored, its moisture content and its relative degree of biodegradation. Odors in some cases can be extremely strong especially if putrefaction is in process and may be "carried over" into watercourses in runoff.

SECTION VII

CONTROL AND TREATMENT TECHNOLOGY

GENERAL

To put each of the technologies into proper perspective within the framework of total feedlot waste management, a series of groupings and classifications has been performed. The first logical grouping step is to differentiate between "in-process" and "end-of-process" technologies. In-process technology is discussed in detail under the heading "FEEDLOT ANALYSIS". End-of-process technology is discussed in detail under the heading "END-OF-PROCESS CONTROL AND TREATMENT TECHNOLOGY IDENTIFICATION", and each technology is then discussed under its own heading.

In-Process Technology

This term refers to the physical and operational characteristics of the feedlot and their impact on waste management. Specific elements are feed formulation and utilization, water utilization, bedding and litter utilization, site selection, housekeeping, and selection of method of production. All of these elements are directly concerned with what is happening within the feedlot itself, although they all have an direct effect on the waste materials leaving the feedlot. Facilities for collection and storage of waste that are physically part of the feedlot and are closely associated with the livestock are considered in-process technology. Therefore, pen design, pen or stall cleaning, underfloor manure pits, and manure stockpiling are included in this category. Settling basins, lagoons, and remote waste treatment processes are not.

End-of-Process Technology

These technologies affect the waste materials after they leave the feedlot proper. A considerable number of end-of-process technologies are evaluated later in this section. In preparation for that evaluation, it is helpful to classify those processes.

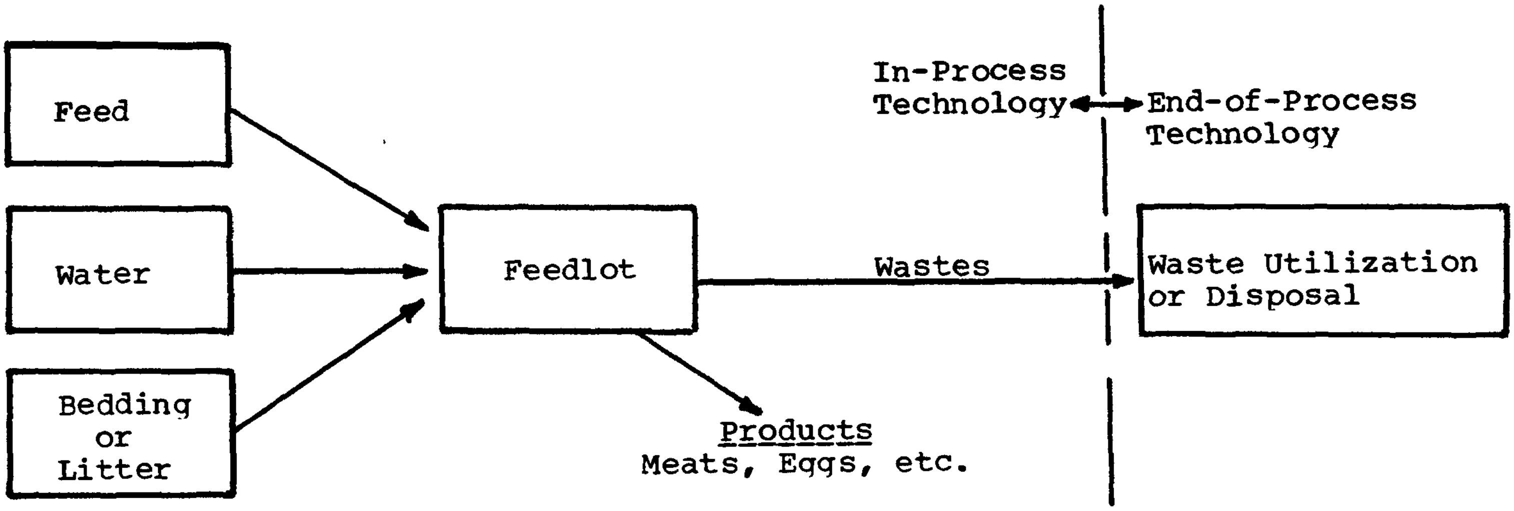
As presented in Section V, waste materials are either raw or partially degraded manure or contaminated runoff. The technologies for manure treatment may be classified as either partial or complete, although classification of some of the experimental technologies is uncertain. For the purposes of this report, partial treatment is defined as one that produces a product that is neither sold nor completely utilized on the feedlot or is one that produces a byproduct, residue, or waste water stream of questionable economic value. A complete treatment, on the other hand, produces a readily marketable product or a product that may be entirely reused on the feedlot, and has no appreciable byproducts, residues, or polluted water. Some examples will illustrate these definitions. The Dehydrate and Sell technology is a complete treatment. The Dehydrate and Feed technology is an incomplete treatment because, taking laying hens as an example, only half of the manure (corresponding to about 15 percent of the dry feed ration) can be utilized efficiently. At higher refeeding rates, egg production drops off and other problems arise. The Fly Larvae Reduction technolgoy is a partial treatment. Although all the manure can subsequently be utilized as a feed supplement growth medium, disposal of the byproduct composted manure must be accomplished, requiring an additional activity such as land spreading or a marketing program. Gasification is a partial treatment because although the gas may be marketable, a significant quantity of ash must be disposed of.

Treatment of runoff also can be classified as partial or complete, but an additional function is required: containment. Containment is covered largely under the heading "RUNOFF CONTROL". However, it is also mentioned under "LAGOONS FOR WASTE TREATMENT" and "EVAPORATION", both of which serve the dual purposes of containment and partial treatment. These technologies are classified under partial treatment because lagoon effluent is generally not suitable for discharge, and both lagoons and evaporation ponds generally require sludge disposal. Most of the other technologies classified under runoff are also partial treatments. Thus, even if algae and hyacinths are entirely feedable, the water from which they derive their nutrients remains significantly polluted. Trickling filters and the rotating contractor leave an algae mat or sludge that requires disposal, and spray runoff requires disposal of the grass. The "Barriered Landscape Water Renovation System" (BLWRS) may prove to be a complete treatment.

This classification of waste treatment technologies is important to an economic analysis, because it assures that the analysis will be as complete as available data permits. A feedlot generally requires some management of both manure and runoff. If the selected treatment for either manure or runoff falls in the "partial" category, a "complete" treatment -- probably land utilization -- will be required as a supplement.

FEEDLOT ANALYSIS

The process of feedlot operation can be diagramed very simply as shown below. In addition to feed formulation and usage, water usage, and bedding or litter utilization, three other factors should be considered as in-process parameters: site selection, housekeeping practice and selection of method of production.



Feed Formulation and Utilization

The two most important factors which determine the character and quantity of wastes voided by an animal are the type of animal and the type of feed. However, for a given type of animal, the feed formulation is relatively fixed. The causes for this are as follows:

a. Each animal has a general set of dietary needs.

b. An animal feeder must use an "optimum" diet in order to remain economically competitive, and this diet is then essentially the same at each facility.

The actual ingredients of a diet may vary depending on the market price variations of different ingredients; however, the nutrient content of the diet in terms of protein, fat, fiber, etc., will remain relatively fixed.

It is interesting to note that different types of animals have a wide range of feeding efficiencies (kilograms or pounds of feed required for each kilogram or pound of weight gain). This gives an indication of what percentage of the feed passes through the animal without being absorbed or utilized (digested). The following are typical feed efficiencies for growing animals:

Beef:	7 - 9	kilograms (pounds) of feed kilograms (pound) of gain
Swine:	3 - 4	"
Chickens:	2 - 3	"
Sheep:	5 - 7	"
Turkeys:	3 - 4	"
Ducks:	2 - 3	"

For purely economic reasons, it is in the interest of the animal feeder to keep these numbers as low as practical. It is possible that improvements can be made by breeding, but this process of improvement is slow.

It is evident that although the feed formulation has a major effect on the character and quantity of the wastes, there is very little room for in-process changes in this area which could reduce pollutional loads.

Water Utilization

As evidenced by the waste tables in Section V, water is the largest variable in feedlot waste loads. This is due to two reasons:

a. Climate (specifically precipitation versus evaporation)

b. Water use practices.

Climate is best discussed under the topic of site selection, so remarks here will be limited to a discussion of water use practices.

Water is not a pollutant, however, it has a marked effect on pollution control. If wastes are to be biodegraded, water is a necessity. On the other hand, if the organic content of the wastes is to be processed into a useful product, biodegradation may not be advantageous. In this case, the wastes should be stored in a relatively dry form. In addition, odors and flies are reduced by keeping the wastes dry. However, handling of wastes by "dry" handling practices such as scraping equipment, bucket loaders, etc., is often more expensive than the practice of flushing out pens and pumping the resulting slurry in or out of storage tanks. It is general practice in many feedlots, particularly dairies, to add water to the wastes in order to allow them to be pumped, and thus reduce the cost or labor requirements of handling. Of course, in an area where water is at a premium, such a practice is not suitable.

Reuse of water is a possible means of water savings which in turn decreases the gross pollutional load to be handled. There are two major arguments against water reuse. Where water is abundant and inexpensive, it is not economical to reuse water because it requires additional equipment. In addition, many commercial feedlot operators fear disease problems caused by recycled water. This is especially true for poultry and swine, although experiments at universities and at least one commercial swine facility have involved reuse of processed waste wash water, and no problems have yet been encountered. Since the presence of large quantities of water in the wastes may or may not present a problem, it is necessary that each situation be reviewed individually.

Bedding or Litter Utilization

Litter is a term for various absorbent materials used as a floor covering in many types of poultry houses. It provides both moisture absorbing capability and a medium for biodegradation of the wastes. Bedding is used for larger animals; swine (to a minor extent), cattle, sheep, and horses. The bedding provides a moisture absorbing capability, a medium for biodegradation of the wastes, and in some cases protects the animals from hard or cold floors. The use of bedding or litter results in increased waste output of a feedlot; however, it aids in biostabilization of the wastes, minimizes odors, helps control fly problems, and sometimes helps control disease. Some users add commercial enzymes to the bedding or litter to aid in the biodegradation of the wastes.

Bedding and litter materials are becoming more expensive and difficult to obtain. As a result, their use is kept to a minimum, and reuse of litter is becoming more prevalent, especially in confinement housing of turkeys.

Site Selection

Although site selection would not be considered an in-process control for most other industries, the feedlot industry depends to a great extent on weather and other environmental factors for efficient operation. Efficient site selection can minimize the adverse effects of nearly all environmental factors including runoff, odor or dust. A recent EPA report on beef cattle site selection stated: "The actual application of good site selection principles is a matter of common sense... There are no standard numerical guidelines and mathematical formulas applicable to each site selection in every part of the country." This statement holds true for the entire feedlot industry. However, major considereations are: climate (general and local), geography and geology.

Climate - These considerations include rainfall, snowfall, winds and temperature. Variations, both local and national can be quite large.

Rainfall and snowmelt relate directly to runoff problems; consequently, open feedlots in areas of high rainfall and snowmelt will have to provide more extensive runoff diversion and collection facilities. With proper feedlot layout, this can be accomplished, but it represents a cost which a housed feedlct does not have to consider. Prevailing winds have an effect on open feedlots in that odors may be carried long distances to populated centers. Here, of course, the best solution is to locate downwind from population centers or at a distance which provides sufficient dilution of the odors. Furthermore, odors from open feedlots are likely to be stronger in wet areas of the country.

Geography - Important mainly to open feedlots, major geographical considerations are:

a. Slope of land for good drainage.
b. Streams running through or adjacent to the feedlot.
c. Proper grading to prevent puddles in low spots.
d. Topography of surrounding land in reference to adding to feedlot runoff and also isolating the feedlot as far as wind-carried odors are concerned.

Good drainage is essential if feedlot surfaces are to dry quickly A slope of at least 2% is recommended for beef feedlots. This may have to be accomplished by earth moving, which will also take care of low spots and puddles. Ditches and holding ponds for collecting and holding runoff are also necessary. Streams running through the property or land uphill of the feedlot complicate the problem by requiring extra dikes to isolate the feedlot from such features, thereby preventing stream pollution and preventing excess runoff water from crossing the feedlot. The proximity of hills, mountains, and wooded areas can provide isolation of the feedlot from population centers but can also complicate the determination of wind direction.

Geology - Geological considerations relate mostly to the pollution of groundwater; however, some soil and rock formations may transport polluted seepage water directly to surface water. In some areas of the country, it is virtually impossible to prevent groundwater contamination. A good example of this is Florida, where groundwater is essentially at the surface. Such an area does not lend itself well to open concentrated feedlots. Local geology should always be considered in site selection to prevent water pollution. A clay soil is advantageous as it tends to hold water and prevent seepage of pollutants. Some states have required that holding ponds have clay bottoms in order to prevent seepage.

Housekeeping Practices

Housekeeping in a feedlot generally involves the maintenance and cleaning of equipment and the removal of animal wastes. Cleaning and pest control compounds are an insignificant addition to the feedlot waste load. Proper maintenance of equipment, such as waterers, can have a significant effect on feedlot waste loads, since leakage from watering equipment can add large quantities of water to the feedlot wastes. This is particularly true of continuous overflow waterers.

The removal of animal wastes from feedlot surfaces can have significant effects on the total waste load both from the standpoint of how often the wastes are removed and how they are removed. The practice of infrequent cleaning allows both biodegradation and evaporation to occur. On the other hand, a greater volume of solids and pollutants may be carried off these lots in a given runoff event. In addition, infrequent cleaning may be the cause of odor and fly problems. Biodegradation of wastes on a beef feedlot which is cleaned only once each six months generally results in a 20% decrease in total solids, while evaporation may decrease water content from 85% to about 30%. In view of the possibility of increased amounts of pollutants in runoff and odor and fly problems, the question of how often to clean a feedlot depends on the following considerations:

a. Climate
b. Type of facility
c. Economics
d. Method of ultimate disposal or utilization of the wastes (biodegradation may decrease the value of the wastes as a useful product)
e. site location
f. animal husbandry requirements

The method of waste removal can likewise be significant. Some feedlots will scrape dirt pens only down to the point where a thin layer of compacted wastes remain. This is most prevalent in the beef industry. The layer of manure remaining is often a good barrier to moisture and nutrient infiltration into groundwater. Where potential groundwater contamination is not a problem,removal of all wastes and some underlying soil is sometimes practiced. This then requires back filling. This method of cleaning has no particular advantage except that the pens are kept cleaner and the soil then absorbs more of the moisture in the wastes. As a result of this, however, the feedlot waste load is somewhat higher and usually contains a higher percentage of inert solids. This may be a disadvantage to some processes of ultimate disposal but in all probability will not affect the use of the wastes as fertilizer other than to increase spreading costs slightly.

Selection of Method of Production

The type of production method selected for use on a feedlot can produce large differences in the type of wastes to be handled as well as smaller differences in the quantities of waste solids to be handled. In each case, sufficient storage capacity must be provided to contain the wastes during the period of time when they cannot be utilized. The basic types of facilities and their respective waste outputs are listed below:

Type of Facility	Type of Waste
Open Lot	Manure scrapings and runoff
Housed Solid Floor	Manure (liquid or solid) with or without bedding or litter
Housed Slotted Floor	Manure (liquid or solid) biodegraded or fresh
Housed in Cages	Manure (liquid or solid) biodegraded or fresh

Description of these types of facilities and the wastes emanating from them are given in detail in Sections IV and V of this report.

Facility choice is usually determined by one or more of the following factors:

a. Type of animal
b. Climate
c. Cost of land
d. Cost of construction
e. Cost of labor
f. Availability of water

Enclosed facilities are generally best suited to areas where rainfall exceeds evaporation and areas of cooler weather. These facilities offer the ability to control the wastes better and also control secondary pollution such as flies and odors. However, the cost of such facilities is very high compared to open lots, and in dry, mild climates away from population centers, open feedlots do not generally present pollution problems that can justify the cost of housed facilities. This is especially true in view of the fact that in spite of potentially increased feedlot waste loads (runoff) open facilities thus located may readily manage waste problems. It simply becomes a question of the relative cost of land and the handling of increased waste loads, such as runoff, as compared to the high cost of housed facilities. Other than pollutional or cost aspects, the type of facility is usually chosen on the basis of the type of animal involved and individual cultural practices.

END-OF-PROCESS CONTROL AND TREATMENT TECHNOLOGY IDENTIFICATION

As discussed earlier, the end-of-process technologies can be classified in terms of their applicability to manure or runoff, and the completeness of the process. Table 39 presents this classification of all the technologies studied, by indicating whether the technology applies to manure or runoff, and whether it represents containment, partial treatment, or complete treatment. It also indicates whether the technology is "Best Practicable Control Technology Currently Available;, (BPCTCA), "Best Available Technology Economically Achievable", (BATEA, or experimental, as discussed in Section IX, X and XI. Finally, the table indicates whether the technology is primarily a biological or a physicalchemical process.

The discussion which follows in this Section deals first with the two major technology concepts being used by, and available to, feedlot operators--land utilization and runoff control. Following these, the technologies are presented as two subgroups as shown in Table 39--those alternatives related to treatment as control of manure solids, and those alternatives related to treatment and control of runoff. Except as offered in Table 39, no preference is intended to be conveyed with respect to either the order of presentation or degree to which any technology may be implemented.

LAND UTILIZATION OF ANIMAL WASTES

The use of animal waste as fertilizer is a long standing practice. At normal (i.e., commensurate with recommended fertilization requirements of crops) application rates it is beneficial to soils and crops and provides an excellent means for the utilization of wastes from animal feedlots. Although experience with normal application rates is extensive, no specific rules for such applications can be formulated. Each situation must be reviewed for nutrient requirements in order to establish proper application rates. Application of animal wastes to croplands at higher rates for the purpose of disposal is a new idea and does not have a long history. Disposal rates of application has many problems which still need to be solved such as poor crop response. In addition, it has a higher potential for secondary pollution such as seepage or runoff of nutrients and odor.

Land utilization of animal wastes in any form has a natural applicability to feedlot pollution abatement since equipment is readily available and the system is generally understood by the agricultural community.

Technical Description

Two approaches to land utilization of animal wastes have been considered in this study:

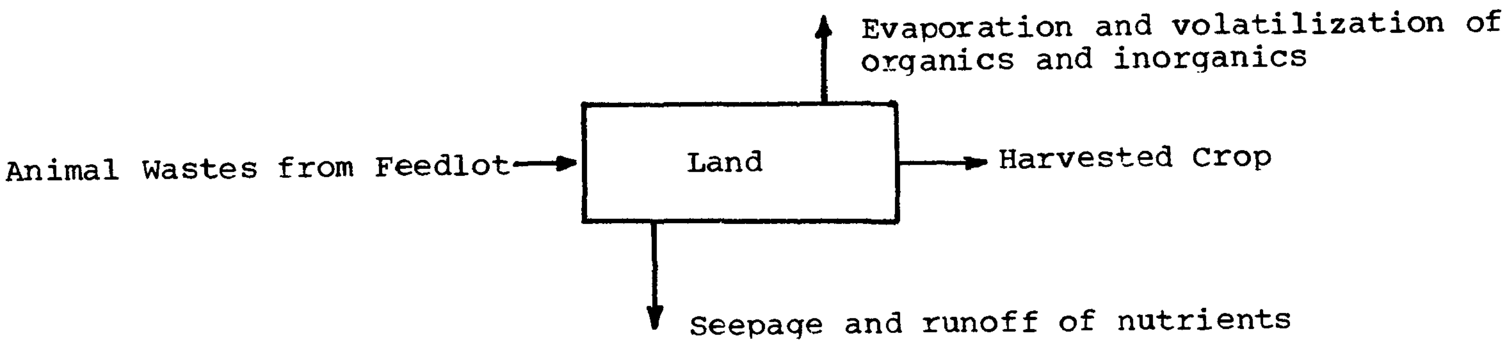
a. Land spreading for crop fertilization and irrigation
b. Land spreading for waste disposal.

TABLE 39 - END-OF-PROCESS TECHNOLOGY CLASSIFICATION

TECHNOLOGY	APPLICATION		FUNCTION			STATUS			TYPE OF PROCESS	
	Manure	Run-off	Contain ment	Com-plete Treat-ment	Partial Treat-ment	BPCTCA	BATEA	Experi-mental	Bio-chem-ical	Physical Chemical
Land Utilization	x	x		x		x			x	
Compost and Sell	x			x		x			x	
Dehydration (Sell or Feed)	x			x		x (Sell)	x (Feed)			x
Converstion to Industrial Products	x			x				x		x
Aerobic SCP Production	x			x				x	x	
Aerobic Yeast Production	x			x				x	x	
Anaerobic SCP Production	x			x				x	x	
Feed Recycle	x			x				x		x
Cxidation Ditch (Spread or Feed)	x				x	x (Spread)	x (Feed)		x	
Activated Sludge	x				x		x		x	
Wastelage	x				x		x		x	
Anaerobic Fuel Gas	x				x			x	x	
Fly Larvae Production	x				x			x	x	
Biochemical Recycle	x				x			x	x	
Conversion to Oil	x				x			x		x
Gasification	x				x			x		x
Pyrolysis	x				x			x		x
Incineration	x				x			x		x
Hydrolysis	x				x			x		x
Chemical Extraction	x				x			x		x
Runoff Control		x	x			x				
BLWRS		x		x				x	x	
Lagoons for Treatment		x	x		x	x			x	
Evaporation		x	x		x	x				x
Trickling Filters		x			x			x	x	
Spray Runoff		x			x			x	x	
Rotating Biological Contactor		x			x			x	x	
Water Hyacinths		x			x			x	x	
Algae		x			x			x	x	

Land spreading for fertilization and irrigation encompasses those situations where no more waste matter is applied than that necessary to provide the optimum crop growth conditions. Land spreading for the purpose of waste disposal encompasses those situations where wastes are applied to cropland at a rate in excess of that required for crop fertiliztion or irrigation. Both systems of waste utilization are schematically the same. The utilization system encompasses only the loading, hauling and application of the wastes since the removal and storage of the wastes is considered a normal part of feedlot operations.

Land utilization of animal wastes can be schematically shown as:



Due to the variability of waste characteristics, the type of crop, soil, the climate, etc., no numerical values are assigned to the inputs and outputs. It is again necessary to note that a separate analysis must be made for each situation in order to set up a properly balanced system. Seepage and runoff from cropland receiving fertilization and irrigation rate applications are not considered to be excessive. In any event, land would be fertilized with inorganic fertilizers if the animal waste was not available. Disposal rate application may not have excessive seepage and runoff losses either but there is not enough experience with this system to prove it. In any case, these losses can be minimized by proper land management such as proper site selection, contour plowing, and tail water collection.

<u>Fertilization and Irrigation</u> - Conceptually speaking, land spreading for crop utilization is simple; however, each situation is unique. In general, the amount applied and method of application is dependent upon the following:

a. Physical and chemical characteristics of the waste as applied

b. Chemical and physical characteristics of the soil
c. Type of crop.

Waste Characteristics - The variation in character of wastes as removed from the feedlot has a marked effect on thé rate at which the wastes are applied to the land. Major considerations are type of animal, amount of litter or bedding used, moisture content of the waste, residual salts content, nutrient content, and the amount of dirt or sand which may be included in the wastes when pens are scraped. Stockpiling, liquid storage or treatment of the collected wastes can change the character of the wastes. A review of waste characteristics in Section V gives a good indication of how difficult it is to generalize about waste outputs of different feedlots. However, should it be required, chemical testing can be done by commercial or government laboratories to determine the character of wastes from a particular feedlot. A few states have put out publications which provide basic characteristic data about animal wastes and on this basis recommend certain levels of cropland application. These recommendations, however, may not always be optimum and individual crop, soil and waste considerations need careful attention before any "design" is implemented.

The significant characteristic which generally governs the method of application of feedlot wastes to cropland is moisture content. The three major means of application are:

1. Solid spreading (for wastes which cannot be pumped)
2. Liquid spreading (for thick waste slurries which can be pumped)
3. Irrigation (for thin waste slurries).

Equipment for hauling and spreading animal wastes are commonly available. Liquid hauling and spreading are usually accomplished by the same piece of equipment (usually a tank truck or trailer with a built in spreader). Hauling and spreading of solid wastes may be accomplished by the manure spreader itself; however, in cases where large hauling distances are involved, trucks are usually used with transfer of the wastes to a spreader at the application site.

Removal of the wastes from a feedlot prior to land spreading is also accomplished on a solids or liquids handling basis. Typical of solids handling equipment are bucket loaders, bulldozers, etc. Liquid handling equipment can be anything from gravity feed piping or ditching to high pressure, high volume pumping equipment.

Removal and land application are integrated in some feedlots. A number of dairies, for instance, pump liquids directly from lagoons or holding tanks to irrigation systems for pasture irrigation.

Soil Characteristics - Chemical and physical characteristics of soils vary greatly from one area of the country to another. The major characteristics are the natural nutrient content of the soil, its ability to hold applied nutrients, its water holding capacity and its ease of cultivation.

Relatively simple tests can be made to determine these characteristics. The ability of a soil to hold nutrients and water and its ease of cultivation can almost always be improved or at least maintained by the addition of organic matter. If, in addition, the organic matter applied has a significant nutrient content, the nutrient level of the soil can likewise be improved. Animal wastes indeed have both of these qualities and therefore can be used advantageously on cropland.

Each crop has a given ability to remove nutrients from the soil. Usually, the major nutrients (micronutrients) to be considered are nitrogen, phosphorus and potassium. The approximate application requirements in kilograms/hectare/crop (pounds/acre/crop) for corn and wheat are given below to provide indication of the wide variation in crop requirements.

	Nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K_2O)
Corn	202 (180)	78 (70)	157 (140)
Wheat	78 (70)	22 (20)	28 (25)

This utilization is not totally efficient even under the best of circumstances. For instance, the uptake of nitrogen from soil by a crop is typically only 50% of what is applied. The remaining nitrogen (in the form of nitrates, nitrites or ammonia) is lost by means of volatilization, seepage, or surface runoff. Phosphorus usually becomes fixed by minerals in the soil and therefore is not generally lost. Potassium on the other hand, usually remains soluable and can be lost by runoff or seepage. Other elements (micronutrients) are also required by crops but usually only in trace amounts. Animal wastes usually contain much of the necessary trace elements and more than enough phosphorus and potassium. The limiting nutrient is usually nitrogen. Therefore, fertilization rates are normally based on nitrogen requirements and due to normal losses, the actual application rate is usually about twice the theoretical requirement of the crop. Of course, crops also require water for growth. Runoff water (and other thin slurry waste) from open feedlots can be and is used as irrigation water. It has an additional advantage of containing nutrients such as nitrogen; however, the wastes may contain high levels of salts (sodium chloride, etc) which must be considered to preclude excess salt accumulation in soils which can occur even at application rates based upon nutrient and moisture needs. It is a frequent practice to run fresh water through an irrigation system after the waste slurry has been applied. This cleans the irrigation equipment and washes plant surfaces of harmful salt residues.

In order to determine the proper application rate a full analysis of the above parameters must be made and reviewed by experienced personnel (usually state or federal personnel involved in agriculture). It is virtually impossible to generalize although fertilization rates are typically less than 34 kkg (dry basis) per hectare (15 tons dry basis per acre) for fresh manure. In many instances where this type of waste utilization is being practiced, the actual application rate is not monitored and is determined by experience. No doubt, in some of these cases, the proper application rate may actually be exceeded. In any case, it is evident that land spreading for crop fertilization and irrigation is a technically sound means for animal waste utilization.

Disposal - The spreading of animal wastes on land for the purpose of disposal is conceptually identical to spreading for fertilization. The main difference is that disposal application of animal waste is a high rate application in terms of metric tons (tons) of waste per hectare (acre). In some cases, this requires special equipment for spreading. A number of experiments are underway to prove the feasibility of this concept. Some of the problems encountered are as follows:

1. Crop response problems due to salt toxicity
2. Lack of commercial equipment capable of applying large quantities of waste per hectare (acre)
3. Odor problems
4. Reduced economic value of the wastes as fertilizer
5. Increased cost of application
6. Excess nitrates for given moisture levels in growing crops
7. Possible indiffuse (nonpoint) pollution runoff and groundwater contamination
8. Improper nutrient balance
9. Fly control problems.

Experiments so far have been limited to determining the maximum allowable application rate of animal wastes on the basis of whether or not the crop growth is diminished. Some plants, such as corn and coastal bermuda grass, have shown high tolerances to intense applications of animal waste. Others show low tolerances with the major problem being late or no germination due to salt or ammonia toxicity.

Application rates have run as high as 2000 kkg (wet)/hectare (900 tons (wet)/acre) or about 1400 kkg per hectare (630 tons per acre) on a dry basis. Except for irrigation equipment, commercially available manure spreaders are designed for maximum application rates of 22 to 45 kkg (wet)/hectare (10 to 20 tons (wet)/acre) on a one-pass basis. As a result, some experimenters have built their own special equipment. In addition, some equipment has been built for deep plowing methods of manure application which cffers two potential advantages:

1. The roots can be isolated from high waste concentrations (i.e., salts) and still receive an adequate supply of nutrients.

2. Objectionable odors are reduced due to the depth of soil cover especially if the furrow or ditch is covered simultaneously with waste application.

It is evident from the experiments that the value of manure in terms of dollars per kkg (ton) is decreased significantly when applied at a disposal rate because the return in crop yield is not increased above that experienced when the wastes are applied at a fertilization rate.

Secondary Pollution

The potential for secondary pollution, aesthetic or actual, is similar for both fertilization and disposal schemes. These include runoff, seepage, odor, and possible soil contamination. The differences are mainly a question of degree. It is evident that fertilization rate application of animal wastes generally does not have secondary pollution characteristics in excess of inorganic fertilization. To some extent, it may have less since the ability of the soil to hold moisture is usually increased by the application of animal wastes. Disposal rate application, on the other hand, has an undetermined potential for pollutional runoff or seepage and for adverse soil effects. Future experiments may show this question to be insignificant if proper procedures are followed; however, due to a present lack of information to the contrary, the secondary pollution potential of disposal rate application of animal wastes must be considered to be in excess of that encountered with normal crop fertilization.

Development Status

Fertilization - For the most part, the use of animal wastes as fertilizers is governed by the same considerations which govern the use of inorganic fertilizers. Some states publish guidelines for fertilization of crops grown in their agricultural regions and all states have the capability of determining fertilization rates based on crop and soil characteristics. Although the use of animal wastes as fertilizer is not practiced as extensively as it could be, there is a history of successful use extending far back before the introduction of inorganic fertilizers. It must be concluded that the use of animal wastes as fertilizer is developed to the point of full scale operation. There are innumerable examples of such practice.

Disposal - Seven references were reviewed that discussed experimental work applying animal wastes at disposal rates. These experiments are only beginning to answer the many questions involved. As a result, the status of disposal rate application of animal wastes is considered to be experimental at this time.

Reliability and Applicability

Reliability - Due to the extensive history of fertilization of crops with animal wastes and the present analytical capabilities of agriculturists to determine proper fertilization rates, the reliability of this system of animal wastes utilization is considered to be excellent.

Experiments with disposal have been underway for only a few years with only a limited number of parameters having been considered. The reliability of the system as a valid scheme for waste utilization is therefore questionable. This is especially true if one considers asking a farmer to practice this method on a crop which represents his only income.

Applicability - There is no definable limit due to climate, geography, size of operation, crop, etc., which may preclude the use of animal wastes on cropland.

However, these factors will influence the amount of wastes and the period of time they must be stored prior to land utilization. The storage facilities required must be determined on an individual basis due to the variability of the factors discussed above.

RUNOFF CONTROL

Runoff control undoubtedly constitutes the single most important technology available to the feedlot industry for preventing discharge to navigable water bodies. The uniqueness of each feedlot operation adds enormously to the entire task of implementing satisfactory runoff control schemes for each situation. Each runoff control problem must be addressed separately and may require the attention of several organizations, generally including the state agency responsible for pollution control, the Environmental Protection Agency, , Soil Conservation Service, Agricultural Extension Service of the applicable state university, or possibly consultants hired to design the system. At present, only a relatively small percentage of the total number of feedlot operators have instituted runoff controls, but the situation is improving at an increasing rate.

The majority of large operations for all animal types, for example, have installed or are now building runoff control facilities.

To better understand the runoff control problem, a look at the nature and extent of runoff from animal feedlots is required. First, the runoff from feedlots is not readily amenable to classical methods of treating water borne wastes from a pipe or similar very discrete conveyance. Second, the waste flow is almost completely dependent upon rainfall or snowmelt for conveyance from the lot and is therefore unpredictable in duration and quality. Third, the wastes are extremely variable in quality while remaining consistently strong in organic constitutents. Fourth, the raw wastes vary widely in characteristics depending upon many factors, among which are the type of feed, the ambient temperature, the species and age of the animal, the type of housing, and many other factors.

Animal waste not controlled and permitted to enter streams, such as rainfall runoff or snowmelt, can cause stream pollution, result in fish kills, upset the ecological balances of the stream, and seriously degrade the water for further domestic and recreational uses. A potential also exists for pollution of underground water by percolation of contaminants through the soil to the ground water. In actual practice, however, only a relatively small percentage of the waste, 10% or less, actually leaves the lot area. This percentage could grow with the increased practice of confined animal feeding if pollution abatement is not implemented.

With respect to the Water Quality Act of 1965, all states are required to have, by Federal law, approved water quality standards. This is a fact regardless of whether or not the state has a specific law governing animal waste storage, transport, or disposal. A number of states have, however, either enacted animal waste pollution legislation or proposed laws dealing with feedlot construction and/or operation. A review of some of the states having specific animal waste control regulations reveals a great deal of difference in the content of the regulations because of variances in livestock types, climatic regimes, and drainage conditions from region to region. Uniformity is the exception rather than the rule.

Most of the regulations contain information on water pollution abatement facilities. They establish a procedure for determining the need for such facilities, their design requirements, operation, and upkeep. The beef feeding states generally require that a complete retention system (i.e., terraces, ponds, etc.) for the entire feeding area must be capable of holding the runoff from a 10 year to 24 hour storm. These rules emphasize that these pond systems are not treatment structures. Rather, as soon as possible after an occurance, the liquids should be pumped or irrigated onto the land and the solids removed in order to maintain the required capacity for subsequent runoff activity. In most instances, diversion of "clean" or "foreign" waters around the yard is also required. Diversion of outside runoff is one of the more important considerations for any given feedlot location. Effective site selection may obviate the need for structural diversions. On the other hand, if diversion (e.g. ditches and berms) are required they help to offset total storage requirements and generally aid in reducing land areas needed for control structures.

The economic impact of installing proper runoff controls can vary widely depending upon many factors for any specific feedlot site. The fact that many existing feedlot operation sites were selected for reasons other than runoff control may compound the problem. Permitting drainage of large areas of land through the confinement area, for instance, can result in fairly elaborate, hence expensive, runoff control structures. At the other extreme, a feedlot located such that all runoff is confined to a natural low spot, wholly within the properties of the operator and not involved with any state water course, will require little, if any, runoff controls. Many of the runoff control structures presently in existence were completed on a cost sharing basis under the Rural Environmental Assistance Program (REAP).

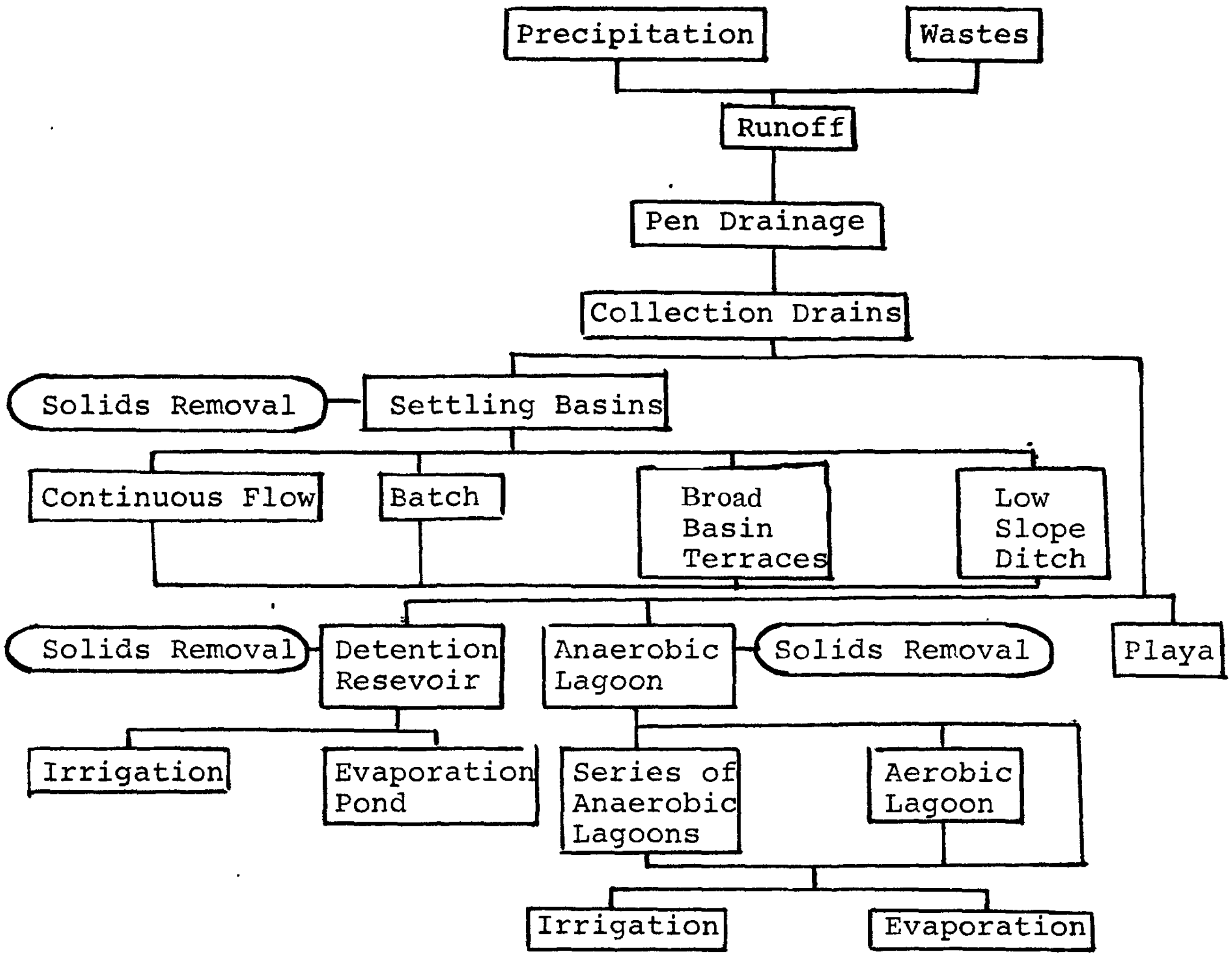
Complete runoff control goes beyond that associated with confined feedlot operations. Runoff controls are not a waste treatment facility in themselves and subsequent treatment or disposal of the wastes is required. While treatment may be incorporated within the runoff control structure (e.g. aerators on the holding pond), ultimate disposal usually involves land spreading of the liquids and solids. Again, the implementation of these controls is dependent upon the specific set of conditions involved with the operation in question, as they are with the confined animal facility. The controls may include retention structures, the limitation of land spread rates, or a combination of these factors.

Proper management is the key to any waste control system and runoff control is no exception. With an adequate design and disciplined maintenance, a runoff control system should give long life and trouble free results.

Technical Description

Runoff controls apply to any feedlot with a pollution potential. This pollution potential may be the result of land slope, location or management and may be related to surface or subsurface water. Runoff control from feedlots should be an integral part of the feedlot design and operation.

There is a variety of alternatives for the handling, treatment and disposal of runoff carried wastes as shown in the diagram below.


Precipitation
Wastes
Runoff
Pen Drainage
Collection Drains
Solids Removal
Settling Basins
Continuous Flow
Batch
Broad Basin Terraces
Low Slope Ditch
Solids Removal
Detention Resevoir
Anaerobic Lagoon
Solids Removal
Playa
Irrigation
Evaporation Pond
Series of Anaerobic Lagoons
Aerobic Lagoon
Irrigation
Evaporation

The system consists of the pen drainage system, collection and transport drains, solids settling area for some designs, holding or treatment area, and ultimate disposal, chiefly by irrigation or evaporation.

There are many variables which influence feedlot runoff both as to volume of water and amount of waterborne wastes. Factors include the size of the lot, the density of livestock in the pens, the cleanliness of the lot, general topography of the area, antecedent moisture and slope of the lot, the amount and intensity of rainfall, and the nature of the drainage basin.

Pollution control, therfore, requires a system that prevents feedlot runoff from entering the streams, helps stabilize the runoff, returns the waste to the land, or some combination of these methods. The solution for runoff control consists essentially of retaining the runoff and returning the collected runoff to cropland by irrigation. The design of a feedlot runoff control facility requires knowledge of the hydrology of the geographical area and the application of hydraulic principles to the specific lot.

Precipitation and evaporation are two climatic variables that must be known for the particular site. The site selection of the feedlot is a very major consideration when designing the collection and runoff control facilities. As noted above, it is recommended that diversion terraces be constructed above (uphill side) the feedlot to prevent runoff from adjacent land from traversing the feedlot. This practice will allow smaller collection and disposal facilities. Of particular importance is the cleanliness of the pens. A regular program of solids removal will often help lessen the amount of solids flushed into internal drainage facilities and overall runoff control facilities and reduce the amount of dissolved organics in a liquid runoff. However, it should be pointed out that according to some studies, it is a good practice to leave a thin layer of manure on the lot surface during the cleaning operation in order to reduce the possibility of movement of nitrates and other pollutants into the ground water. This is particularly advantageous in humid areas wherein the residual layer maintains a physical/chemical barrier to subsurface pollution.

A number of considerations enter into the location and design of the retention facilities. Some of these considerations are the availability of a suitable site, the terrain, the feedlot runoff conveyance systems, accessability and allowance for expansion. The optimum capacity of the retention facility will be determined essentially by the size of the feedlot, climatic conditions, and terrain. Properly designed debris basins make the removal of the solids that have been flushed from the feedlot surface easier than cleaning the bottom of a large volume pond.

Development Status

The development status of runoff control systems is well established by virtue of the relatively large number of commercial applications that have been designed and installed in the feedlot industry. The development of runoff control techniques has been a learning process for all concerned, the system designer as well as the feedlot operator. Vast amounts of design data have been developed and are readily available to the agricultural community.

Reliability and Applicability

Properly designed and managed runoff control systems are very reliable. No moving parts are involved with the exception of the waste servicing and disposal equipment.

The runoff control system is applicable to nearly all feedlot applications where potential runoff pollution exists and adequate land is available to construct the necessary runoff control structures.

Runoff Containment Requirements

In the feedlot industry the amount of discharge from open lots in the form of runoff is dependent on uncontrolled weather phenomena. Since weather data are statistical in nature, the sizing of containment systems must likewise be based on statistics. No matter what size containment facility is constructed there is always some finite chance or probability that it will overflow under some extreme condition. A good example of such a situation is the "25 year 24 hour rainfall" criteria for runoff containment used in Texas. Texas feedlots are required to have runoff retention ponds which can hold the runoff from that 24 hour rainfall which has a 4% probability of being exceeded in any one year. Under these conditions the feedlot is said to meet "zero discharge" requirements. However, the amount of pollutants discharged in the improbable case when the capacity is exceeded remains undetermined.

In the South, where application of runoff liquids on land can be done at virtually any time of year, it might be sufficient to base retention pond capacity on a particular worst case rainfall and require that runoff holding ponds be emptied by irrigation of cropland within a specified number of days after a rainfall event. In the North, conditions are not so simple. Cropland irrigation may be prevented by frozen ground, low air temperatures or muddy field conditions due to spring rains. It may be necessary in the North to contain the runoff or snowmelt from several months of precipitation. Much of the climatological data required for setting up requirements for various areas of the country already exists in one form or another. Even so, other data, such as that for the muddy field conditions mentioned above, does not exist at present. These conditions vary across the country and dividing lines between one dominant criterion and another are extremely difficult to determine purely on the basis of available data. In addition, establishing the requirement in terms of animal live weight represents a further complication because of the different feedlot management techniques used for different animals.

Therefore, the formulation of equitable waste containment requirements which are uniform for the whole country is impractical. Due to the great variation in conditions affecting containment requirements, the real answer is to determine the proper requirements on an individual basis at the local level.

COMPOSTING

Composting is a biochemical method of solid, organic waste decomposition which can be effected by microorganisms of the aerobic, thermophilic variety. Aerobic thermophilic composting has advantages because it is hygienically effective and produces a humus-like product that may be recycled into the environment as a soil additive. If oxygen is not available within the material, anaerobic microorganisms take over, and some of the decomposition compounds have objectionable odors. The aerobic process does not produce offensive odors, is faster, and produces more heat. Other important environmental factors that affect the rate and type of decomposition include particle size of the material, moisture content, aeration, temperature, pH, initial carbon-nitrogen ratio, and size and shape of the mass.

Two major methods are presently being used to implement the composting process for animal waste -- turned compost windrow and aerated compost windrow. Both concepts are presently active on a fullscale basis. Costs of from $0.55 to $13.25 per kkg ($0.50 to $12.00 per ton) of composted material have been reported.

Thus, composting is an available technology practiced on a large scale. Air pollution by ammonia is minor. To be economical, a reliable market is required. This market exists, but it is limited in size.

Technical Description

Manure is scraped from the floor of the pen areas and loaded for transportation to the composting site. Here, the manure is either spread in windrows three to four feet high or deposited in tanks or bins. Often, the manure will contain sawdust, woodchips, or straw from bedding, or else these substances or previously composted manure will be added to aid in the compost process. Figure 36 schematically depicts the process.

Aeration of the manure is accomplished by turning the windrow over with a special machine or pumping air through the tank containing manure. In addition, periodic agitation is required to break up chunks, provide a uniform mixture, and prevent channeling of circulating air. Initial temperature of the manure is usually near ambient. The mixture is subjected to an aerobic, thermophilic composting process. Temperature within the pile climbs to the 140° to 175°F range for rapid composting. The heat for maintaining the temperatures is released by thermophilic organisms. Lower temperatures may result, depending on the composition of the manure, and time for biodegradation will increase. Moisture content is an important criterion for the composting process and should be maintained between 40% and 60%. Lower moisture will delay the process, and higher levels may allow anaerobic organisms to form, causing malodorous gas release. Moisture levels above 75% will also result in lower temperatures and longer process times.

The products of the composting process are carbon dioxide, ammonia, water vapor, and humus, and a mass balance is shown in Figure 36. Process times are from 7 to 14 days for forced aeration in tanks to about 30 days for windrowing. A post-composting cure time is usually incorporated prior to bagging for sale. Location of an adequate market for the composted material may be a problem with this process.

Development Status

Composting is a relatively well established concept for handling animal waste products. Full-scale commercial operations have been in business for many years. More recent developments in rapid composting, effected by mechanical aeration, have also been demonstrated in a commercial operation.

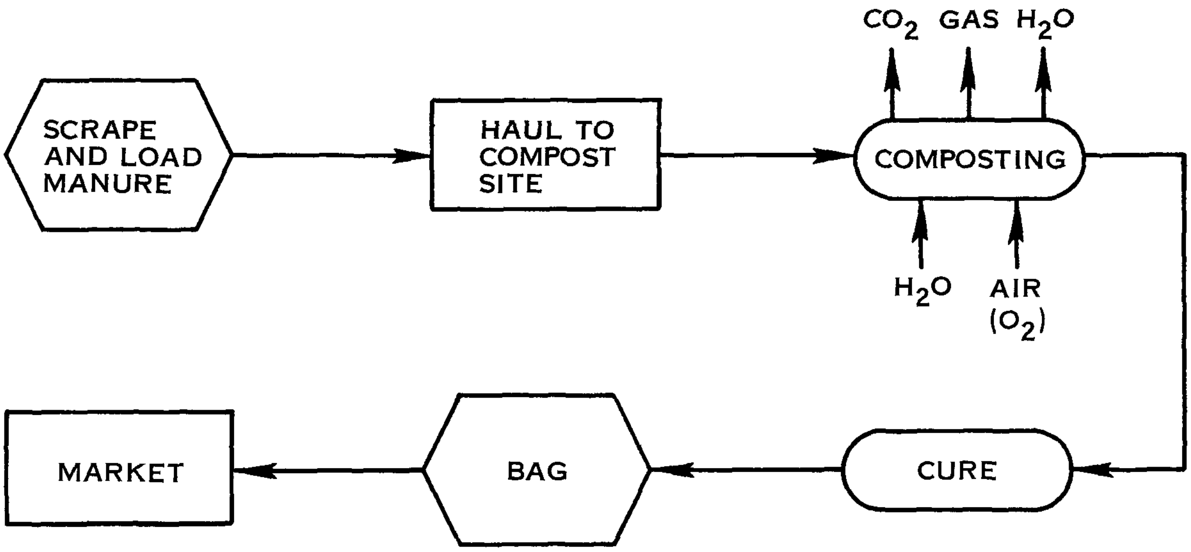
Reliability and Applicability

Basically, composting is a very simple system with high reliability.

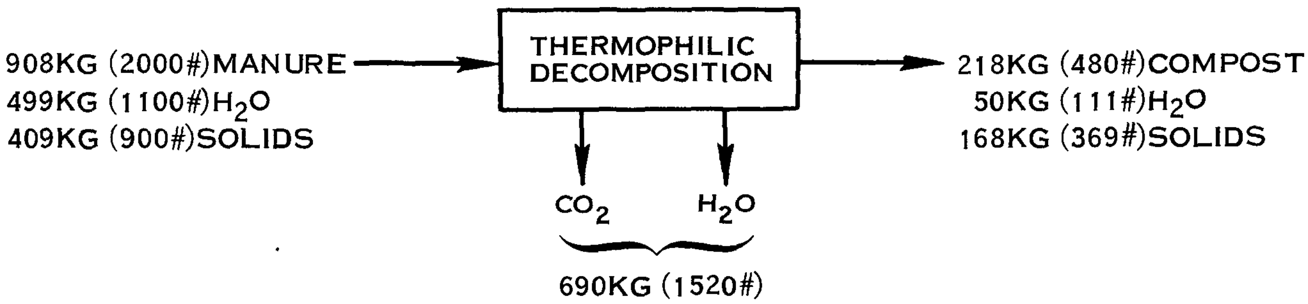
The primary restraint for large-scale composting operations is location of an adequate market for the final product. Otherwise, composting is applicable to all animal waste. At facilities where the composting occurs out of doors, control of the process due to rainfall may be more difficult.

DEHYDRATION

Drying of animal waste is a practiced, commercial technology with the dehydrated product sold as fertilizer, primarily to the garden trade. It is an expensive process which can only be economical where the market for the product exists at a price level necessary to support the process. Recent experimental work has been directed towards refeeding the dried waste back to the animals as a feed ingredient. Due to the higher value of animal feedstuffs, the cost to dry can be more readily borne when utilized as a feed ingredient. A major university has



SCHEMATIC



MASS BALANCE

FIGURE 36. COMPOSTING

demonstrated this refeeding technique by incorporating dried poultry waste at several levels to a 400 bird flock of laying hens for over one year. The best results were obtained at the 10 to 15% feed level for all the poultry tests reviewed, which represents only about fifty percent of the total waste produced. Thus, the remaining waste must still be disposed of in some other manner. Also, the lack of FDA approval for the use of manure as a feed ingredient is a restraint upon the large-scale commercial acceptance of this technology.

Full-scale drying operations have been established with animal manure, in some cases for over eight years. Size of units reported range from small portable units to systems capable of processing 136,000 kkg (150,000 tons) per year. Costs for the drying operation of from $16 to $39 per kkg (15 to $35 per ton) have been reported. As a feed ingredient, a value of up to $70 per kkg ($70 per ton) has been assigned to dried poultry waste based on nutritional value of the product.

Technical Description

Feedlot manure is collected and dried from an initial moisture content of about 75% to a moisture content of from 10% to 15%. The drying process is usually accomplished utilizing a commercial drier shown typically in Figure 37. The input requirement for most commercial driers requires that the raw material be mixed with previously dried material to reduce the average moisture content of the input mixture to less than 40% water. This is required to facilitate process handling of the material to be dried.

The mixture is fed into a hammermill where it is pulverized and injected into the drier. An afterburner is generally incorporated to control offensive odors. The resultant dried material is either stockpiled or bagged, depending on the ultimate method of disposal selected.

The output material (dried to less than 10% moisture content) is an odorless, fine, granular material. With a moisture content of from 10% to 15%, a slight odor may be noted. Crude protein levels of from 17% to 50% have been reported in dried poultry waste. When utilized as a feed ingredient, the dried waste is blended with selected feed ingredients, with the dried waste material supplying from a portion to a majority of the crude protein in the feed ration, and fed directly to the animals.

Figure 38 presents a mass balance based on a refeed program for 1000 laying hens. A refeed portion of the ration has been arbitrarily set at 12-1/2% on a dry weight basis.

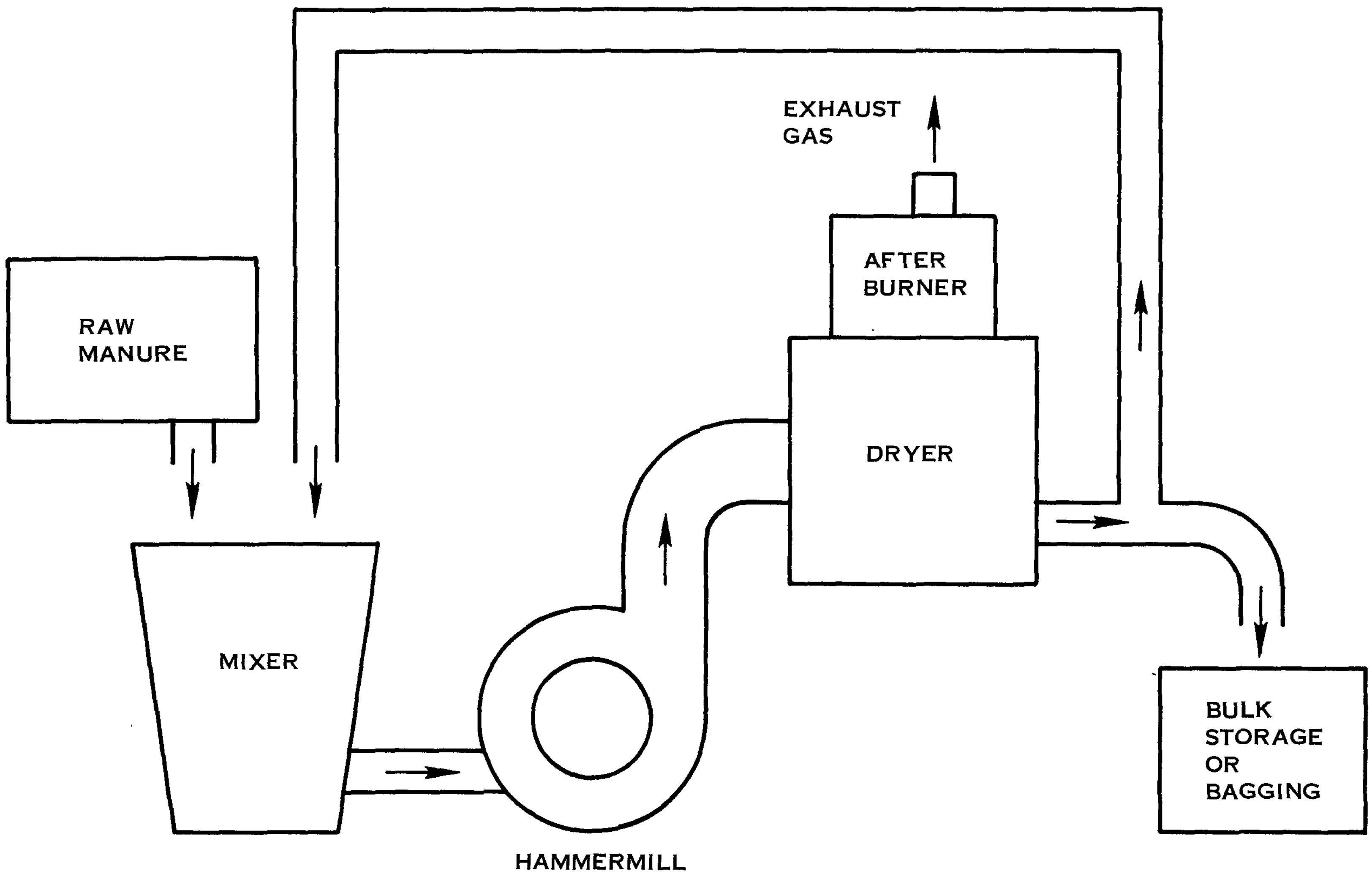


FIGURE 37. DEHYDRATION

Development Status

The status of dehydrating animal manure is well established. A number of manufacturers offer a line of dehydration equipment specifically designed for this purpose. Some drying operations

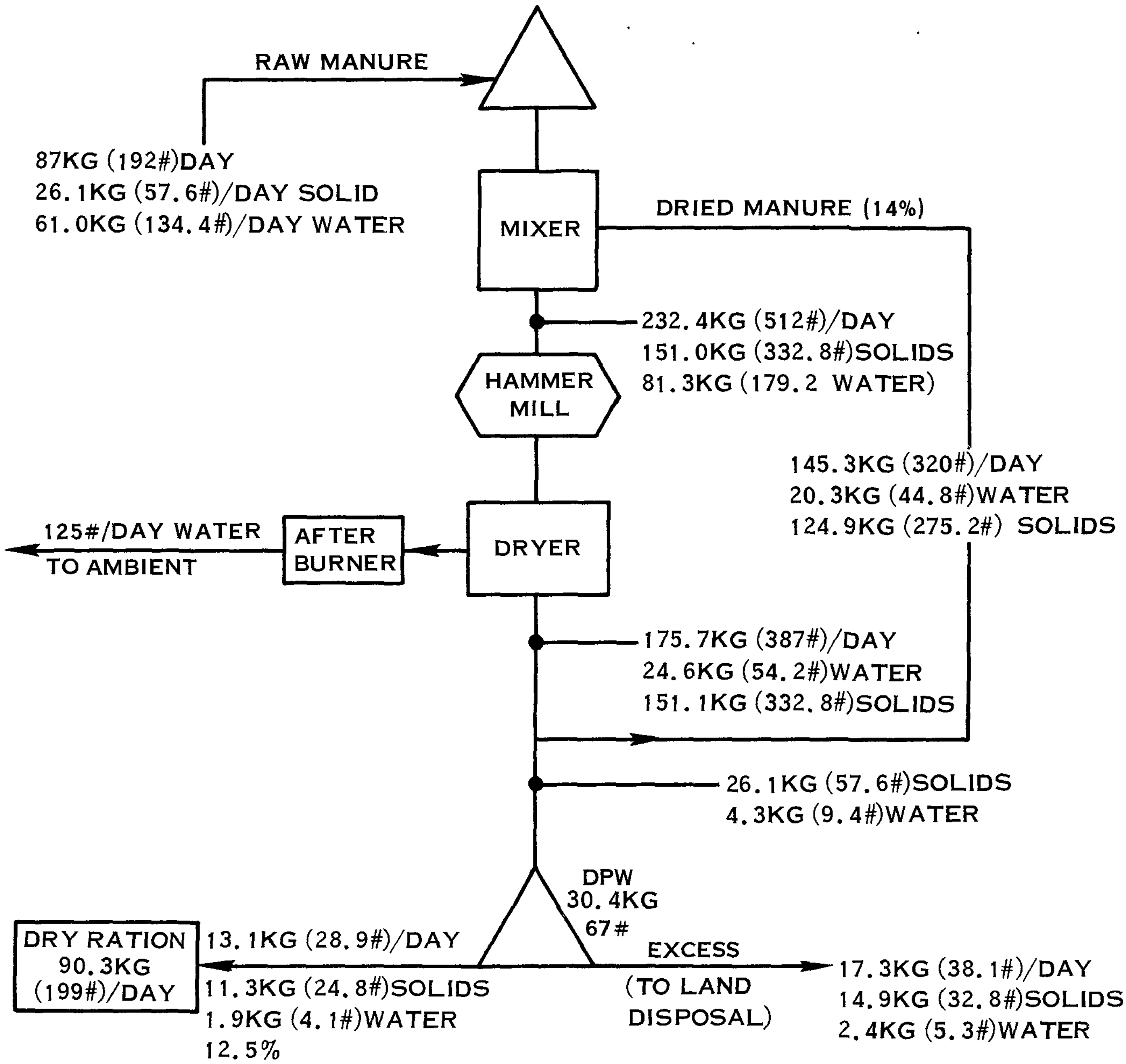


FIGURE 38. DEHYDRATION-MASS BALANCE

have existed for over eight years. Some brands of commercial dryers have experienced development problems but generally reliable operation has been reported. Sizes range from small portable models to systems capable of processing 136,000 kkg (150,000 tons) per year.

Operating efficiencies of from 37% to 69% are reported, based on kilograms (pounds) of water removed per kilogram-calorie (BTU) of thermal energy. These units are high consumers of fuel oil or natural gas, the usual soruces of thermal energy. Energy requirements are highly dependent on the initial moisture content of the raw manure. Refeeding in pilot lot quantities, under controlled conditions, has been achieved on numerous occasions for ruminents, swine, and poultry. Operations for herds of up to 75 steers has been reported from Denmark, where dried poultry waste constituted up to 40% of the total ration. For poultry, the optimum reported from most tests is 10% to 15% of the ration.

In general, good results were obtained from these refeed programs, both in terms of economics and performance. Carcass inspections of test animals revealed no reported indications of problems from having been fed a partial animal waste diet. The primary restraint for full-scale operation in the United States appears to be lack of Food and Drug Administration (FDA) approval.

Reliability and Applicability

Reliability of the dehydration process is fairly good. Routine maintenance of the equipment is required.

Dehydration is generally applicable to all feedlot programs; however, a majority of refeed developemnt effort has been directed toward poultry litter with subsequent refeed of the dried material to ruminants and poultry. Extended periods of reprocessing the same waste and refeeding has reportedly resulted in a gradual reduction in protein content. This may be due to loss of ammonia during the drying process.

CONVERSION TO INDUSTRIAL PRODUCTS

Manure has been pyrolyzed at temperatures exceeding 300°C to form a black powder. The developer calls the product TCD (Treated Cow Dung). The powder is being promoted as a substitute for lampblack, with potential application in tire and printing ink manufacture. Other uses for the TCD have also been developed, based on mixing the powder with melted, recycled glass. Mixing the powder with an equal weight of glass results in a high quality ceramic tile. Mixing the powder (5 - 10 percent) with glass (90 - 95 percent) and aerating the mixture results in a product similar to styrofoam (at low density) or brick (at higher density). These processes are applicable to solid wastes from any type of livestock. Two pilot plants are now operating, one to produce the powder and the other to produce the tile or foamed products. The powder plant processes 9 kkg (10 tons) of stockpiled manure per day. The ceramic plant produces .23 cubic meters (100 board-feet) of foamed glass per day. Manufacturing cost is estimated at $12.86 per cubic meter (three cents per board-foot), or five cents per unit for the denser brick.

The value of the process will be based on the ability to establish a market at a price greater than the production cost. Until a good market and large scale production have been established, the approach must be considered experimental.

AEROBIC PRODUCTION OF SINGLE CELL PROTEIN

Aerobic treatment of animal waste to produce a colony of proteinaceous single cell microorganisms has reached the demonstration phase. However, difficulties ensued, and these latest efforts have been unsuccessful. Consequently, the technology must be considered experimental.

The process produces a valuable product (protein) with little or no pollutional discharge.

Technical Description

The nutrient reclamation system utilizes selected thermophilic bacteria to treat waste material. Figure 39 is a schematic of this process. Entering manure stock is shredded and weighed. The material is then directed to a slurry tank where both recycled and, when necessary, fresh make-up water are added. Sand is separated at this point. The fibrous mixture is then screened to separate the liquid fraction from the fiber. The liquid fraction then goes to a "solubles treatment tank" where additions of nitrogen are made, dilution to volume occurs, and the temperature is increased to the thermophilic range. This mixture is then piped directly to the last fermentation tank to provide a nutrient broth for the propagation of bacteria.

The fiberous material, on the other hand, is treated with alkalai to assist in the breakdown of the fibrous material, thereby facilitating microbial attack of its structure. The alkalai is then neutralized, before nitrogen additions and volume dilutions occur. The material then flows through a series of connected fermentation tanks where oxygen is added and microbial conversion of the materials to additional bacteria occurs. The time required for this fermentation to occur is reported to be three days. At each stage, a portion of the soluble fraction is sent to the final fermentation tank to provide additional nutrient material to aid growth of the bacterial colony.

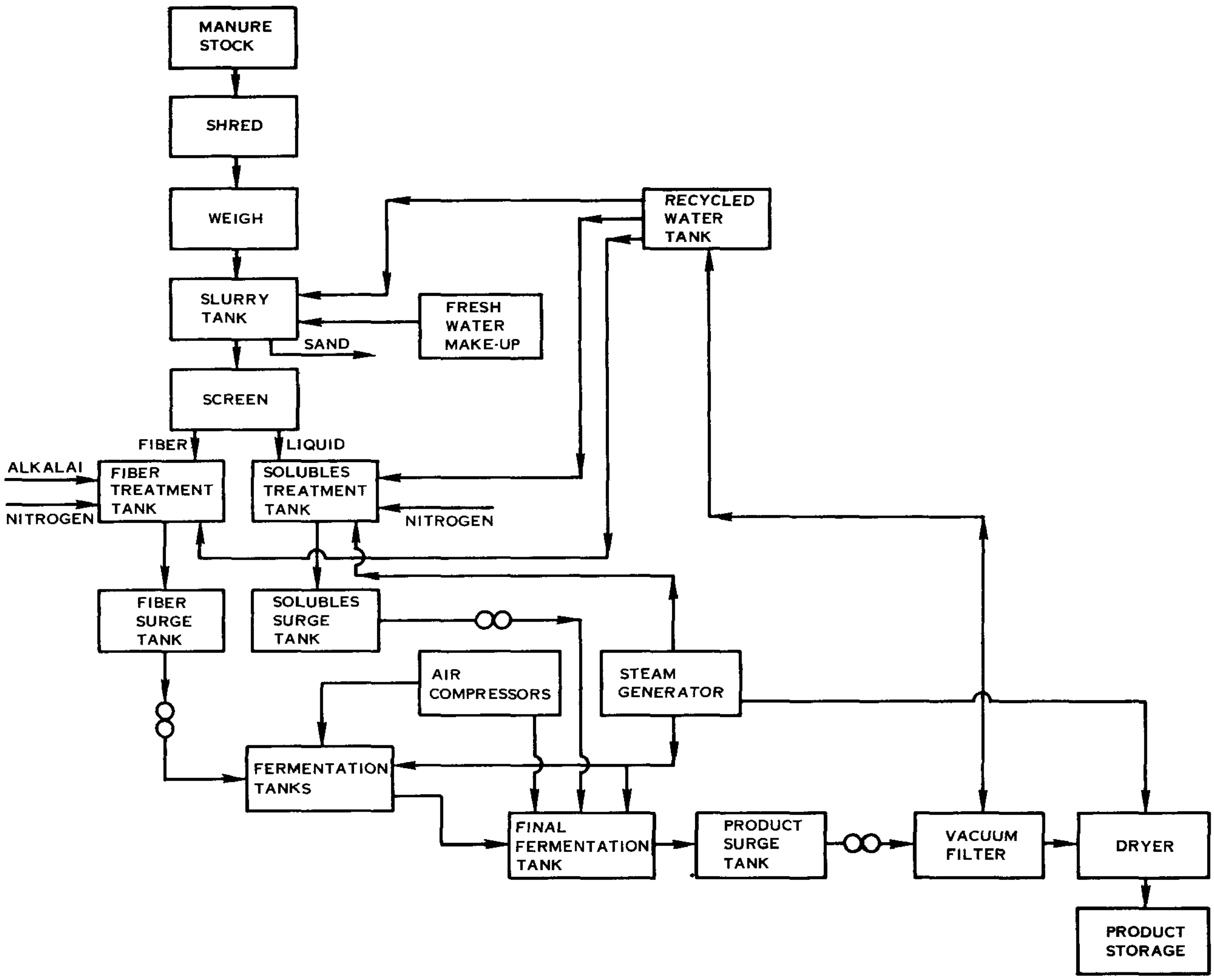


FIGURE 39. AEROBIC PRODUCTION OF SINGLE CELL PROTEIN

The effluent from the final fermentation tank is collected in a surge tank before transfer to a vacuum filter where the bacterial product is removed as a wet cake. This product is delivered to a drum dryer where the remainder of the water is evaporated. Dried, the product is then ready for use as an animal feed supplement. The bulk of the water removed by filtration is recycled to the beginning of the process. Air compressors and a steam generator are required to maintain the proper environment in each of the fermentation tanks for the growth of the bacteria.

The end product would be utilized as a refeed ingredient by acting as a substitute for a portion of the protein-providing feed ingredients (e.g., soybean meal). Early indications are that the product has a protein content of 50% to 55% (versus 44% for a common soybean meal) and a 70% digestibility.

Available quantitative information is insufficient for a mass balance. Overall 227 kilograms (500 pounds) (dry basis) of manure input to the system results in 113.5 kilograms (250 pounds) of output, which is 50% protein.

Development Status

A pilot plant utilizing this concept of nutrient reclamation has been built and operated at Casa Grande Arizona, with the goal of gathering enough information to proceed with full-sized production facilities. Besides the anitcipated production of proteinaceous material, factors such as costs involved and the results of feeding trials were anticipated. However, since late 1972, the facility has been shut down. Available information indicates that the reasons for the closing are complex and include difificulties with maintenance of the pure bacterial cultures utilized in the process.

A suggestion has been made that the fermentations might be adequately performed in ditches rather than the fermentation tanks currently envisioned. This concept has not yet been investigated and would require extensive effort to maintain the proper environment for the culture medium.

Discussions with the program technical director have indicated that re-opening of the pilot plant is not expected until late 1973. Investigations are currently underway back at the laboratory facilities.

News releases have indicated that clearance by the Food and Drug Administration for use of the product would be required. The original timetable estimated that enough information concerning the product would have been reviewed by the FDA to allow an opinion by mid-1973. That timetable has been extended for some indefinite time due to the closure of the Casa Grande facility.

Reliability and Applicability

While much of the equipment utilized appears to be standard and commercially available, the use of "pure" bacterial cultures as a processing mechanism presents problems. Maintenance of the "purity" of the environment is foremost among these. Depending upon the sensitivity of the particular cultures used, "invasion" by other species may prove highly damaging.

All efforts to date have centered around beef cattle waste products. It should be a relatively easy matter to extend the process to cover dairy cattle manures. too. However, use of swine and poultry manures may prove a problem due to their relatively low fiber level. A facility built along the lines of the pilot plant should eliminate geography and climate as potential difficulties. If, however, use of oxidation ditches instead of fermentation tanks is developed, some care must be exercised in their placement and operation.

AEROBIC PRODUCTION OF YEAST

A process for the growing of yeast is in the preliminary laboratory stage of development. Basically, the process includes separating swine waste into solid and liquid fractions. The liquid fraction is concentrated and is added directly to the yeast fermentation system while the solid fraction is treated by various chemical, microbial, and enzyme hydrolysis techniques to produce substrates which are then added to the fermentation system. The yeast is harvested and its cell wall disintergrated to improve digestibility before use as a feed supplement.

Insufficient effort has been performed to economically evaluate the process. Discussions with the program microbiologist indicate that the approach taken was one of sophisticated laboratory exploration without consideration of engineering practicalities. The system utilizes many stages for processing, advanced separation techniques, etc., and will have to be engineered into a practical system once the technical basis has been established.

Technical Description

The laboratory facility is a fourteen liter fermentation tank, and the steps in the operation are shown in Figure 40. The separations occur continuously and utilize membrane filters. After initial separation, chemical hydrolysis utilizing a 2% HCL solution is employed to remove any hemicellulose present.

This is followed by several microbial hydrolysis steps utilizing specific cultures (Trichoderma viride QM 9123, Puria subacida FP 94457-SP, and Streptomycetes Sp.). Use of culture extracts instead of the actual microorganism is now under consideration.

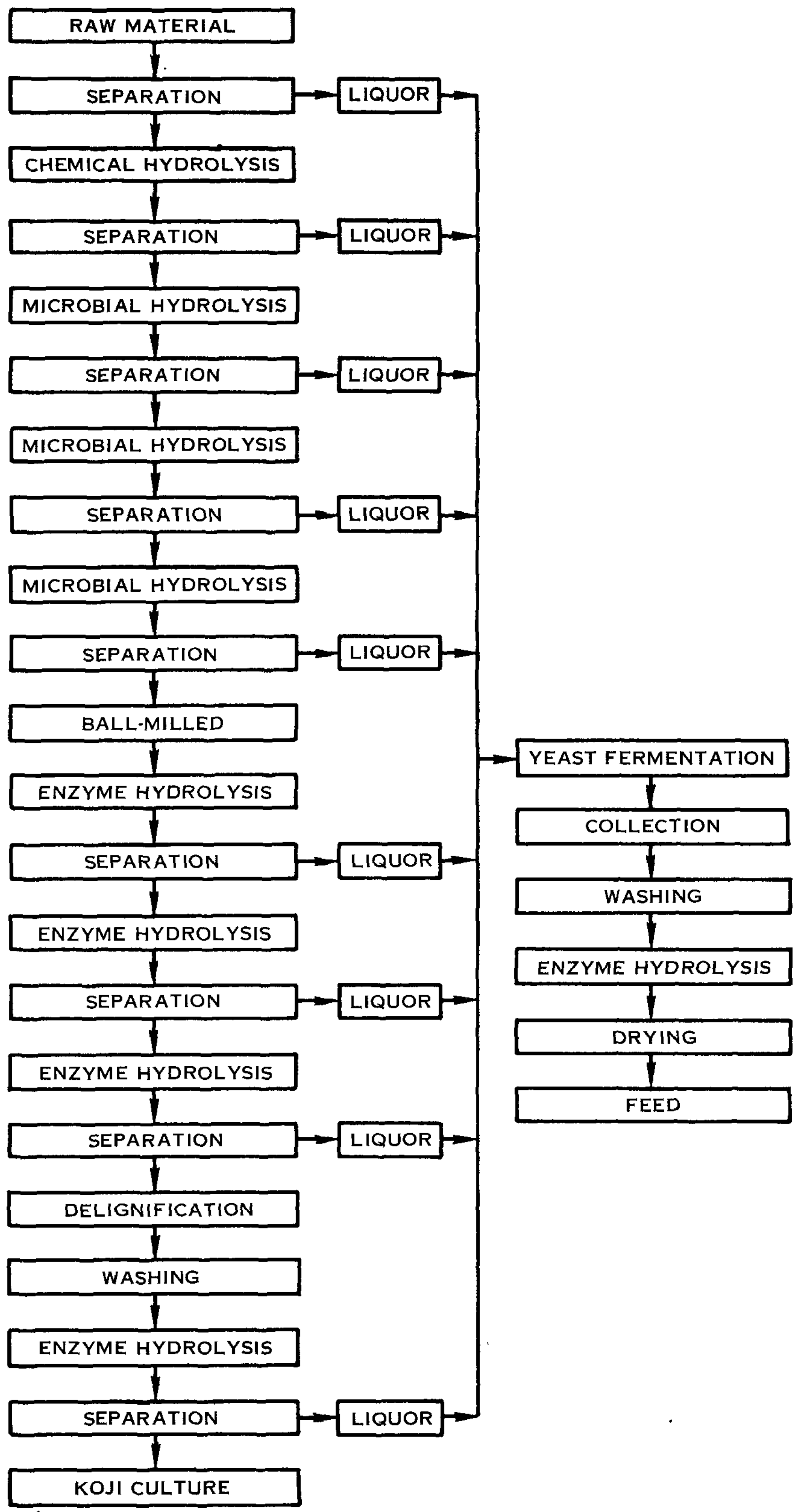


FIGURE 40. AEROBIC PRODUCTION OF YEAST

After ball milling, several enzymatic hydrolysis steps occur utilizing specific enzymes such as cellulase to aid in the total solubilization of the material. Through use of the membrane filters, the enzymes remain in the active feed and are reuseable. After additional separation, the remaining material undergoes deliquification. This is accomplished through the use of peracetic acid (highly corrosive, explosive at 43.3°C ±110°F1, and a strong oxidizing agent). Additional washing and separation then precede use of a Kojiculture. This is a continuous-type culture mechanism which proceeds at a slow rate.

After liquid portions from all the separation stages are sent to a yeast fermentation tank. After collection and washing, the material undergoes another hydrolysis step to aid in the disintergration of the cell wall and an aid to digestibility of the material. The remaining material is then dried prior to use as a feed supplement.

Development Status

The system described is still in a preliminary laboratory stage. After deciding on a purely microbiological basis what processes are required to perform the various functions and coming up with a rather unwieldy system, the investigators involved are giving the system another look to determine where steps could be modified or eliminated.

No economic analysis work has been performed mainly due to the fact that the system is not really completely defined. The process developers judge that at least three more years are required before a system capable of being shown to interested parties is available.

Reliability and Applicability

An analysis of reliability must await better system definition. Although swine waste is the only material tried so far, it would appear that the process (from a technical standpoint) could be utilized for cattle wastes. In fact, due to the higher fiber content of cattle wastes, the process would probably work better.

ANAEROBIC PRODUCTION OF SINGLE CELL PROTEIN

This experimetal technology recycles cattle waste by means of anaerobic fermentation into a proteinaceous feed ingredient and a fuel gas (methane). The process has been operated successfully in the laboratory and some limited evaluations of the nutrient quality of the material as a feed ingredient have been performed. Analyses indicate that the process can be profitable for cattle feedlots 5000 head or larger. The processing utilizes relatively little power which, in fact, is generated during the fermentation. Since all process materials are recycled, there is a zero pollutional discharge. Investigations of the process and improvement in the nutritional quality of the effluent solids are still under active investigation.

Technical Description

Anaerobic fermentation is usually considered to be a biological two-step process. Firstly, a solubilization process occurs in which carbohydrates are enzymatically reduced to sugars. These sugars are then capable of absorption through the cell wall of the microorganism. The products of the first state of fermentation consist primarily of simple acids and alcohols as well as hydrogen and carbon dioxide. The materials then act as substrates for the second phase of the process, in which methane and carbon dioxide are formed. The usual nomencalture for these phases are "acid-forming" and "methane-forming" respectively. The process of anaerobic fermentation may be directed towards maximized growth of the bacterial colony (for "harvesting" and use as a refeed ingredient) or maximized fuel (methane) production.

The system, as practiced, utilizes cattle manure slurry at a solids concentration of 10%. Manure is mixed with water and ground in a blender in an attempt to achieve a solids concentration of approximately 20%. The material is then frozen until needed. Before use, additonal water is added to achieve a 10% solids concentration. Use of a maximum of 10% solids mixture has been dictated by the size of the laboratory equipment. The material is then automatically fed to the fermenters at levels as high as 16.2 kilograms volatile solids/cubic meter/day (1.0 pound volatile solids/cubic foot/day). During the fermentation, the microbial colony present (no specific culture is used) reduces the original mass while producing methane and carbon dioxide. The effluent liquid is discharged at a solids concentration of 5% indicating a mass destruction rate of 50%. The material is then dewatered and the proteinaceous microbial colony "harvested".

A schematic for a full-size plant utilizing anaerobic fermentation of cattle wastes is shown in Figure 41. The entering material is mixed in the slurry tanks with water that has been separated from the output material by centrifuges. The solids content inside the slurry tanks is maintained at 10%. Within the slurry tanks, the material is recirculated to assure thorough homegeneity. After leaving the slurry tanks, the material is passed through a heat exchanger in order to heat the incoming material to the operating temperature of the fermenter. Some additional heat must also be provided to compensate for heat losses from the surface of the fermenter. Within the fermenter, the contents are mixed continuously. The microbial population is capable of utilizing the raw materials in its metabolic activities and, in so doing, additional microorganisms are produced as well as gaseous discharge consisting of methane and carbon dioxide. This gaseous effluent is burned to provide all the heat required for the process and, through the use of an engine-generator, all of the electrical energy required.

The liquid/solid effluent discharged from the fermenter contains half the solids of the incoming material, the other half having been utilized in the digestion process. This material then passes into a centrifuge for dewatering. The excess moisture is pumped back for use in slurrying the incoming material. The solids cake leaving the centrifuge is then sent to a rotary kiln dryer for final processing. The finished product may then be stored for future use.

Due to conservation of nitrogen, the product contains twice the nitrogen concentration of the incoming material. Laboratory analysis has shown that the amino acid concentration has quadrupled, indicating a substantial conversion of non-protein nitrogen sources into proteinaceous material. The quality of the product's amino acids is similar to that of soybean meal, which it can replace in a diet. Chick feeding trials utilizing the product have indicated that the material is neither toxic nor inhibiting. An analysis of utilization of the material as a refeed ingredient for cattle has indicated that an iso-nitrogeneous and iso-energy ration can be formulated using this product. The diet would contain sightly more mass than the standard diet but this amount is small enough not to be a problem.

In the mass balance, shown in Figure 42, rates are shown on a daily basis. The waste material is indicated as entering the system at 53.8% moisture, because this is the value that conserves water within the system. At higher moisture levels, facilities for tempporary storage of excess water must be provided. Makeup water facilities will also be needed. A water storage lagoon could fulfill both of these needs.

Development Status

The system is currently in the laboratory stage. A pilot plant operation is needed to establish operational and design specifications regarding actual cattle feed systems.

Reliability and Applicability

The laboratory test program has shown the anaerobic fermentation process to be stable and reliable. Changes in temperature, loading rate, residence time and addition of various minerals have not led to failure conditions. The components used in the system are off-the-shelf hardware.

Since the waste material is being processed, climate and geography do not bear on the applicability of the concept. However, some care must be taken with the input material. Poultry manure having a high uric

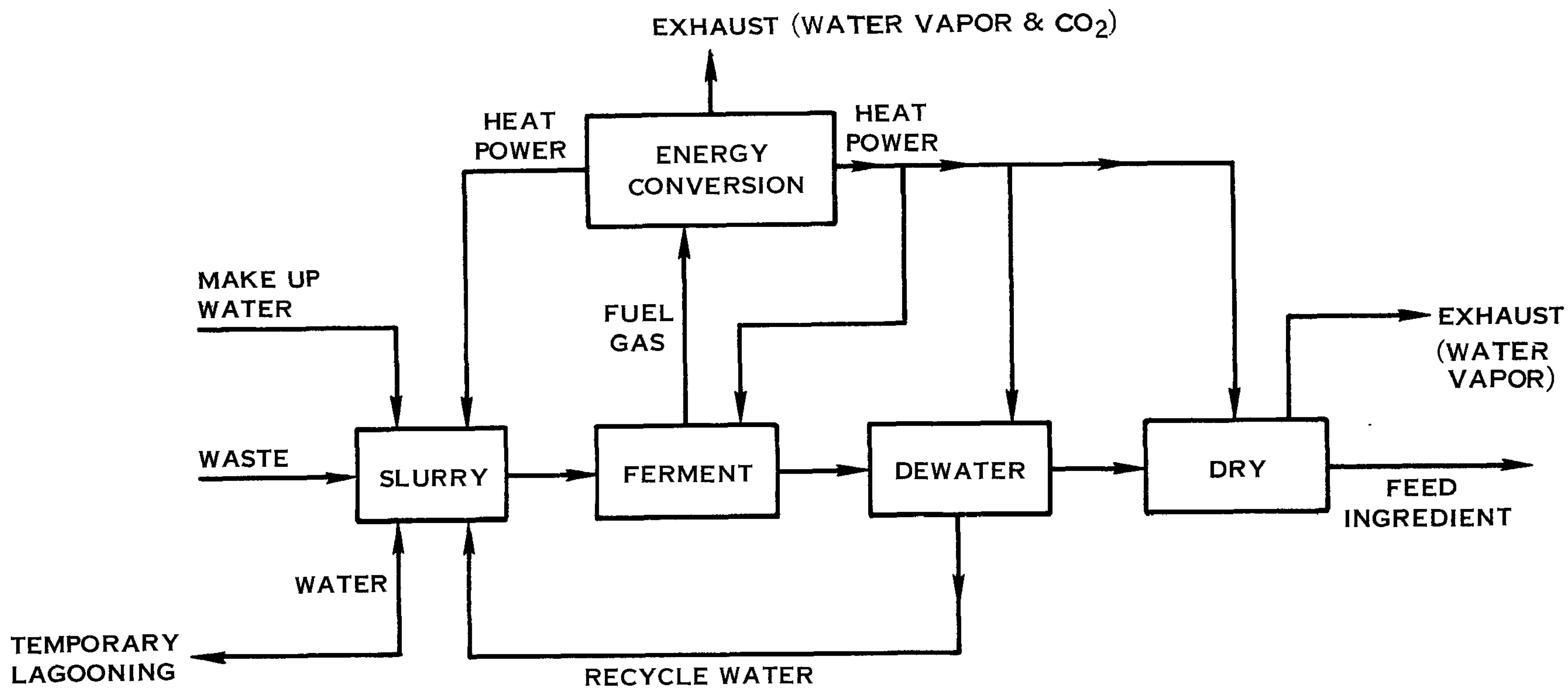


FIGURE 41. ANAEROBIC PRODUCTION OF SINGLE CELL PROTEIN

acid concentration, for example, could lead to adverse effects on organisms in the fermenters.

FEED RECYCLE PROCESS

The Feed Recycle Process is a proprietary process which has undergone a number of recent modifications. The process separates nondigestible sand and fiber from the digestible portion of the manure by physical-chemical means with reported 89% protein recovery; the value of the protein is not reported. The process is not yet fully developed and is, therefore, regarded as experimental.

Technical Description

Figure 43 represents the latest simplified version of the Feed Recycle Process. Raw manure enters a settling tank. If the raw manure contains less than 50% moisture, it is first broken up in a mill. After a one-hour residence time in the settling tank, where sand is removed, the material is centrifuged. This centrifugation separates fibrous material from protein, fats, and sugars, which are liquified or held in suspension. The liquid next goes through a floculation step, which involves pH adjustment and iron solubilization. The slurry is then dewatered in a rotary drum vacuum filter. The liquid is recycled to the settling step. The filter cake is delivered to a rotary drying unit operating at 121 - 126 °C (250 - 260°F). The resulting product is granular and sterile. It consists of 20% protein, 6% fats and sugars, 19% starch, 37% cellulose and lignin, 6% salts, and 12% salt-free ash.

Based on 0.9 kkg (one ton) (dry basis) of manure scraped from a sandy feedlot 91 kilograms (200 pounds) of sand will be removed in the settling tank, and 91 kilograms (200 pounds) of fiber will be removed by the Tolhurst centrifuge. This leaves 726 kilograms (1600 pounds) of dry product. This product (composition listed earlier) contains 89% of the protein in the raw manure. These figures appear to be somewhat optimistic because they imply that the raw manure is 18% protein, and they also neglect biological reduction of some of the material to gases, which occurs to some extent.

Development Status

A pilot plant has been operating for several months at a California feedlot. Capacity has been estimated at 13.6 kkg (15 tons) per day (dry basis). One series of feeding trials resulted in elimination of molasses extraction from the fiber, simplifying the process. A second set of feeding trials is now underway. In these trials, recycled material constitutes from 5% to 13% of the feed ration.

Reliability and Applicability

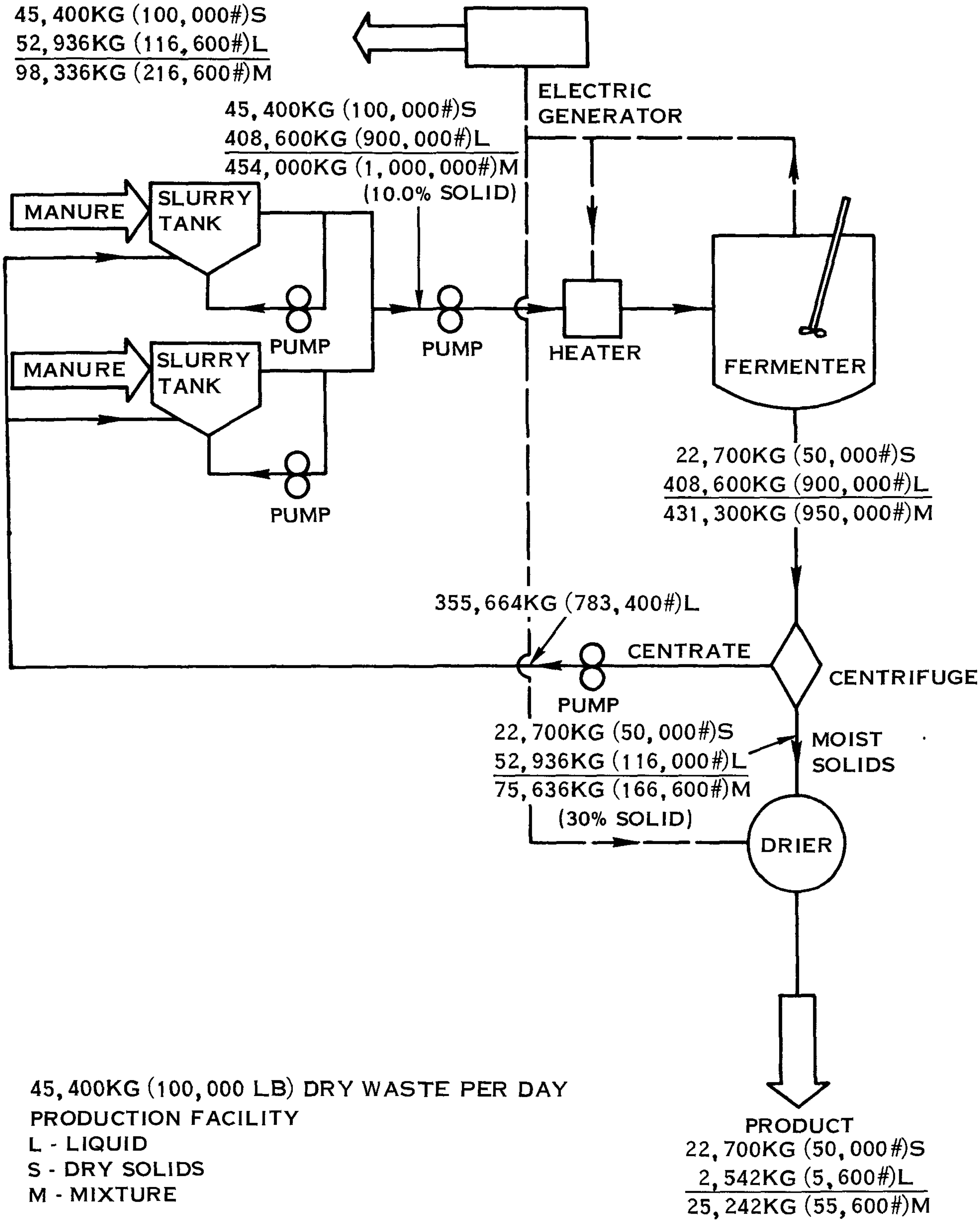


FIGURE 42. ANAEROBIC PRODUCTION OF SINGLE CELL PROTEIN— MASS BALANCE

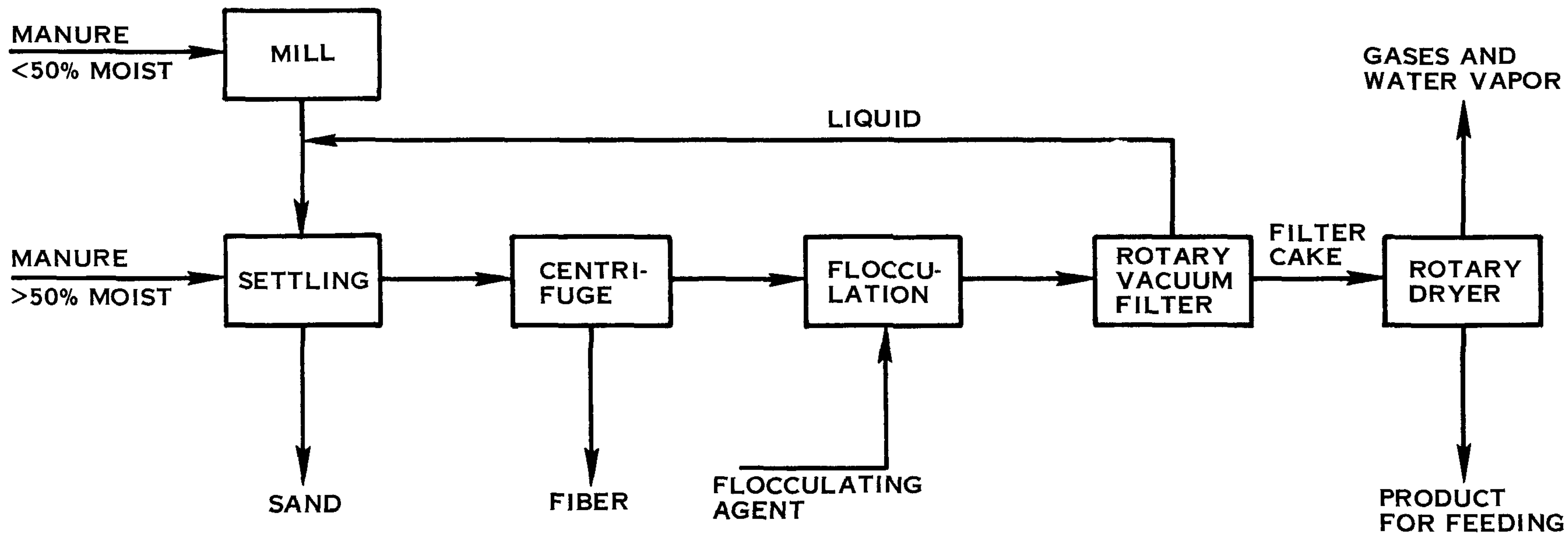


FIGURE 43. FEED RECYCLE PROCESS

Equipment used in the process is moderately complex. Malfunction correction may thus require relatively frequent attention.

The Feed Recycle Process can be used to process manure from any feedlot situation. In fact, certain types of operation (e.g., slatted floor systems) may permit a high degree of automation in manure collection, assuring a steady supply to the processing equipment

OXIDATION DITCH

The oxidation ditch is made up of two principle parts, a continuous open channel ditch, usually shaped like a race track, and an aeration rotor that circulates the ditch contents and supplies oxygen. The oxidation ditch is a modified form of the activated sludge process and may be classed as an extended aeration type of treatment. Aerobic bacteria use the organic matter in the waste deposited in the ditch as food for their metabolic processes, thus reducing the biologically degradable organics to stable material with carbon dioxide and water as the major by-products.

The oxidation ditch is a commercially used technology in the feedlot industry and offers the primary benefits of near odorless operation plus reduced waste management labor and clean feeding facilities when incorporated with slotted floor animal confinement. The system is, however, a relatively high rate consumer of electrical power and water.

Although biological reduction of solids in the ditch has been demonstrated, the removal of solids is required in order to maintain a solids concentration of the mixed liquor at a near optimum level to keep the aerobic bacteria metabolism more active. Sludge removal can be effected by pumping from a trap constructed for this purpose, diluting by adding water to the ditch and collecting the overlfow for further treatment and disposal, pumping from the ditch and mixing with the ration for refeed use, or a combination of the methods.

The results obtained to date on a refeed program suggests that animal waste biologically processed through the oxidation ditch system has an acceptable nutritional value and can be used effectively as a partial protein and mineral supplement in the feed ration of ruminants. There appear to be no animal health or meat quality problems. However, investment in the oxidation ditch for the purpose of refeeding is not presently practical due to lack of FDA approval of the concept. Costs of $120 per head of beef cattle have been reported for a complete housed, slotted floor, oxidation ditch facility. With other costs reported for housed, slotted floor facilities of $65 to $75 per head, the cost attributed to the oxidation ditch alone is about $50 per head to install.

Technical Description

Raw manure is deposited directly into the oxidation ditch, either on a continuous basis where livestock are confined on slotted floors over the ditch, or periodically by collecting and transporting the manure to the ditch. Oxidation ditches have been shown to be relatively insensitive to batch loading. A rotor, immersed from 5 cm (2 inches) to 15 cm (6 inches) in the mixed liquor, rotates at sufficient speed to circulate the ditch contents so that solids will be kept in suspension and not settle. The rotor also supplies the oxygen to the mixed liquor for biological oxidation in which residual plant material and intestinal bacteria are broken down. Figure 44 shows this system schematically.

Water is added to maintain the depth in the ditch at a constant level, in conjunction with an overflow device, and to maintain a relatively constant solids percentage in the ditch by diluting the ditch contents and carrying entrained solids out the overflow. Effluent from the oxidation ditch is piped to a settling tank or or lagoon where solids can be periodically removed and spread on land for fertilizer. The biological oxidation product, CO_2, is released to the atmosphere.

For animal refeed, the liquid animal waste material is pumped directly from the oxidation ditch into a mixing wagon containing the adjusted control ration, thoroughly mixed and then augered into the feed bunk. The feed mixture is prepared and fed on a twice daily basis.

The data for the mass balance in Figure 45 were supplied by one of the principal developers of the oxidation ditch concept for beef feedlot application. The balance is based on one 384 kilogram (845 pound) steer.

Development Status

The oxidation ditch is in a relatively advanced stage of development. Over 400 installations are reported with a significant number in full-scale operation. The oxidation ditch is one of the simplest and easiest to maintain of all waste treatment systems. However, every system must have regular maintenance and good management if it is to function properly over an extended period of time.

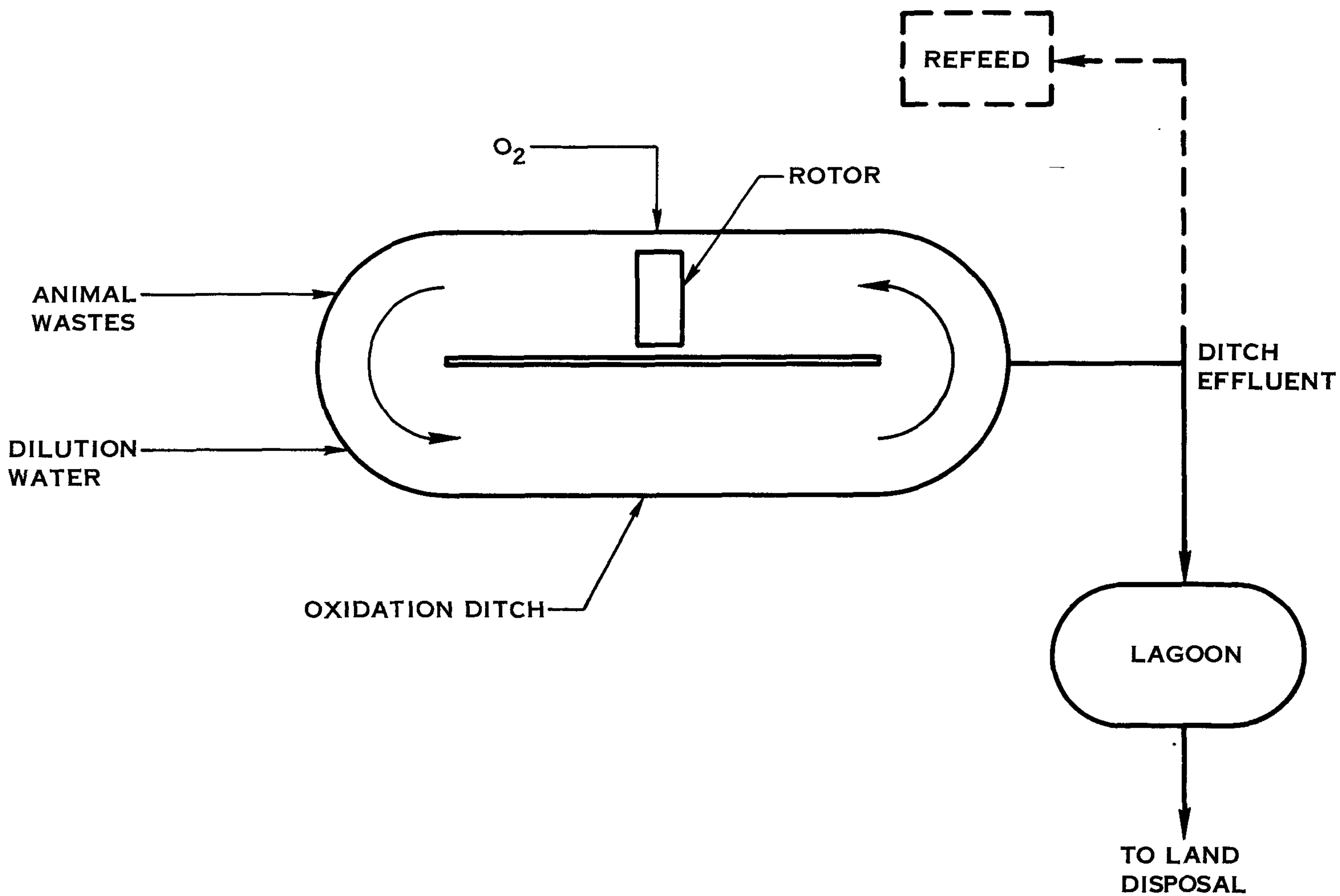


FIGURE 44. OXIDATION DITCH

The most critical period of operation is system start-up. Excessive foaming, gases and odors have been reported, especially when septic manure is present. Periods of up to 12 weeks have been reported before a ditch becomes acclimated to the waste loading. Also, when the ditch contents approach freezing temperatures, oxidation rate slows considerably and heat may have to be added. Once proper operation of an oxidation ditch has been established, the contents should probably never be completely pumped out, but rather a portion of the ditch contents should be replaced with tap water when the solids or mineral concentration becomes too high. A properly operated oxidation ditch has been shown to be effective for odor control, manure handling in conjunction with

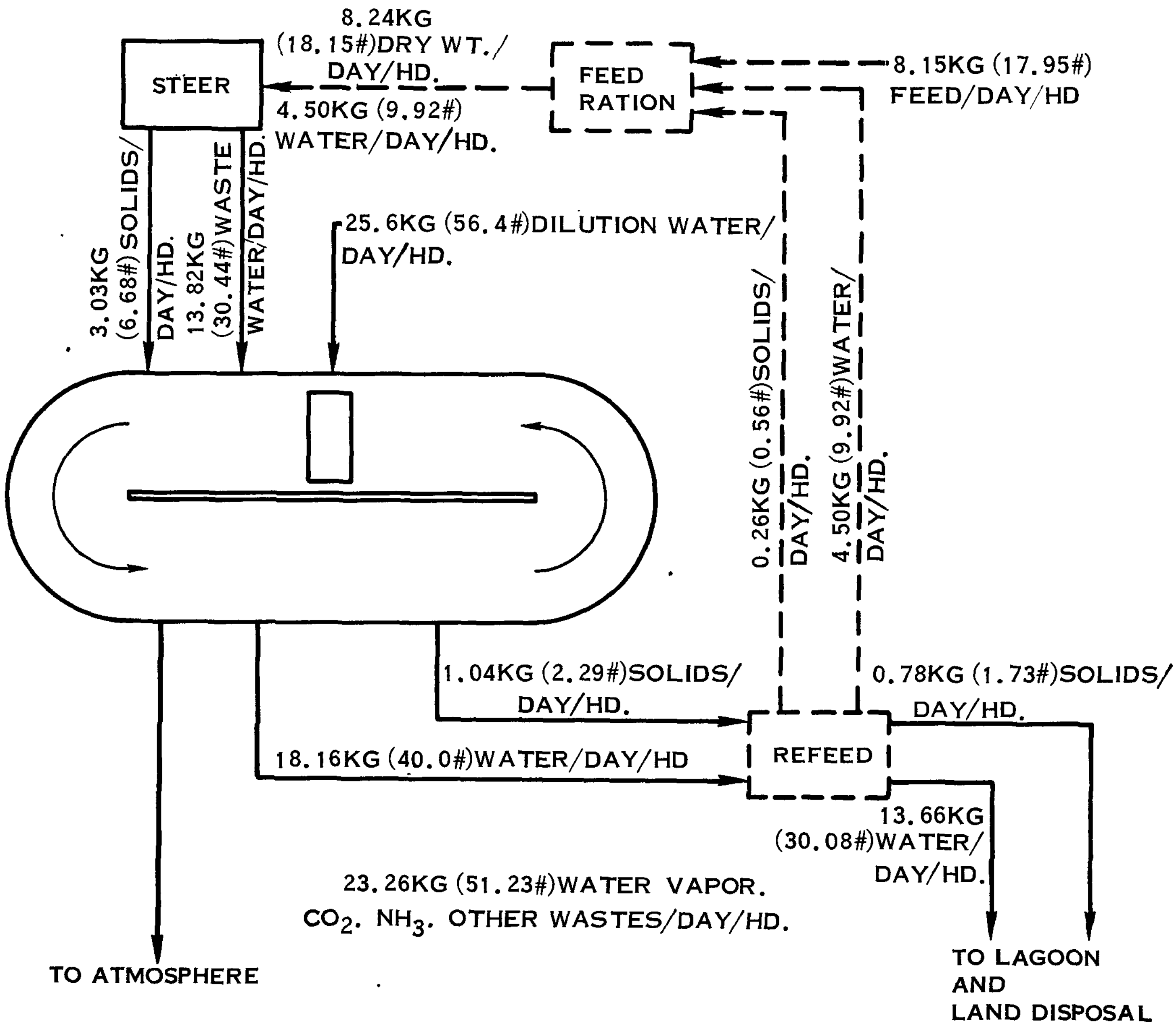


FIGURE 45. OXIDATION DITCH—MASS BALANCE

slotted floor installations, and reported solids reduction of 34% to 90%.

Extensive research data are still needed to adequately evaluate the systems as an approved feeding concept. Additional feeding outlets or methods of concentrating the effluent material are needed if feeding is the desired procedure for utilizing all the animal waste production. The simplicity of recycling the material from the ditch and the potential economic value makes the oxidation ditch system a worthwhile concept for further study. To date, over 500 cattle have been fed a diet supplemented with oxidation ditch effluent in five different experiments.

Reliability and Applicability

The reliability of the oxidation ditch is relatively high as it is a fairly simple system if it is operated properly.

The oxidation ditch is generallly applicable to all feedlot operations. The concept has been utilized for cattle, poultry, and swine applications as an odor and waste management technique. Refeed of ditch effluent has been experimentally demonstrated for beef cattle. On the other hand, maintenance requirements, power and water use can be quite high, and release of harmful gases can occur during shutdown (such as following a mechanical failure).

ACTIVATED SLUDGE

For this discussion, these processes are defined as bacterial digestion in an aerated tank. Most of the currently active programs are on a demonstration scale, and are summarized below.

These processes are relatively complex, but they greatly reduce land spreading, and they can be operated in winter conditions. Power and operating costs are high. Activated sludge, as developed in Program E, is considered ready for commercial application and is, therefore BATEA technology.

Program	Waste	Operation	Pretreatment	Main Treatment	Post Treatment	Reference
A	dairy flush and wash	Batch (24 hour)	Grit removal	Aeration-setting	Aeration - chlorination	113
B	flushed swine manure	Continuous	None	Aeration	Evaporation	114,115, 120,124 125,126

C	beef feedlot runoff	Continuous	None	Aeration	Clarification	121,122, 127
D	dairy manure, etc.	Continous	Comminu-tion	Aerated thermophilic digestion	None	116,123, 128
E	dairy manure etc.	Semi-batch or continuous	None	Aerated thermo-philic digestion	Flotation	117,118, 119,129

Technical Description

Some activated sludge processes are more sophisticated than others, and each has some distinguishing characteristic. The Location A operation is conducted batchwise, with an aeraation phase and a settling phase. Following the settling phase, liquid is drawn off to another tank, where it aerated and chlorinated before being recycled as flush water. The Location B treatment is the simplest consisting of a single tank with floating aerator. The effluent goes to an evaporation pond, ultimately leaving an odor-free mass of dead bacteria (sludge) suitable for spreading on cropland. The Location C approach is closest to the standard municipal activated sludge process. Liquid is continuously transferred from an aerated mixed liquor tank to a conical-bottom clarifier. Liquid drawn off the clarifier goes to a lagoon, while sludge is continuously air lifted back to the aerated tank. The Location D installation provides continuous, multistage, temperature-controlled, aerated digestion of liquid wastes. The Location E operation is similar but adds (when desired) a flotation tank and drying bed for sludge removal and dewatering, a settling tank for liquid clarification, a chemical precipitation stage for decolorizing, and a chlorination stage for sterilization.

The Location E approach is shown in Figure 46 because it is a flexible, modular concept that contains the elements of most of the other approaches. The one exception is the concept of sludge recycling (by means of the aeration compressor) used at Location C. Depending on the type of waste and the degree of treatment desired, the Location E system may comprise anything from a single aerated tank to the complete system shown in Figure 46. Mass balance information is available for operations at Locations A, B and E. The Location B information represents actual data, whereas the other information may be actual or projected. In general, the mass balance represents:

Input: animal waste, oxygen, chlorine (optional)
Output: carbon dioxide, ammonia, renovated water, sludge

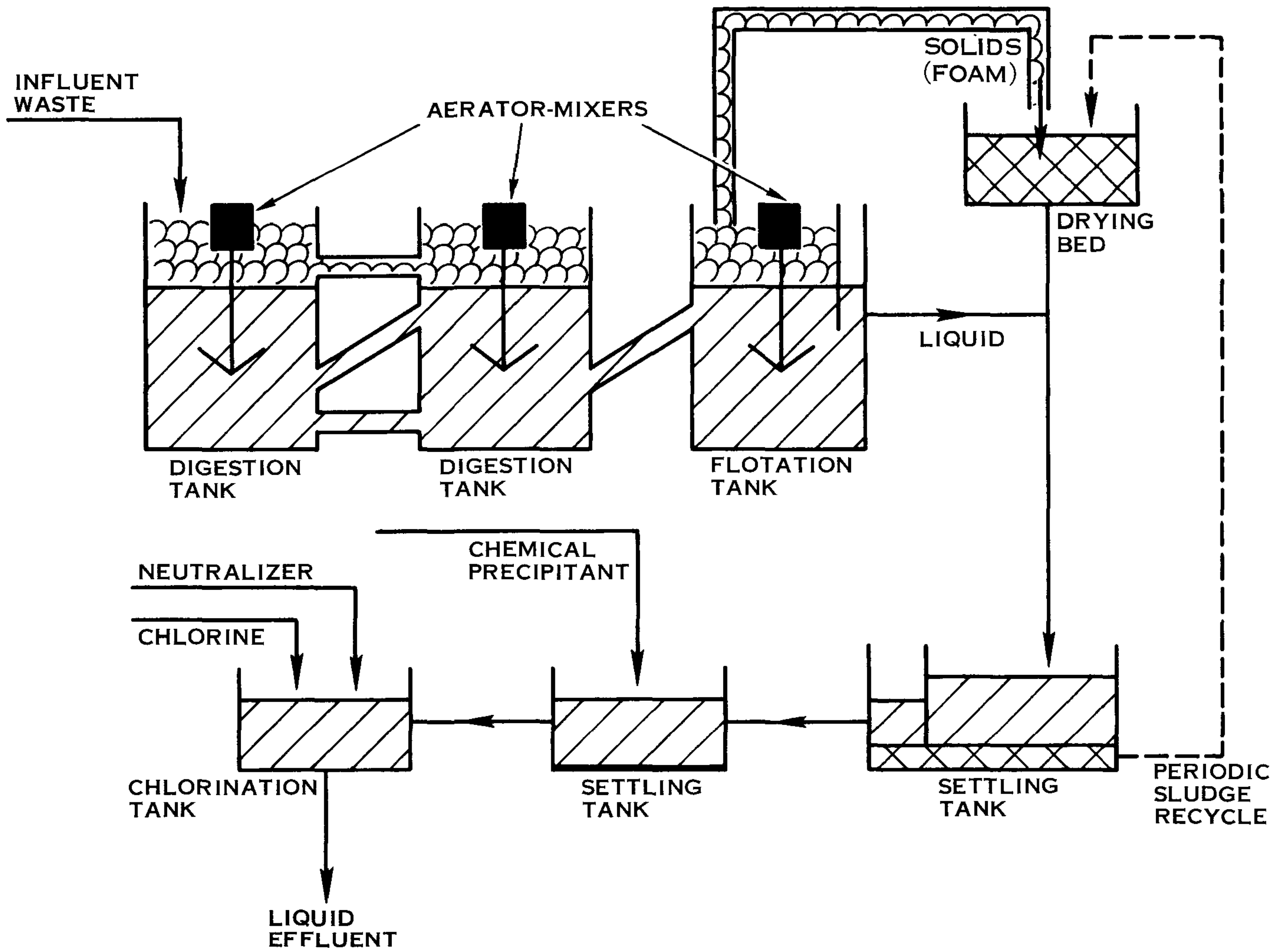


FIGURE 46. ACTIVATED SLUDGE

Operation A handles wastes associated with 175 dairy cows. System inputs are as follows:

INPUT	FLOW LITERS (GAL)/DAY	BOD KG (LB)/DAY
Waste:		
Flush Water	33,120 (8,750)	
Manure	4,540 (1,200)	51 (112)
Wash Water*	75,700 (20,000)	6 (13)
Domestic	190 (50)	- (1)
Total	113,550 (30,000)	57 (126)
Rain	0-156,700 (0-41,400)	-
Oxygen	113.50 (250)**	

*From milking parlor and processing plant.
**Oxygen absorbed in kg/day (lb/day). Requires 9260 liters/min (327)/cfm) air throughput.

System output is not defined, except that dissolved oxygen must exceed 5 mg/liter and residual chlorine must exceed 1.0 mg/liter. Operation B has a stated capacity of 1000 90 kilogram (200 pound) hogs, but the available data represents 750 hogs during a 14 week period where the average weight increased from 23 to 80 kilograms (50 to 175 pounds). In the following table, the influent represents manure diluted with flush water, while the effluent represents the average of conditions in the aeraation tank before and after waste addition. The manure was flushed with 5700 to 10,200 liters (1500 to 2700 gallons) of water, generally three times each week.

WASTE COMPONENT	CONCENTRATION, MG/LITER INFLUENT	EFFLUENT
BOD	46,400	1,680
COD	99,100	8,210
Suspended Solids	75,800	8,130
Total Nitrogen	6,760	703

Location E mass balance information is presented on the basis of 100 dairy cows:

WASTE COMPONENT OR SOURCE	INPUT L/DAY GAL/DAY	INPUT KG/DAY LB/DAY	OUTPUT L/DAY GAL/DAY	OUTPUT KG/DAY LB/DAY
Milkhouse	2540	2550	--	--

	(670)	(5,620		
Manure	4540	4585	--	--
	(1,200)	(10,100)		
Liquid	--	--	3140	3170
			(830)	(6,980)
Fibrous Matter	--	--	300	300
			(80)	(670)
O_2, CO_2, NH_3	--	--	---	?
Total	7080	7135	3440	3470
	(1,870)	(15,720)	(910)	(7,650)
BOD	--	98	--	5.2
		(215)		(11.5)
COD	--	128		10.6
		(281)		(23.3)
Organic Notrogen	--	9		2.7
		(20)		(6)

(20) (6)

The output figures represent processing without chemical posttreatment. Based on the output values, the following mass balance for the precipitation-neutralization-chlorination step can be written:

COMPONENT	INPUT KG/DAY (LB/DAY	OUTPUT KG/DAY (LB/DAY)
Liquid	3170 (6,980)	3170 (6,980)
Chlorine	1.1 (2.4)	Unknown
BOD	5.1 (11.5)	0.09 (0.2)
Ammonia	Unknown	0.009 (0.02)

Development Status

For the most part, the activated sludge processes are operating on a medium scale demonstration level in the field. The size or capacity of installations currently operating has already been indicated. Status of the Location E approach is perhaps most advanced, with three demonstration units operating in the field and several more installations planned for the near future. The largest handles 500 dairy cows.

Reliability and Applicability

The activated sludge processes are moderately complex and malfunctions may, therefore, be relatively frequent until a firm foundation of design experience is built. Municipal sewage installations are relatively trouble-free, but units processing animal waste have had a significant number of breakdowns.

The activated sludge processes have been applied to several types of animal waste. They permit waste treatment in all weather conditions and minimize or eliminate the need for land spreading.

WASTELAGE

Beef cattle waste collected from livestock reared in confinement is used as animal feed. The use of feedlot manure as an ingredient for animal rations has been under experimental evaluation at a university agricultural experiment station for over eleven years. The concept has evolved from feeding a ration mixed with fresh, washed, or cooked manure to the present technique of mixing corn, corn silage, and manure and ensiling this mixture for ten days prior to feeding. The results of published feeding trials generally indicate a benefit in feed efficiency for animal weight gain by including manure in the mixture. The ensiled mixture has been fed to beef cattle, breeding cattle, and ewes. It is not feasible to return all the manure to the steer from which it is collected, so that disposal of from 1/2 to 2/3 of the unused portion is required. Wastelage is available for use on commercial feedlots, although FDA approval has not been received.

Technical Description

Raw manure is scraped either daily or 2 to 3 times per week from the floor of confined cattle pens to a conveyor. The waste is transported to a common storage facility or directly to the mixer. The ration is prepared by mixing 42 parts of corn, 18 parts corn silage and 40 parts of manure on a wet weight basis. The mixture is then blown to the top of an oxygen controlled silo and allowed to age for ten days. The wastelage is unloaded from the bottom into a feed delivery wagon and deposited in the feed bunkers.

Development Status

The wastelage refeed concept has been under development for about 10 years. A series of pilot lot operations has been conducted during this period. The pilot lot tests conducted to date have shown the wastelage ration to be readily consumed by cattle. Feed and cost effectiveness have been indicated. The first full-scale operation, consisting of 200 head of beef cattle, is about to get underway at an undisclosed location.

Reliability and Applicability

Wastelage is basically a simple process, so reliability should be good. Care is required to maintain consistent wastelage quality.

Application is limited to ruminants maintained on hard surface or slotted floors.

ANAEROBIC PRODUCTION OF FUEL GAS

The production of methane fuel gas by anaerobic fermentation of animal wastes is currently under investigation at several locations. While considerable laboratory work has been performed, no field demonstration plant is yet in operation. Economic projections for the various systems indicate that fuel production is economically practical only for systems that are sized for the largest commercial feedlots. Therefore, profitable operation is available only to processing plants that are regional in nature. This would, in turn, invite additional costs for purchase and transportation of the raw material. Economic utilization of the remaining sludge is necessary to avoid the added expense of sludge removal and disposal.

Technical Description

A schematic of one version of the process is shown in Figure 47, which also indicates a mass balance. The manure enters a feed tank after having been slurried. This material then enters primary fermentation tanks for partial digestion. Fermentation of the effluent material continues in secondary fermenters.

The liquid effluent from these secondary units is then thickened using "flotation" techniques before being sent to dewatering beds. Waste water from the thickening process is sent to an oxidation pond for storage. The dewatered solids are then dried for use as a soil conditioner.

The effluent gases from the fermenters are sent to a compressorscrubber. Here, the carbon dioxide and hydrogen sulfide are removed, and the resultant methane-rich gas is compressed for introduction into a pipeline. Estimates of methane production range from 374 liter/kg (6.0 cubic foot/pound) volatile solids to 480 liter/kg (7.7 cubic foot/pound) volatile solids.

Figure 48 depicts an alternative version of the process. It should be noted that this system is based on utilizing municipal waste; however, utilization of animal manures would lead to essentially the same processing.

Development Status

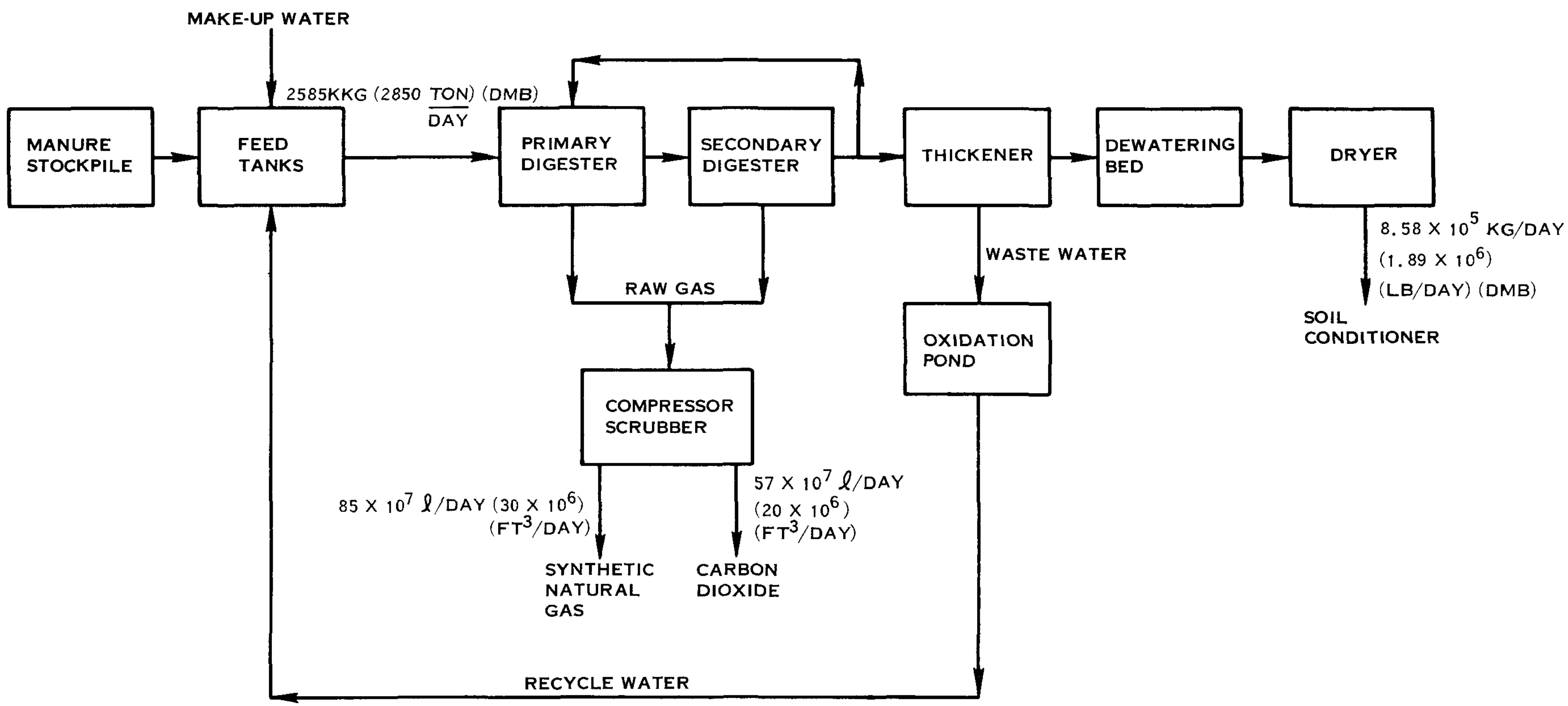


FIGURE 47. ANAEROBIC PRODUCTION OF FUEL GAS

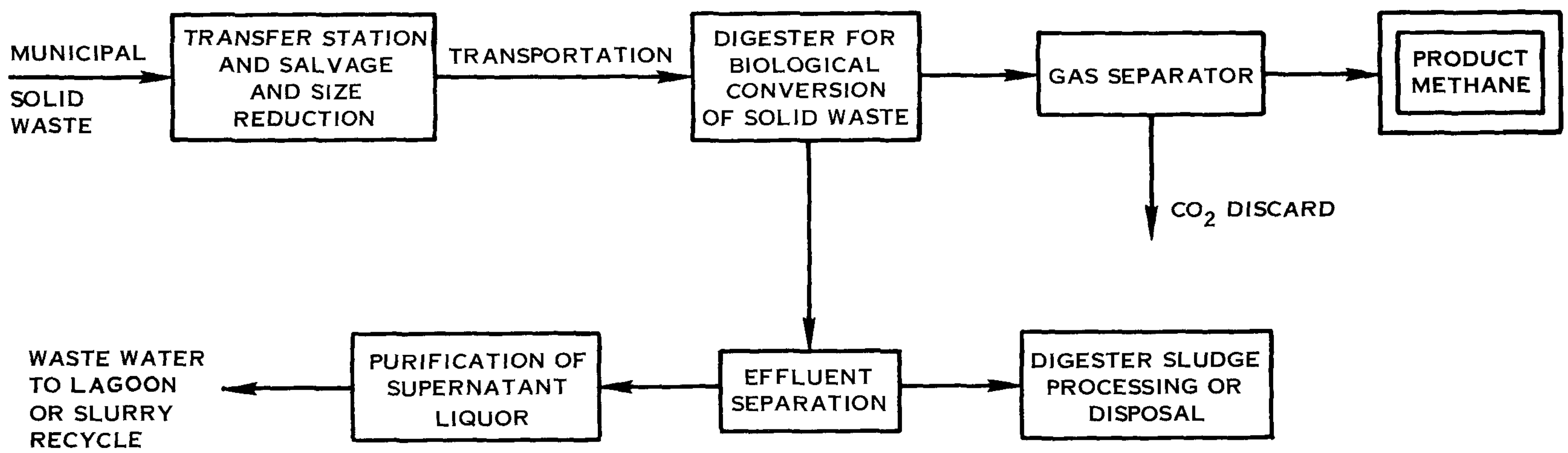


FIGURE 48. CONVERSION OF SOLID WASTES TO METHANE

The process has not yet progressed to the pilot plant stage. Arrangements are in the formulation stage to build a pilot plant in either New Mexico or Texas, because both areas have high concentrations of feedlot waste available. An estimate of 18 months before completion of the plans is anticipated. A pilot plant may be part of a large waste water treatment facility at the site. A verbal agreement with the gas company for purchase of all substitute natural gas (SNG) or methane produced has been made, but a legal contract has yet to be executed.

Obtaining sufficient manure from local feedlot owners is proving a problem. The preferred set-up is use of feedlot equipment to load trucks which would then deliver the manure to the processing plant. In this manner, no "purchase" is necessary. However, long-term contracts are required before a plant can be built, and the feedlot owners are reluctant to sign any agreements, believeing that their manure pile will soon "turn to gold". Most likely, if contracts are signed, some purchase price will be involved.

The process developer indicated last year that estimates of construction and operating costs of the scrubbing equipment had been substantially incorrect. It also indicated that based on gas sales alone (no credit for byproduct sales) the sale price required for the SNG to be profitable had doubled from the original figure.

Before constructing a full-size production facility, extensive pilot plant development work is necessary.

Reliability and Applicability

Almost all of the components used in the system are standard items. The "thickener" is the one non-standard hardware item and may, therefore, tend to be a potential trouble spot.

Location of a SNG plant is limited to a relatively small area close to feedlots. Haulage rates can drastically affect production costs. If credits are to be taken for sale of byproducts, shipping costs also become a factor. Access to significantly more than 100,000 head of cattle within a relatively small radius is necessary for economic production of SNG.

REDUCTION WITH FLY LARVAE

Utilization of livestock manure as a growth substrate for fly pupae, which would be used as a high protein feed supplement, is in the experimental stage. Work in the laboratory on poultry manure has produced a product with an attractive nutrient analysis. Economics are uncertain, and feed utilization needs to be demonstrated in feeding trials. The residual waste solids should be marketable as composted manure.

Technical Description

Manure is placed in a rotating drum resembling a cement mixer and is innoculated with house fly eggs. As the drum rotates, air is sparged in through the perforated shaft. The air is pre-heated to 25-35°C, and is pre-dried to less than 40% relative humidity. During a period of about five days, fly larvae hatch from the eggs and tunnel through the manure, promoting thorough aeration and rapid biodegradation. The mixture is then removed and spread on a screen. The top of the screen is exposed to a bright light, which drives the larvae through the screen into a dark box, where they pupate. The pupae are then ready for drying and grinding to form a high protein meal. The material remaining on the screen may be used for land fill or as a soil conditioner. Air emerging from the processor passes through an acid bath, an alkaline bath, and a dehumidifier, before recycling through the processor. These steps remove ammonia, volatile acids, and moisture. The process is represented in Figure 49.

Each fly produces 200 to 300 eggs in a batch. These eggs are used at the rate of 3.0 eggs per gram of manure. Then, one ton of manure requires 10,000 - 14,000 flies to produce about 2.7 million eggs. The process results in 23 to 27 kilograms (50 to 60 pounds) of protein feed supplement (dried, ground pupae) and 450 to 540 kilograms (1000 to 1200 pounds) of "semi-dry practically odorless soil conditioner". About 0.6 kilograms (1.4 pounds) of the pupae produced may be saved for fly breeding. Most of the balance of the original .9 kkg (ton) of manure will have been removed in the air stream as water vapor and carbon dioxide, along with some ammonia and small quantities of volatile acids, ketones, skatol, etc. The resulting protein meal is 63.1% protein, 15.5% fat, 3.9% moisture, 5.3% ash, and 12.2% nitrogen free extract, fiber, and other. It contains many amino and fatty acids.

Development Status

All work thus far has been on a laboratory scale. However, a small automatic demonstration unit is nearly ready for operation. This unit will process a 1.8 kkg (two ton) batch of manure. In the laboratory, the process has been successfully applied to manure from several types of animals.

Reliability and Applicability

Equipment may be rather conventional, but it is uncertain how much complexity the air scrubbing operation adds. In addition, good control of paramenters such as temperature, humidity, processing duration, and innoculation rate is required. Thus, unexpected problems in reliable operation may arise.

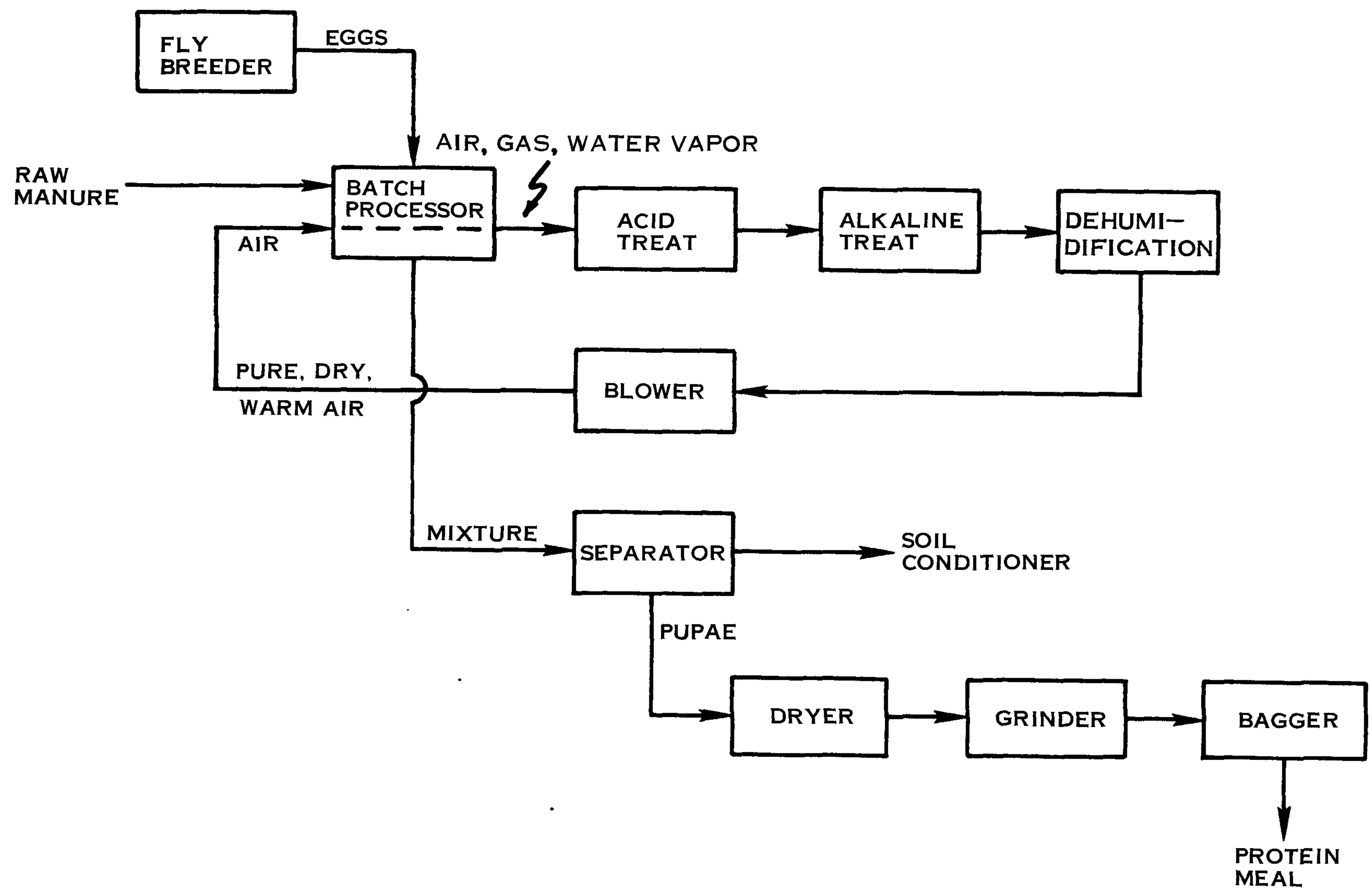


FIGURE 49. REDUCTION WITH FLY LARVAE

Although most effective for swine manure, the process may be used for any animal manure. The developers claim that a single processing unit would require only part-time attention (a few hours, once every five days) from someone with no special skills. A large, multi-unit installation would probably need full-time attention.

BIOCHEMICAL RECYCLE PROCESS

The Biochemical Recycle Process, designed for flushed dairy waste, produces roughage or bedding, fertilizer, and good purity water from liquid manure. The process is essentially biological (aerobic) and is carried out in chemical processing equipment. The value of the fiber as a feed roughage has not been established, and the fertilizer is a wet product not suitable for transportation to market.

The process is proprietary, and available information was not sufficient to substantiate the developer's claims. The process appears to be complex and expensive, with no demonstratable payback. The first full-scale demonstration is now being started.

Technical Description

The Biochemical Recycle Process is described in Figure 50. From the manure pit, liquid manure is pumped to two countercurrent classification stages. In the primary classifier, water from reaction stage (described later) is added, and the fibrous solids are separated from the liquid and sent to the final classifier.

In the final classifier, water from the second settler (described later) is used to rinse the fibers, which are separated, squeezed-dried to not more than 25% moisture, and collected for later use as feed roughage or bedding. Liquid from the final classifier and from the squeeze-dryer is sent to the flocculation step (described later).

Liquid from the primary classifier is discharged into the top of a reaction tower. Also entering the top of the reaction tower are air and recycled liquid. In the tower, the liquid passes down through a series of sieve trays (perforated plates), and foaming occurs, saturating the liquid with oxygen and promoting growth of aerobic bacteria. The base of the tower is called the reaction vessel and provides 80 minutes holdup time for aerobic digestion of the waste. The liquid overflows from the reaction vessel to an "enzyme vessel", which provides an additional 80 minutes holdup time. Liquid flows through this reaction system at a net rate of about 3.8 liter per minute (one gallon per minute) but liquid from the reaction and enzyme vessels is recycled to the top of the reaction tower at a rate of about 380 liter per minute (100 gallon per minute). Some of this liquid is also recycled to the primary classifier for fiber rinsing.

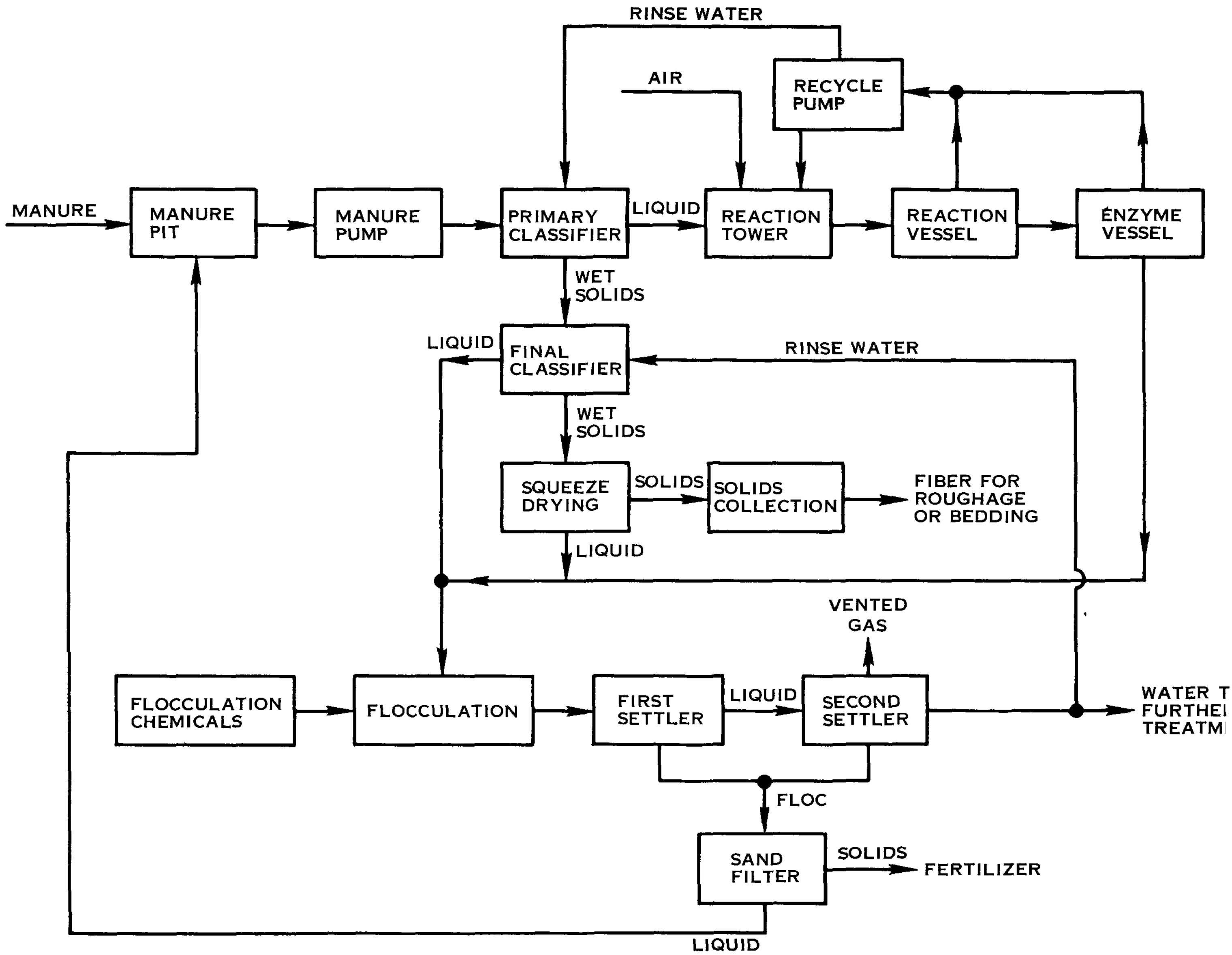


FIGURE 50. BIOCHEMICAL RECYCLE PROCESS

From the biochemical reaction stage, the liquid overflows to a flocculation tank, where chemicals (alum, ferrous sulfate, ferric chloride, and/or polyelectrolytes) are added to form the floc and adjust the pH to between 4.5 and 5.0. The resulting slurry is then transferred to a two-stage settling operation. The first settler overflows into the second settler, which is vented to the atmosphere. Part of the liquid from the second settler is recycled to the final classifier for fiber rinsing. The rest of the liquid is discharged for use as flushing water or treatment with ion exchange resins and charcoal before release to a natural waterway. This settler effluent has a BOD of less than 20 ppm and 1000 - 2000 ppm dissolved solids, mainly sodium salts.

Floc is emptied from the two settlers once or twice a week into a sand filter. The filtrate is returned to the manure pit. The solids are removed for use as fertilizer.

The following mass balance is for a 100 cow system:

Input:	Total manure	- 4240 - 5750 kg/day (9330 - 12,670 lb/day)
	Solids	- 658 - 1070 kg/day (1450 - 2350 lb/day)
	Alum	- 1.3 - 1.6 kg/day (3 - 3.5 lb/day)

Output:	Roughage (@25% H_2O)	- 110 - 200 kg/day (240 - 440 lb/day)
	Fertilizer	- unknown
	Specification water	- unknown
	NH_3 and CO_2	- unknown

Development Status

The system manufacturer stated that the first full-scale unit is now ready to begin operation but would not divulge the location of this system. The device is being built for 100 cow size units (45 kg/cow/day) (100 lb/cow/day) and has been under development for several years. The system still requires full-scale verfification and refeed data.

Reliability and Applicability No reliability data are available, but the system is relatively complex, so that above average maintenance is anticipated.

This system was designed and sized specifically with a dairy operation in mind. However, this system would probably be applicable to other feedlot operations. No limitations due to geography or climate are apparent. Sizing accomodation would require installation of multiple units based on specific requirements.

CONVERSION TO OIL

Manure is predried to 20% water and dispersed in recycled product oil. The reaction mixture is then heated with synthesis gas (carbon monoxide and hydrogen) to 325°C at a pressure of more than 205 atmospheres (3000 psi) for about 15 minutes. Manure conversion is roughly 90%, forming a thick oil that must be heated to make it flow. Heating value is about 8,800 kg/cal/kg (16,000 Btu per pound). Operating costs are high, and the value of the oil is low. Consequently, this experimental process is not economically attractive at this time.

The basic problem is that under economically practical operating conditions (synthesis gas reactant, no catalyst, relatively low temperature) the properties of the product limit its application. Viscosity and oxygen content are very high, and the quantity of water in the raw manure makes separation of the product oil difficult. In addition, high pressure (272 atmospheres) (4000 psi) is needed to obtain even fair yields.

GASIFICATION

Manure is partially oxidized in the presence of steam to form a synthesis gas that can be used as an intermediate in ammonia production by conventional manufacturing plants. The ammonia plants would produce fertilizer. A thorough economic evaluation has not been made to date. Classified as experimental technology, development is in the early laboratory stage. Product value is moderately high, but the relatively complex process has a high power requirement and is economically restricted to a centralized location with regard to feedlots.

Technical Description

The concept is based on coal gasification, where coal is partially oxidized in the presence of steam to form carbon monoxide and hydrogen, with additional coal burned to provide the heat of reaction. Manure gasification is similar, except that air is used instead of pure oxygen, because nitrogen is needed to react with the hydrogen to form ammonia rather than pipeline gas. In essence, the gasification process extracts hydrogen from manure and nitrogen from air for subsequent combination to form ammonia. Gasification is the first of three steps in the ammonia production process:

a. Manure plus air plus water equals carbon monoxide plus hydrogen plus nitrogen

The remaining two steps are carried out in the conventional ammonia production plant, with addition of water and physical removal of carbon dioxide formed in the shift reaction:

b. Carbon monoxide plus hydrogen plus nitrogen plus water equals carbon dioxide plus hydrogen plus nitrogen.

c. Hydrogen plus nitrogen equals ammonia.

Thus, the first reaction, which converts manure to synthesis gas, is of primary interest here, with the synthesis gas regarded as a saleable product.

Manure is partially oxidized with a controlled quantity of air at an elevated temperature. Water for the reaction is already contained in the manure. The temperature range used for thus far is 370°C - 400°C (700°F - 750°F), but higher temperature as well as a catalyst may be needed to obtain a practical reaction rate. Atmospheric pressure has been used thus far, but a higher pressure may be desirable. Heat to drive the endothermic reaction is supplied by burning additional manure in air. Figure 51 represents the entire process schematically.

The objective is to control the process to obtain a 3:1 hydrogen: nitrogen mole ration for Step c. This is done by using just enough air in Step a. to result in the following molar balance (where the first term representa manure):

a. $C_{3.14}H_{4.6}O_{1.67}$ + $0.49O_2$ + $1.96N_2$ + $0.49H_2O$ = 3.14 CO + $1.96N_2$ + $2.79H_2$ + residue

Step b. adds additional water to obtain:

b. 3.14 CO plus $3.14H_2O$ equals $3.14CO_2$ plus $3.14H_2$

This brings the total moles of hydrogen (per mole of manure) from a. and b. to 5.93, which is roughly three times the 1.96 moles of nitrogen liberated from the air.

Assuming that the effective molecular weight of manure averages 100 (including sand and other inorganics), the mass balance for Step a. is as follows:

	Kilograms Reacted (Pounds Reacted)	Kilograms Formed (Pounds Formed)
Manure (Dry basis)	45.4 (100.0)	--
Air	32.0 (70.6)	--
Wacter	4.0 (8.8)	--
Carbon monoxide	--	39.9 (87.9)

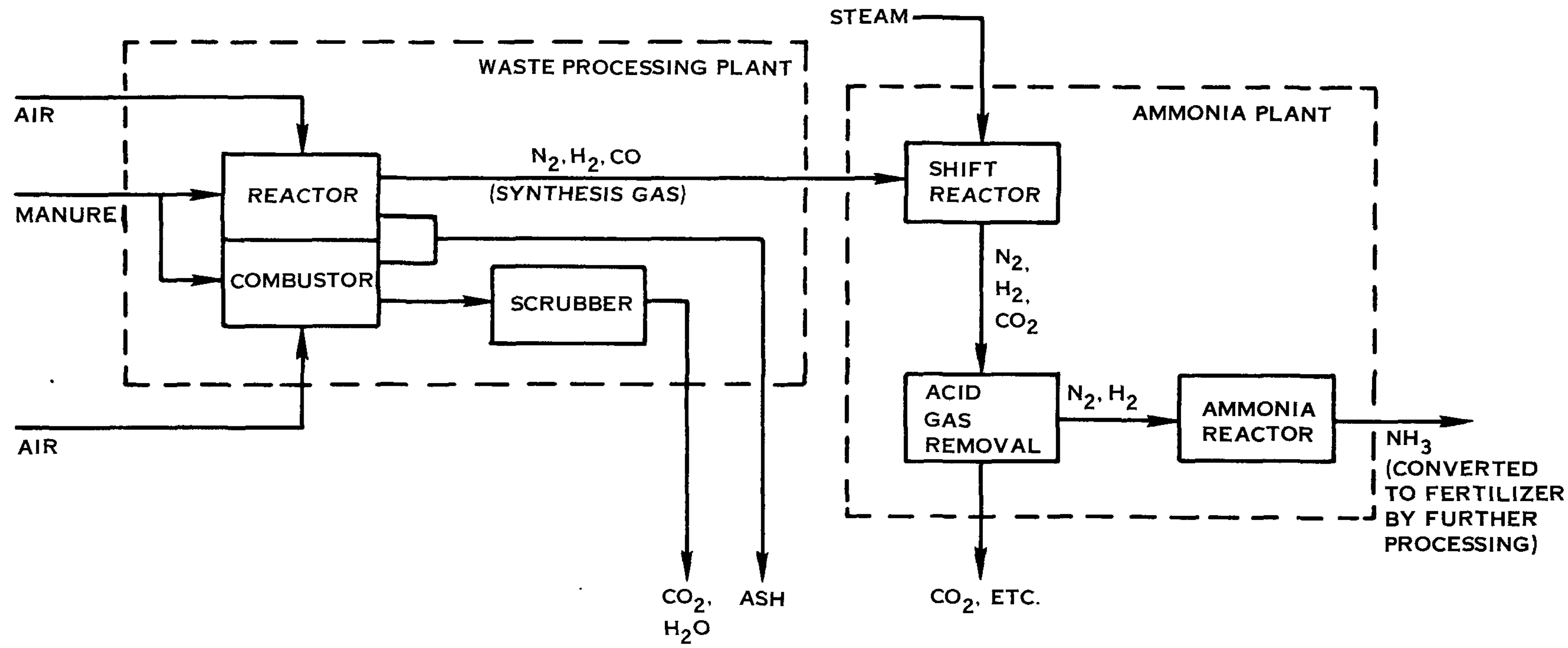


FIGURE 51. GASIFICATION

Nitrogen	--	24.9 (54.9)
Hydrogen	--	2.5 (5.6)
Residue	--	14.1 (31.0)
Total	81.4 (179.4)	81.4 (179.4)

In the ammonia plant, the carbon monoxide would be reacted with additional water to form 2.9 more kiligrams (6.3 more pounds) of hydrogen, and the total of 5.4 kilograms (11.9 pounds) of hydrogen would be reacted with the 24.9 kilograms (54.9 pounds) of nitrogen to form 30.3 kilograms (66.8 pounds) of ammonia.

However, because the heat of reaction is 1806 kg cal/kg (3254 Btu/lb) manure reacted and the heat of combustion is about 3330 kg cal/kg (6000 Btu/lb) manure burned, 1806/3330 = 0.542 kilograms (3254/6000 = 0.542 pounds) must be burned as fuel for every kilogram (pound) converted to synthesis gas. Hence, the gasification process generated (71.4-14.1)/(1.542 x 100) = 0.44 kilograms 179.4-31.01/1.542 x 1001 = 0.96 pounds) of synthesis gas for every kilogram (pound) of manure (dry basis) consumed. Ultimately, the three-step process results in 30.3/(1542x100) = 0.19 kilograms (66.8/(1.542 x 100) = 0.43 pounds) of ammonia per kilogram (pound) of manure (dry basis) consumed.

The dry basis used for these values is somewhat misleading. For example, if the manure contains only 25% moisture, every kilogram (pound) (dry basis) of manure consumed (as reactant and fuel) actually results in 0.41 kilograms (0.91 pounds) of synthesis gas and 0.19 kilograms (0.41 pounds) of ammonia. As the moisture content increases, the process rapidly becomes less attractive.

Development Status

A tremendous amount of work has been done on coal gasification. However, coal and manure gasification each have their own special problams, and they are not the same. The gasification process, as applied to manure, is in the earliest laboratory stage. Initial work on feasibility of the conversion is in progress. No work has been done on the combustion aspect or on conversioncombustion integration.

Reliability and Applicability

If this manure gasification becomes commercial, equipment is likely to be relatively complex. It will need careful control and constant attention to achieve a reliable operation.

The process would probably be economically limited to areas with high concentrations of feedlot animals, where an ammonia plant could be assured a predictable and adequate supply of manure. Disposal of the granular, inert byproduct (largely sand) would be necessary.

PYROLYSIS

Wastes may be decomposed by heating to high temperatures in an oxygen deficient atmosphere. Pyrolysis of animal manure has been carried out as an offshoot of application of the process to municipal and industrial wastes. However, ash disposal is necessary and air pollution must be controlled. Product value is low. A recent experimental study has concluded that "The pyrolysis process applied to cattle feedlot wastes is uneconomical...". Work now in progress is strictly experimental.

Technical Desicription

Waste material is dried and is then heated to a high temperature (400°C - 900°C) in an atmosphere deficient in oxygen. Under these conditions, the solid waste decomposes to form gases, liquor (oil), and char (ash). These gases include hydrogen, water, methane, carbon monoxide, and ethylene. They are recycled and burned to provide fuel to heat the pyrolyzer. Hence the process is sometimes called pyrolysis-incineration. A proposed system is shown in Figure 52. A material and enrgy balance is shown in Figure 53.

Development Status

Two developers have pyrolyzed animal manure using laboratory glassware. In addition, research groups from two large corporations have run small scale experiments and have proposed large scale processing plants. The Bureau of Mines has done related work on pyrolysis of municipal and industrial wastes.

Reliability and Applicability

The pyrolysis process is highly complex, and reliability is questionable. However, definitive data are not available, due to the experimental nature of the process.

If developed, pyrolysis could obviate the need for land spreading of animal waste. It can operate in any weather and (assuming efficient use of solid, liquid, and gaseous products as fuels) is potentially non-polluting.

INCINERATION

Incineration requires supplemental fuel to evaporate water from the manure. It destroys any useful value the waste may have, and the secondary air pollution problem requires considerable ancillary equipment. Incineration of pyrolysis gases to supply heat for pyrolysis is covered under "PYROLYSIS". The most recent experimental work on simple incineration of manure appears to have been done in 1966 and further work does not appear to be justified.

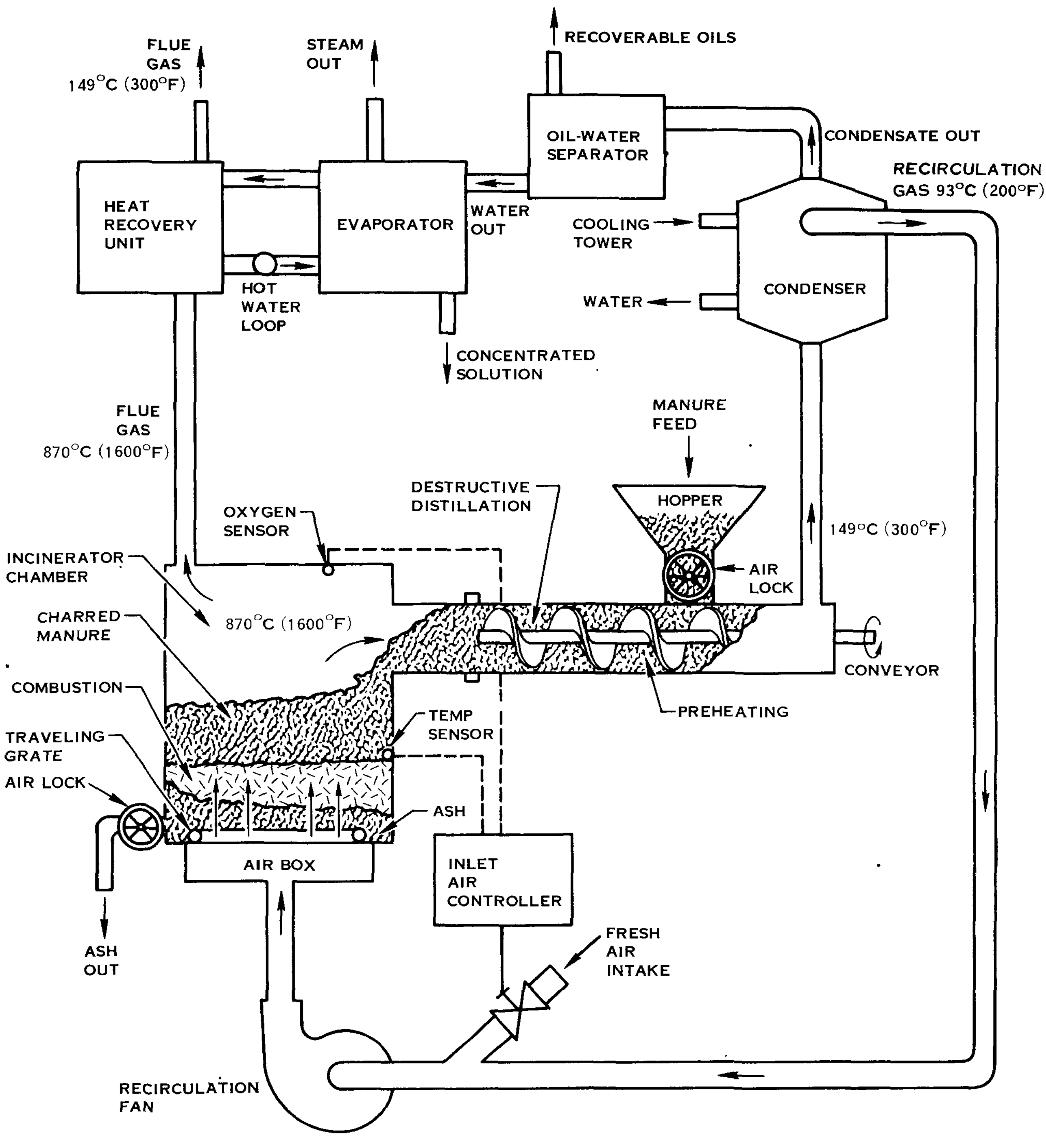


FIGURE 52. PYROLYSIS

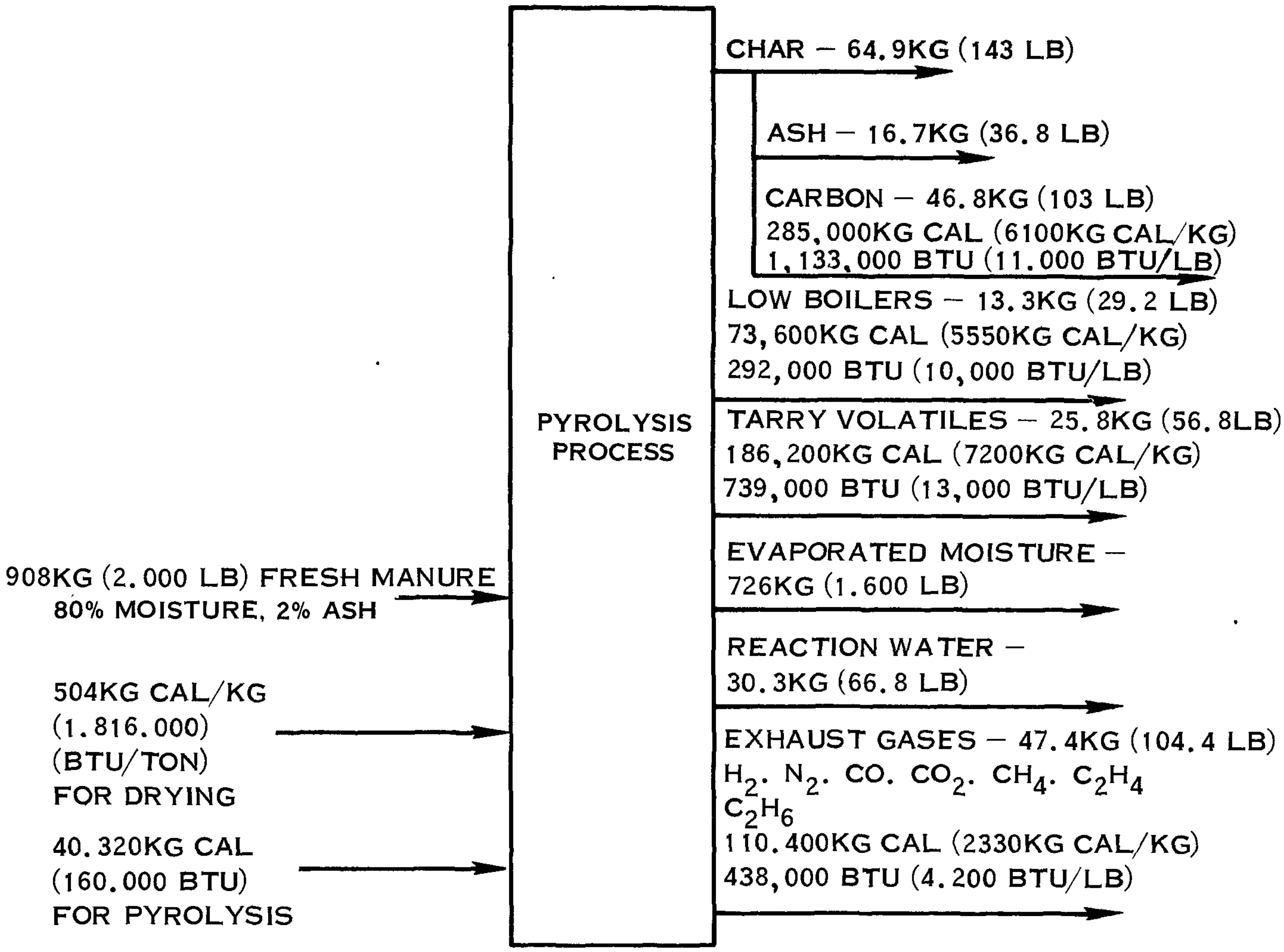


FIGURE 53. PYROLYSIS—MASS BALANCE

HYDROLYSIS AND CHEMICAL TREATMENT

Hydrolysis, especially when aided by treatment with a chemical such as sodium hydroxide, makes animal waste used for refeeding more digestible. The process is experimental and has the potential of producing a more digestible feed supplement than simple drying, but cannot compete with it economically at this time.

Technical Description

Hydrolysis is reaction of a material with water, breaking chemical bonds that block digestibility. This discussion has been extended to include chemicals used at lower temperatures for the same purpose. Work on hydrolysis has been performed at a number of locations, summarized below.

PROGRAM	SOURCE OF WASTE	TREATMENT	REFERENCES
A	Poultry Manure	Pressurized Steam	170, 179, 180, 181
B	Sewage Sludge	Sulfur Dioxide	171
C	Poultry Manure	Pressurized Steam	172, 182, 183,174
D	Forage, Crop Residue	Sodium Hydroxide	173, 174, 175;185
E	Cow Manure	Sodium Hydroxide	175, 176, 186
F	Beef Cattle Manure	Enzyme	177

Most of the programs were directed either at feeding or at refeeding various waste materials following physical and/or chemical treatment. The Location A program emphasized commercial scale development of a hydrolysis process for refeeding poultry manure to poultry. The Location B program concerned the effects of chemical treatment on the properties of activaged sludge and the effect of including sludge molasses in the diets of rats. The Location C program demonstrated the acceptability of feeding either dried or hydrolyzed poultry manure to lambs and beef cattle, using material processed by commercial hydrolysis equipment. The Location D program emphasized the effect of feeding chemically treated forage and crop residue to sheep, and the Location E program did the same thing with cow manure. Finally, the Location F program investigated the influence of enzymatic pretreatment on biological stabilization of manure to facilitate disposal.

A schematic, based on Reference 170, is shown in Figure 54.

Mass balance information on the hydrolysis of manure is generally not avialable. However, Reference 173 compares hydrolyzed poultry waste with dried poultry waste. For dried, hydrolyzed material crude protein is 35.44%, while for dried material it is 24.88%. The hydrolyzed material is correspondingly lower in crude fiber, ether extract, ash, and nitrogen-free extract.

A mass balance on hydrolysis of cattle feces can be determined by comparing an analysis of untreated feces with an analysis of chemical treated feces. The following data are based on chemical treatment with 3 grams sodium hydroxide per 100 grams of wet feces, using feces from cattle on two different feeds. Cell walls include some of the other constituents, so that the percentages are not additive.

	Percent of Dry Matter			
	Untreated Feces		Treated Feces	
Component	Orchard Grass	Alfalfa	Orchard Grass	Alfalfa
Cell Walls	64.2	68.7	39.5	43.2
Hemicellulose	18.4	13.0	2.8	2.1
Cellulose	25.4	28.4	23.0	21.9
Lignin	14.7	27.1	10.1	18.9
Insoluble Ash	5.7	--	3.1	--

Development Status

Much of the work in the hydrolysis and chemical treatment area has been directed toward the effects of refeeding poultry and steer manure to either lambs or steers. In general, this work has shown that the concept is technically practical. Refeeding has generally resulted in good weight gains, carcass characteristics, and eating characteristics.

The process has been operated commercially as a sideline, but this was discontinued due to odor and handling problems and interference with marketing of other product lines. Chemical treatment with enzymes has been used as the first step in the microbial breakdown of manure for disposal but is not applicable to refeeding.

Reliability and Applicability

Equipment is moderately complex with many moving parts. Corrosion and errosion are problems. Considerable routine mechanical maintenance should be expected.

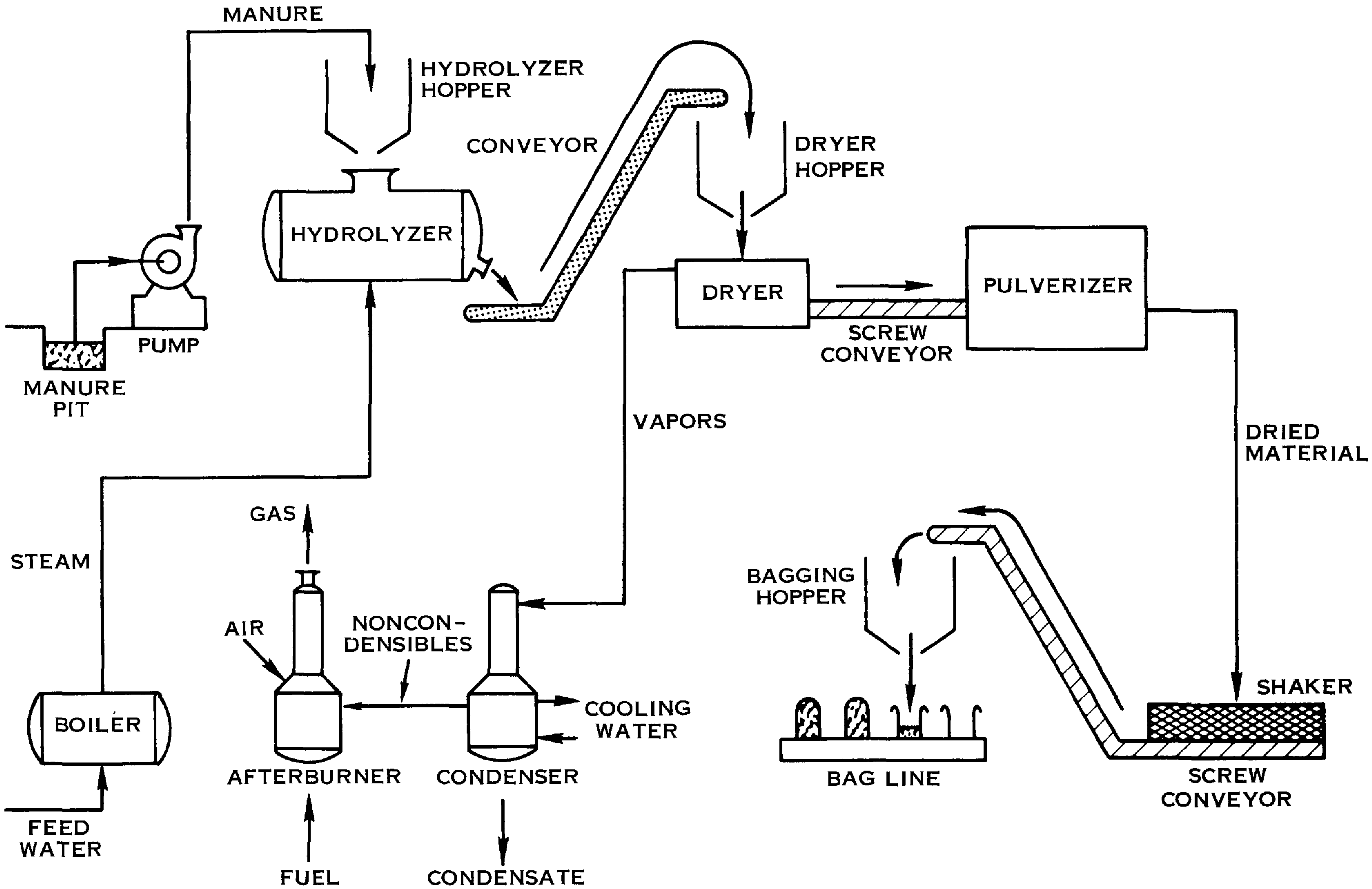


FIGURE 54. STEAM HYDROLYSIS

Hydrolysis and chemical treatment apply to preparation of manure for refeeding to livestock. The process may result in digestibility advantages over drying alone.

CHEMICAL EXTRACTION

Of the two major exponents of chemical extraction treatment of animal waste, one has been investigating processing of poultry manure for approximately 1-1/2 years. This process involves a separation step (proprietary) during which the uric acid, soluble proteins, etc., are removed as a liquid, leaving a material containing, primarily, the undigested food. These solids are then dried at a sufficiently high temperature for pasteurization or about 65°C (150°F) to sterilize the mixture. This material is then to be utilized in the poultry diet. An economic analysis of this experimental process has been performed, but the results are still proprietary. The other exponent feels that this process is neither "usable in practice with commercially avialable enzymes nor economically feasible". These chemical extraction processes are not now available for general use.

Technical Description

The raw material for this process is poultry manure which has been collected as soon as possible after deposition for processing on a 24-hour basis. As shown in Figure 55, separation (involving a proprietary process) is used to isolate the solid from the liquid fractions. According to the developer, the "true" excretory products produced by the chicken are removed with the liquid protion. The solid material remaining is primarily food that was not utilized by the chicken during its first ingestion. In addition, some feather protein, egg shell calcium and mucoid protein are included. Most of the heavy metals, antibiotics, soluble material salts, and small molecular material of all types will be in the liquid fraction. The solid material thus separated is then dried at approximately 65° (150°F) to sterilize the end product. It is this dried material that is to be incorporated into the poultry diet. An analysis of this material is as follows:

Nutrient	Content
Ash	31.4%
Carbohydrate	30.4%
Fiber	17.6%
Protein	11.7%
Fat	4.9%
H_2O	3.6%
Other	0.4%
Calories	2.84 cal/gm

Development Status

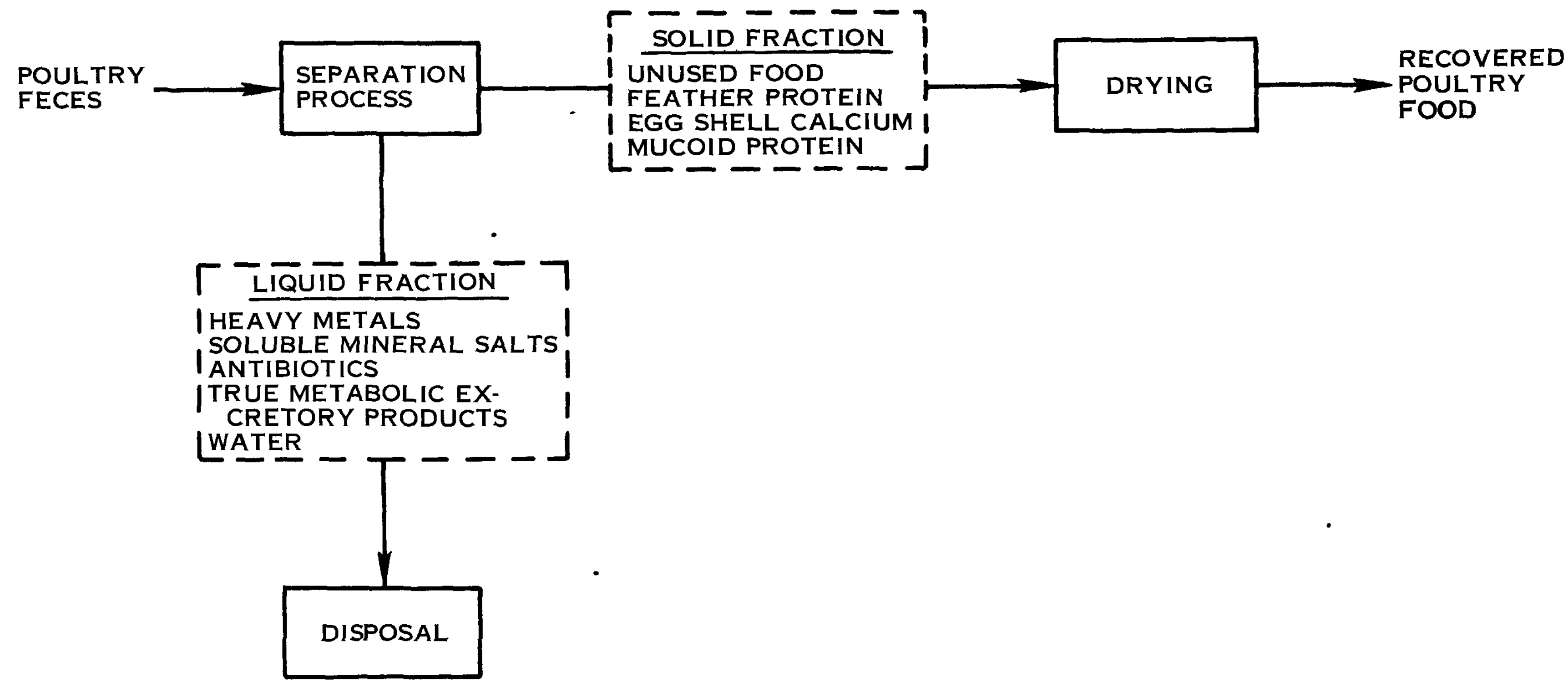


FIGURE 55. CHEMICAL EXTRACTION

Development of the proposed system has been underway at a relatively low level for approximately 1-1/2 years. The laboratory facility must be quite limited in size since they have been able to collect only enough material for a feeding trial utilizing rats. A recycling scheme feeding poultry their own manure after processing has not been attempted. During the rat feeding trials the diet was composed entirely of processed waste material. The only conclusion drawn from this trial was that the rats were able to extract some nutritive value from the material. However, at the 100% level, ration nutrient balancing problems were evident.

A limited number of amino acids analyses have been performed, resulting in data which indicates that while some of the amino acids are present in quantitites corresponding to a standard reference diet (leucine, isoleucine, lysine, histidine, valine, threonine, glycine, arginine), others were very deficient (methionine, cystine, tyrosine, phenylalanine). This material obviously could not be fed at exceptionally high levels without upsetting the ration balance. In fact, approximate feedback rates of only 20% are anticipated. Although chemical analysis indicates carbohydrate present, there is no information as to whether or not any or all of this is liquified. Additionally, it would appear to be very difficult to digest feather protein. Considering the high ash content (more than half of which comes from the egg shell calcium), dumping of the entire batch to prevent build-up on a regular basis is anticipated.

While the system may technically work on a small laboratory scale, a large amount of effort in the areas of chemical analyses of the product and extensive feeding trial results are needed before the process may be considered commercially applicable. Effort is still being expended in choosing the various methods for each of the processing steps involved.

Reliability and Applicability

While the drying operation probably utilizes standard commercially available equipment, the technique for the separation of the liquid and solid fractions is unknown. An estimate of total reliability is, therefore, not possible.

Use of this process is probably limited to animals fed a relatively low fiber roughage diet. Only in this way can the excrement contain nutrients worth reclaiming as opposed to material utilizable only for roughage.

BARRIERED LANDSCAPE WATER RENOVATION SYSTEM

The Barriered Landscape Water Renovation System, or BLWRS, is a modified soil plot for treating waste water. Effluent water may be recycled for flushing or allowed to dissipate. The approach permits waste disposal at rates significantly above the limits for spray irrigation of cropland. Cost is low, although economics are not well defined.

BLWRS is classified as experimental, although the concept is ready for a realistic field demonstration at a feedlot. Its potential lies in low power, decreased land use, and an effluent with very low pollution potential. It is applicable only to sprayable wastes and is limited by soil and climatic conditions.

Technical Description

Waste water sprayed on a mound of modified soil or sand is purified as it flows through aerobic and anaerobic zones of the mound. Figure 56 describes a typical BLWRS. There is no specific practical limitation on size. Waste water sprayed on the top of the mound percolated downward to the plastic sheet (barrier) and then flows laterally to the edges of the sheet. Effluent water may be collected for recycle back to the land or for manure flushing.

In the aerobic zone, organic materials are oxidized to water and carbon dioxide, organic nitrogen and ammonia are converted to nitrates, and phosphates are absorbed by the lime or the soil. In the anerobic zone, nitrates are denitrified to form nitrogen gas. When needed, energy may be injected into the anaerobic zone in some convenient form such as molasses. The BLWRS or each section of a large BLWRS must be rested periodically to allow drying. Waste water application rate is hydraulically limited to 1.0 to 2.0 centimeters (0.4 to 0.8 inches) per day, based on mound area. Typical data for an application rate of 2.1 centimeters (0.84 inches) per day is:

POLLUTANT	CONCENTRATION, MG/L	
	INLET	OUTLET
Organic N + NH_3	532	1.5
NO_3	7.0	1.01
NH_4	438	69
PO_4	11.2	0.02
BOD	1200	3.4
COD	2300	57

Development Status

The process is ready for experimental application to a large feedlot. Two BLWRS were installed in each of two applications: (1) flush water - manure mixture from 80 sows, collected for recycle; and (2) milking parlor holding pen flush water from a 200-300 cow dairy operation. At

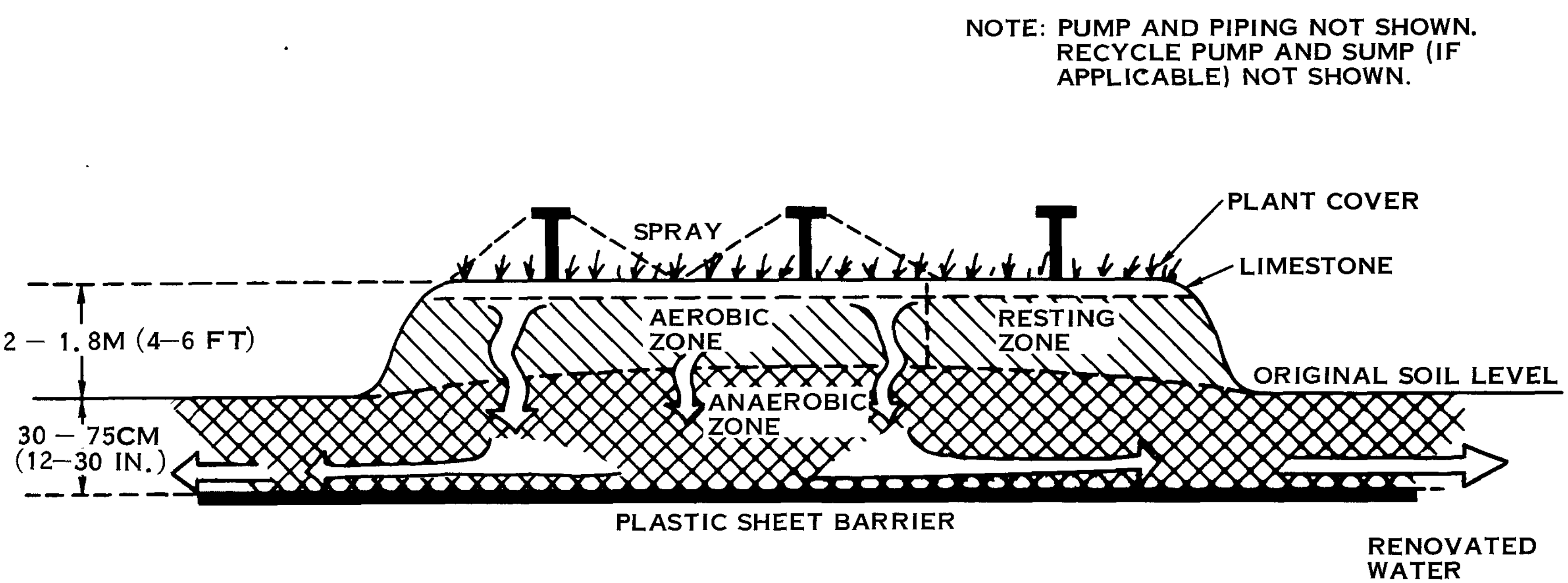


FIGURE 56. BARRIERED LANDSCAPE WATER RENOVATION SYSTEM

each installation, the two BLWRS are used alternately. In a larger installation, which is now planned, a single BLWRS would be operated, with parts of the mound being rested periodically.

Reliability and Applicability

Equipment is simple and conventional. Mechanical breakdown problems should be minimal. Coarse material may need to be sieved out to prevent clogging of the spray equipment.

Application is limited to wastes that are sprayable. Thus, the concept could be applied to flush water, storn runoff, or lagoon effluent. The soil must be permeable. Rainfall may use all of the hydraulic capacity (10 to 20 centimeters 4 to 8 inches) for any particular day of operation. Icing of the spray nozzle or freezing of the BLWRS surface prevents waste water disposal during freezing weather.

LAGOONS FOR WASTE TREATMENT

Lagoons are excavated ponds for biological treatment of waste water and/or manure. They are used extensively in most parts of the country. They work well when properly designed and used, but they do not provide total treatment. Lagoon water is usually used for cropland irrigation, but it is sometimes given further treatment (e.g. final clarification and/or chlorination) and discharged such as is encountered on duck farms. Sludge must generally be removed every few years. Ambient temperature influences design and function. Economics often favor anaerobic rather than aerobic lagoons, although odor control requires close attention.

Technical Description

Naturally aerated lagoons are called oxidation ponds. They are shallow, and sizing is based on surface area, since aerobic oxidation takes place only in the upper 45 centimeters (18 inches) of water. Mechanically aerated lagoons (aerated lagoons) are much deeper, and sizing is based on volume since oxygen (air) is dispersed throughout the lagoon volume by a compressed air diffuser or floating aerator. Anaerobic lagoons are also deep but contain essentially no dissolved oxygen. Detention or holding ponds and evaporation ponds are not for biological treatment of wastes, and they are therefore not discussed here. On the other hand, a lagoon is often needed primarily for its storage capacity but is still designed to assure maximum treatment before its contents are used on the cropland. This reduces odor during irrigation with lagoon water.

Lagoons are biological systems and contain microbial sludges. Oxidation ponds depend on warmth, light, and wind. These factors support a symbiotic relationship between saprophytic bacteria and algae. Thus, the bacteria utilize oxygen released by photosynthesis in the algae, and the algae utilize carbon dioxide and other substances released by bacterial metabolism of the organic waste. In aerated lagoons, the bacteria utilize oxygen dissolved in the water by action of the aerator. The anaerobic lagoon contains a balance of two main types of bacteria. The first type converts the waste to organic acids and related substances, while the second type converts these substances to methane and carbon dioxide gas. Intermediate substances are highly odorous.

In general, an anaerobic lagoon decreases BOD by 70% to 90%, reduces settleable solids in the supernatant by nearly 100%, removes 60% - 80% of total solids from the supernatant, does not affect pH, and increases nitrate nitrogen drastically. When an aerobic lagoon follows an anaerobic lagoon in series flow, the anaerobic lagoon may be assumed to remove 50% of the influent BOD, for purposes of designing the aerobic lagoon.

Development Status All types of lagoons are in common commercial use.

Reliability and Applicability

Serious upsets may occur in each type of lagoon. The oxidation pond may generate too much algae growth, upsetting the bacteria algae symbiotic balance. The aerated lagoon can quickly turn anaerobic and odorous if the aerator stops working. The anaerobic lagoon can turn sour (acid) and odorous if it is shock loaded with too much waste at one time or when it is dredged or disturbed in some other manner. Recovery from these upsets may take weeks. Oxidation ponds are economical where land prices are low and can be used in climates where evaporation is slow. Where land is more expensive, anaerobic lagoons, which do not use much land and require no power, may be the best choice. Aerated lagoons are useful where land is severly limited or where odors are a serious problem. Lagoons provide improved solids, dewatering, reduced solids volume, odor reduction of solids spread on cropland, and (for anaerobic lagoons) pretreatment ahead of aerobic lagoons.

Sizing

Aerobic lagoons or oxidation ponds are generally sized based on allowable loadings expressed as kilograms (pounds) of BOD per day per hectare (per acre) of surface area. Detention time is also used as a supplemental criterion. Loadings as high as 110 kg BOD/day/hectare (100 lb. BOD/day/acre) are given for Southern Florida, but recommendations for more northern areas generally run from 9 (20) in colder areas to 23 (50) in milder areas. Recommended detention times run from 25 days in Southern Florida to 120 days for cold areas. Loadings are also translated into terms of specific animals. For example, based on loading with raw manure:

Poultry	0.92 meter square/kg of animal (4.5 foot square/pound of animal)
Swine	0.51 meter square/kg of animal (2.5 foot square/pound of animal)
Dairy	0.31 meter square/kg of animal 1.5 foot square/pound of animal)
Beef	0.31 meter square/kg of animal (1.5 foot square/pound of animal)

For mechanically aerated lagoons, allowable loadings are based on lagoon volume, because oxygen is dispersed throughout. One guideline recommends 1700 liter/kg (60 cubic foot/pound) BOD/day. Another states that volume should be 50 times the "daily manure production", with a 2 - 3 year detention. The following guideline for mechanically aerated lagoons is expressed in terms of specific animals and may be compared with the values given earlier for oxidation ponds, allowing a depth of 0.9 to 1.2 meters (3 - 4 feet) for oxidation ponds:

Poultry	47 liters/kg of animal (0.75 cubic foot/pound of animal)
Swine	62 liters/kg of animal (1.00 cubic foot/pound of animal)
Dairy	78 liters/kg of animal (1.25 cubic foot/pound of animal)
Beef	47 liters/kg of animal (0.75 cubic foot/pound of animal)

Another reference suggests that the volume of the lagoon be double that of all the waste it will receive during the five cold months of the year, assuming the lagoon is half full at the beginning of that period.

Anaerobic lagoon loadings are generally based on volatile solids, although one reference suggests 1.6 to 8.2 kg BOD/day/100 cubic meter (10 to 50 lb. BOD/day/1000 cubic foot), where the volume does not include that occupied by sludge (e.g., 0.34 cubic meter/ year/hog) (12 cubic foot/year/hog). Based on volatile solids, references generally give a loading range of 16 to 160 or 240 grams vs/day/cubic meter (0.001 to 0.01 or 0.015 lb. vs/day/cubic foot). Some specific values are 65 (0.004) for Texas, 80 (0.005) for the moderate Midwest, and 115 grams vs/day/cubic meter (0.007 lb. vs/day/cubic foot) for Southern Florida with a 15 day minimum detention time. The State of Missouri guideline is 120 grams vs/day/cubic meter (0.0075 lb. vs/day/cubic foot), with a temperature adjustment factor. Guidelines are also expressed in terms of specific animals, with a 1.5 multiplier for sever winter, and 0.75 multiplier for mild winter:

Swine	78 liters/kg of animal (1.25 cubic foot/lb of animal)
Steer	93 liters/kg of animal (1.50 cubic foot/lb of animal)
Hen	125 liters/kg of animal (2.0 cubic foot/lb of animal)

EVAPORATION

Evaporation is an alternative to disposing of liquid runoff wastes by land irrigation. Under proper climate conditions, evaporation can significantly reduce the total quantity of waste material and thereby help to minimize the waste disposal problem. However, solids must be periodically removed and disposed of. For proper operation, this process is limited to those geographical regions where the annual evaporation rates exceed annual precipitation by a reasonable margin. To be effective, large areas of land are required since evaporation rates are a function of exposed surface area as well as low relative humidity, ambient temperature, air movement and solar energy.

Evaporative pond design must also consider the quality of waste effluent being discharged. The accumulation of debris or scum on the evaporative surface will significantly hinder the process, even under the best of climatic conditions.

Costs associated with the pond evaporation treatment process will vary widely depending upon many factors, including climatological influence, waste characteristics of the effluent, land values, and geographical features.

Although this natural phenomenon occurs in all geographical regions at some period during the year, in those areas where evaporation is most effective, the water usually represents a valuable resource for the irrigation of cropland and is so used. As a result, the applicability of evaporation as a viable concept for reducing the total quantity of waste handling is probably limited to the more arrid regions not suitable for raising crops.

TRICKLING FILTER

The trickling filter is a compact, effective means of treating waste water that may be applied to effluent water from a settling basin. Effluent water may be used for flushing or direct discharge to a natural waterway. Although large scale application to treating municipal sewage is common, use in treating feedlot wastes has been limited to the laboratory. The process is, therefore, regarded as experimental.

Technical Description

The trickling filter provides an extended active surface for biological stabilization of waste water within a small land area and volume. The trickling filter is basically a pile of stones, but other materials and configurations are often used. Plastic media have been used in municipal treatment plants. Stones, Douglas fir bark, and a fiberglass ramp or inclined plane have been applied to animal waste. Operation is either batch with repeated recycle or continuous with recycle. Figure 57 represents a unit sized for one dairy cow. Settleable solids must be removed in the primary sedimentation tank to prevent clogging of the trickling filter. A bacterial scum continuously builds up on and sloughs off the stones. Water is aerobically purified as it flows over the surface of the stones. The final sedimentation tank separates sloughed slime. The accumulated slime is nearly free of odor and is suitable for spreading on cropland.

Trickling filter effectiveness is variable, depending on such factors as contact time and recycle rate or duration. The following representative data, however, indicate capability:

Type of Trickling Filter	Influent BOD mg/lit	Effluent BOD mg/lit	Removal Efficiency (%)
Stones	1600	100	94
Bark	300	30	90
Inclined Plane	--	--	52.4*

*Single pass efficiency

Only partial system mass balance information is available. For example, the following values are based on data from Reference 233. The trickling filter represented by the data contained a 0.9 meter (3 foot) depth of 3.8 centimeter (1-1/2 inch) bark with 0.03 square meters (0.35 square foot) superficial area, and the recycle rate within the system (through the filter) was 12.0 kg (26.4 lb.) minimum.

Waste Component	Daily Balance - Kilograms (Pounds) Input	Output
Total (daily batch)	378 (833)	378 (833*)
Total Solids	0.27 (0.60)	0.08 (0.18)
Nitrogen	0.034 ((0.075)	0.0036 (0.008
BOD	0.11 (0.25)	0.014 (0.03)

*Assumed

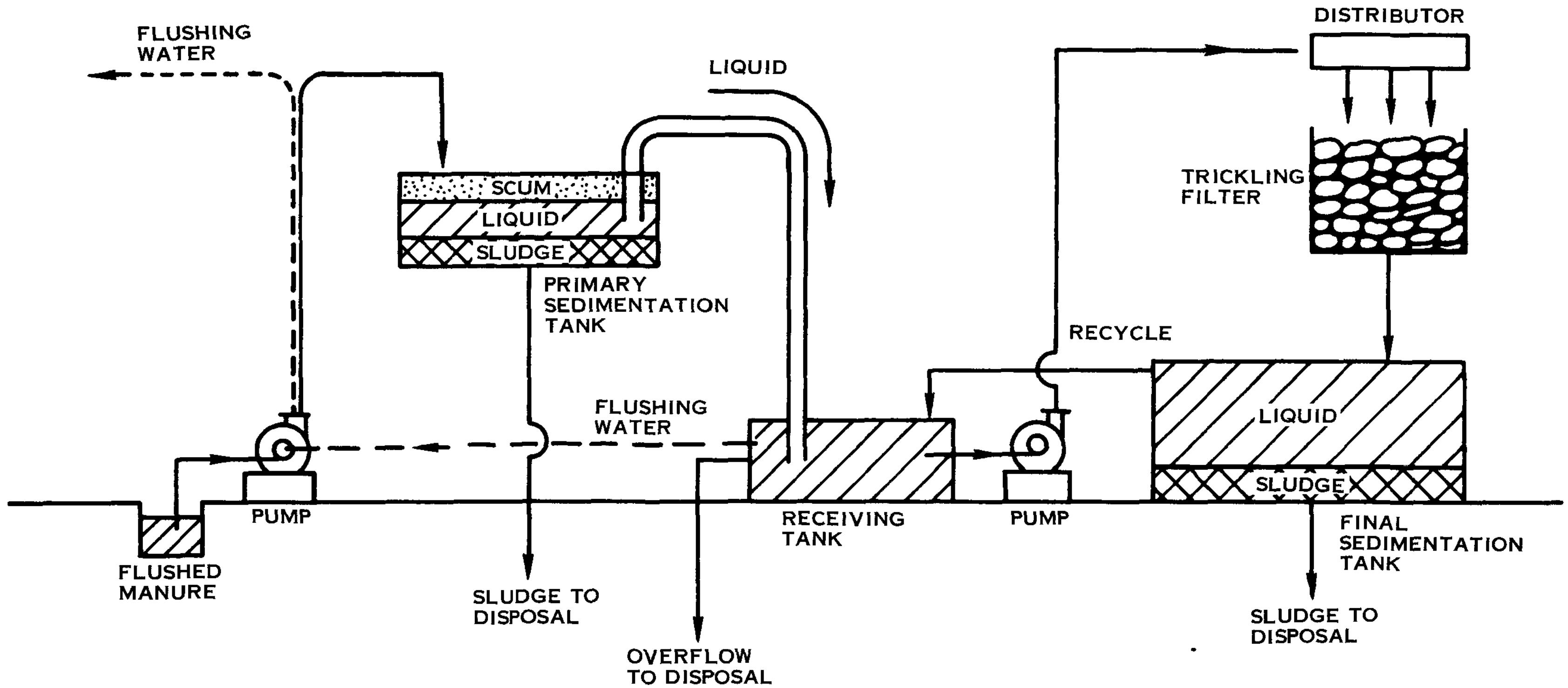


FIGURE 57. TRICKLING FILTER

Development Status Use of trickling filters for treating animal waste water is limited to the laboratory. Work on the unit using stones was discontinued several years ago. The other two units are active, but there are no definite plans for larger scale demonstrations. The capacity of the systems operated thus far is indicated in the following table:

Trickling Filter Type	Source of Waste Water	Characteristic Dimensions	System Influent Rate l/day (gal/day)
Stones	One dairy cow (diluted)	0.6 meter (2 ft. diam.) 1.2 meter (4 ft deep)	231 (61)
Bark	Poultry (diluted and decanted)	20 cm (8 in diam) 0.9 meter (3 ft deep)	378 (100)
Inclined Plane	Swine Waste Lagoon	0.3 meter (1 ft wide) 2.4 meter (8 ft long)	87 (23)

Reliability and Applicability

Equipment is simple and basically conventional. Mechanical breakdown problems should be minimal.

Trickling filters provide waste water treatment using small land area. The influent must be free of settleable solids. Effluent water may be recycled for flushing and probably can be suitable for discharge to natural waterways after sufficient recycling. In cold climates, the unit must be housed to prevent water temperatures below 7°C (45°F).

SPRAY RUNOFF

Spray runoff is an experimental technology. Waste water is sprayed on a grass covered slope, and effluent water is collected at the bottom. The grass and surface soil particles are covered with films of aerobic and anaerobic microorganisms, which act on the pollutants in the water. The process has been applied to at least three large feedlots, but it is in an early stage of development. Its potential lies in low power and decreased land use. Present application is limited to storm runoff.

Technical Description

Figure 58 describes a typical spray runoff system. Running downward from the top of the slope, typical distances are as follows:

Top to first nozzle row	18 - 21 meters (60 - 70 feet)
Nozzle row to terrace	46 - 76 meters (150 - 250 feet)
Terrace to next nozzle row	18 - 21 meters (60 - 70 feet)

Running across the slope, typical distances are:

Between nozzles	9 meters (30 feet)
Side to Side	22 meters (400 feet)

Grading data are as follows:

Slope grade	1-6 percent
Terrace grade	0.2-1.0 percent

The grass must be moisture and salt tolerant. Selected varieties include Native Bermuda, Reed Canary, Tall Fescue, and K31 Fescue. The spray pattern from each nozzle forms a 30 meter (100 foot) diameter circle. Waste water is sprayed on the grass covered slope and is renovated as it runs down the slope. The water is collected at the bottom (or at intervals) by means of a terrace (lateral channel). Recycling is probably necessary to further purify the water before release to a natural waterway, but a recycling technique has not yet been worked out. A mass of microorganisms (mainly aerobic) builds up on the grass and on surface particles of the soil. These microorganisms adsorb organic components of the runoff and convert them to carbon dioxide and water. Similarly, organic nitrogen is converted to ammonia and then to nitrates. It has been hypothesized that the nitrates are either assimilated by the grass or converted to nitrogen and nitrous oxide by anaerobic bacteria. Phosphates are either assimilated by the grass or adsorbed on soil particles.

Application rate is hydraulically limited to 0.15 to 0.5 centimeters (0.06 to 0.20 inches) per hour for eight hours, three or four times per week. Recommended spray rate is 19 liters per minute (5 gallons per minute) per nozzle. As the sprayed water runs down the slope, 65% to 75% is lost, mainly by evaporation. Typical parameters are:

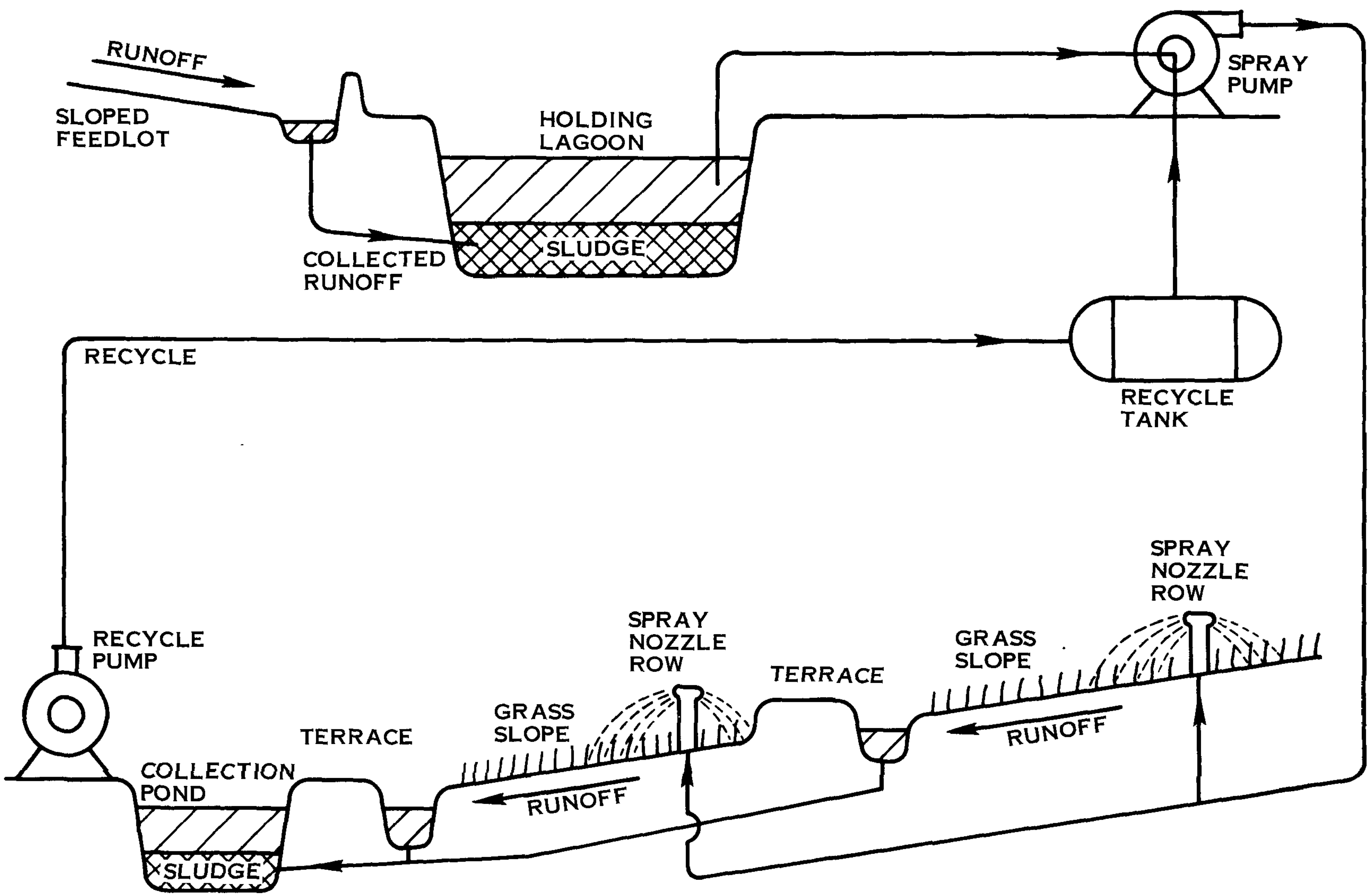


FIGURE 58. SPRAY RUNOFF

Pollutant	Influent Concentration (ppm)	Removal Efficiency (%)
Suspended Solids	195	94
COD	430	71
BOD	63-350	50-80
Phosphate	13.5	0-96
Total nitrogen	28-250	40-81
Ammonia nitrogen	100-125	45-50

Where a range is shown in the preceding tabulation, two different data sources are represented and the lower concentration is associated with the higher removal efficiency.

Two Kansas installations have operated less than one season, as of March 1973. Effluent water has not been found satisfactory for direct release to natural waterways. An effective recycling technique has yet to be worked out. An installation in Texas ran for six months, but the feedlot is no longer operating. Data on this operation are limited and unconfirmed.

Reliability and Applicability

Equipment is simple and conventional. Mechanical breakdown problems should be minimal.

Applicability is limited to wastes that are sprayable. Spray runoff has been considered only in terms of storm runoff, but it could also be applied to flush water or lagoon effluent. Freezing weather prevents use. It is applicable to limited cropland situations, where spray irrigation is not practical.

ROTATING BIOLOGICAL CONTACTOR

The Rotating Biological Contactor or RBC achieves a very high density of biologically active surface per unit volume. It is potentially valuable only where land availability is severely limited. Purchase price is uncertain but relatively high. Work on this experimental approach has been discontinued.

Technical Description

The RBC consists of a row of 104 closely spaced, 3 meter (10 foot) diameter, polystyrene discs. The discs rotate on a horizontal shaft and dip into a waste water bath. An aerobic bacterial film on the discs removes and decomposes organic materials from the waste water. In work carried out at a university facility, success of the RBC in treating swine wastes was limited. There were indications that increasing the waste water residence time (1.2 to 2.5 hours was used) might result in improved performance. In actual use, formation of calcium carbonate deposits resulted in degraded operation and mechanical breakdown.

WATER HYACINTHS

Water hyacinths, when placed in a series of four lagoons located downstream of an anaerobic lagoon, provided partial treatment of the effluent from the anaerobic lagoon. The plants require relatively dilute supernatant concentrations (less than 1000 ppm COD) to provide proper growth cycles. The effluent from the last hyacinth lagoon showed significant reductions in COD, phosphate, and nitrogen content. The plant also has a high rate of evapotranspiration, with water loss from the leaves reported to be over three times that of the free water surface. Extrapolating the harvest data reveals a dry matter production rate of approximately eleven metric tons per hectare (five tons per acre). A major deterrent to the profitable use of water hyacinths is the high water content of the plant. Once harvested, this leads to rapid spoilage and causes handling problems. The average dry matter content of water hyacinths is 5.9%.

The economic feasibility and attractiveness of this system will require that uses for the harvested plants be devised. Limited use has been made of the plants as livestock roughage, although data is insufficient to establish this as an economic practice and palatability is questionable. Work on this concept was at the laboratory level and is no longer being pursued. Hence, it is classified as experimental. Potential application is to warm climates.

Technical Description

A series of lagoons is prepared such that the flow of effluent from an anaerobic lagoon to the prepared lagoons can be controlled. Water hyacinths are placed in this series of lagoons. These plants multiply rapidly, growing on the nutrients contained in the effluent from the anaerobic lagoon, which is periodically allowed to replenish the level of supernatant in the initial water hyacinth lagoon. Effluent from the downstream lagoon, with its lowest level of organic matter, is disposed of either by application to cropland, where less land is required per unit volume discharged, or possible to receiving streams if organic matter and nutrients are sufficiently lowered. Sequentially, the more concentrated supernatant from the lagoon immediately upstream is pumped or allowed to flow, replenishing the level of the downstream lagoons until the initial water hyacinths lagoon is replensished from the anaerobic lagoon.

A portion of the water hyacinths from each lagoon is harvested periodically. These plants may be used for livestock roughage, although data is lacking to establish the feasibility of this practice. Thse plants also exhibit a high rate of evapotranspiration so that over three times the quantity of water evaporated from a free water surface is released by the water hyacinths.

Development Status

The water hyacinths process is in the early stages of laboratory developemnt. The process is not presently being pursued as viable waste treatment concept.

Reliability and Applicability

No mechanical equipment is involved.

Evidence from the reported experiment shows that dilute effluent concentrations from the anaerobic lagoon are required, or stunted growth will take place. Also, climatic conditions will limit the growing season, thus limiting utilization of this process to that period.

ALGAE

Growing algae in the supernatant from a hydraulically flushed animal confinement facility is presently under development on an experimental basis by a major university. The concept utilizes photosynthetic reclamation of the animal wastes in the form of algae production as a method of waste disposal. In theory, the water loop is closed; however, some water is lost in practice and makeup water is required.

Settled solids from the hydraulic flush are discharged to an anaerobic digester with digester supernatant also pumped to the algae growing pond. The stabilized sludge, reduced from 40% to 50% on a total solids basis, requires subsequent disposal when removed from the anaerobic digester.

Effluent from the algae growing pond is pumped either to the animal facility for gutter flushing or, depending on algae concentration, processed so the algae are removed. The harvested algae in either the dried state or as dewatered paste can be used as a protein supplement in the diet of chickens, ruminants, or swine. The product could be used as a high grade fertilizer.

Since the photosynthetic reclamation system is in the earlier stages of development and not practiced on a large scale basis, cost data has not been developed. However, the proponents of this system have estimated that in a large scale operation, dried sewage grown algae could be produced for about $0.09 per kilogram ($0.04 per pound).

An obvious limitation of the photosynthetic process is the quality of the environment in which the system is operated. Abundant sunlight and mild temperatures are necessary ingredients conducive to the goowing of algae.

Technical Description

Algae is an artificial grouping of plants consisting of seven remotely related phyla of Thallophyla which have attained about the same level of rudimentary development and which possess chlorophyll, carry on photosynthesis, and are therefore independent (able to make their own food). The system described here is being developed at a university research laboratory. The concept is designed to develop a partially closed system based on integration of an anaerobic and aerobic phase, recycling of water and reclamation of a usable product. The pilot plant includes a poultry enclosure, a hydraulic system for handling the wastes, a heated anaerobic digester with ancillary equipment, and an algae production pond. Figure 59 shows the flow pattern for this concept.

The animals' wastes are flushed to a holding tank in which settleable solids are separated from the liquid phase. The supernatant is pumped directly to an algae pond and the settled solids are dischareged to an anaerobic digester. Digester supernatant is pumped directly to the algae pond, and the settleable stabilized sludge (dewatered) is removed for disposal. Depending upon the algae concentration, pond effluent either is recycled directly to the animal quarters for flushing the wastes or can be processed so that the algae are removed. A portion of the supernatant from the separation process is pumped to animal quarters for waste flushing. The algae are dried for use as a foodstuff.

Two inputs to the system are of significane: The chicken manure and tap water overflow from the drinking troughs. Outputs are harvested algae, settled solids from the sedimentation tank, grit, digester gas and sump output. Data were compiled on the input, output, and system changes with respect to total solids, volatile solids, unoxidized nitrogen, and energy (not including solar energy). An analysis of the data in terms of the system as a whole reveals that biological activity in the sedimentation tank, digester, and pond decreased the TS by 60%; the VS by 62%; the total unoxidized nitrogen by 45%; and the energy by 56%. Algae yield was extrapolated to be about 45 metric tons of algae (dry weight per hectare (20 tons of algae (dry weight) per acre) of pond surface per year on a year-round basis.

Development Status

Although algae have long been recognized for their biological oxidation effects, the investigation of their potential use on farm animal wastes

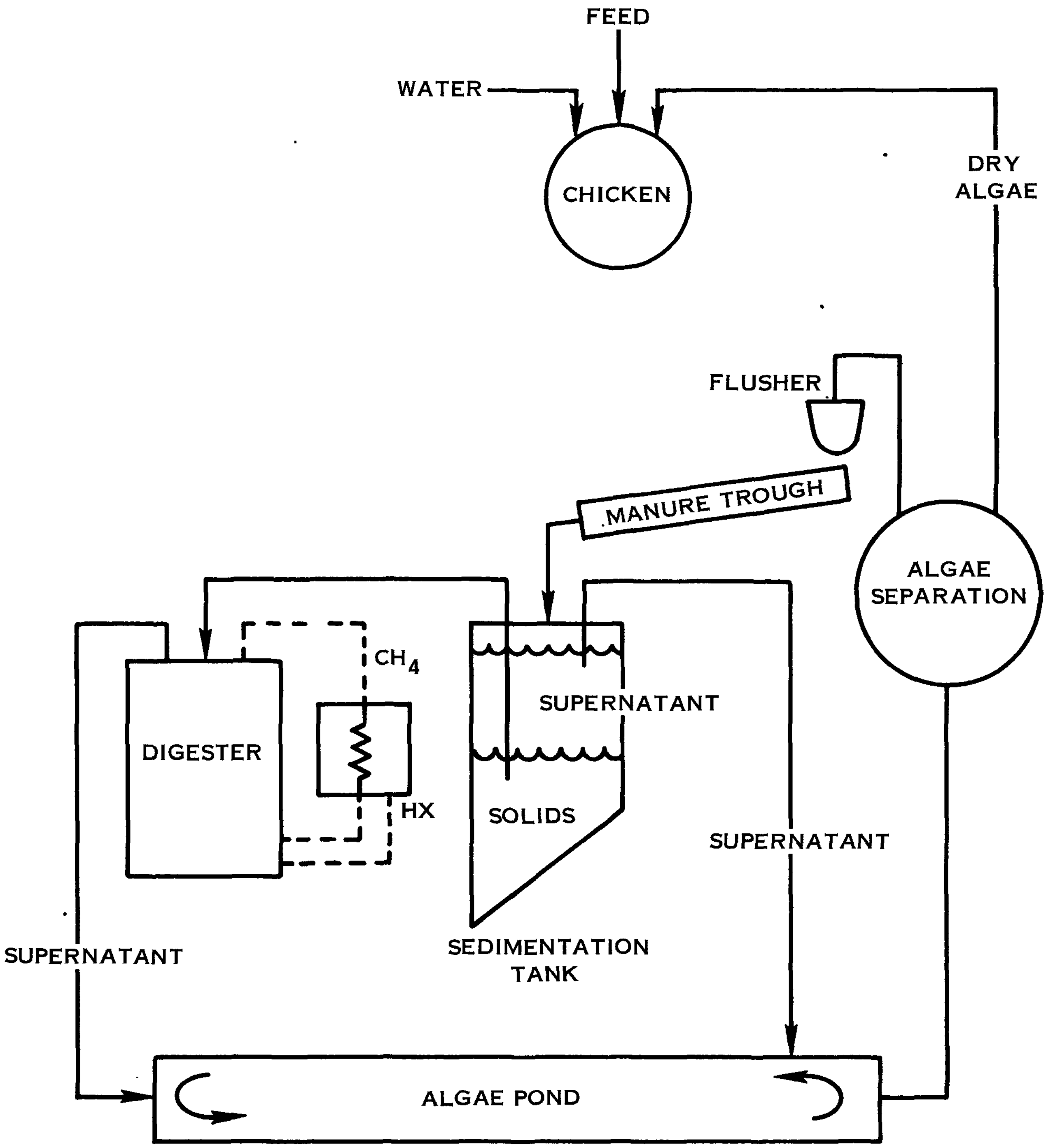


FIGURE 59. ALGAE

is limited to the past few years. Continued development of the system is still required before it can be prudently tried on a large scale. Major technology gaps pertain to the following areas: (1) the length of time in which the system can be operated as a closed system, i.e., without excessive build-up of salts, of toxic (to microorganisms) materials, of sludge, and of pathogens; (2) the extent of concentration of toxic substances (pesticides, trace metals, etc.) by the algae when the algae are harvested; and (3) the regional limitations becuase of climatological factors.

Reliability and Applicability

Reliability is probably lower than average due to the systems reliance on weather factors for proper, economical operation. A supplemental aeration system is needed for the algae growing pond during periods of inclement weather.

Applicability is limited to geographical regions where abundant sunlight and warmer ambient temperatures are prevalent.

SECTION VIII

COST, ENERGY, AND NON-WATER QUALITY ASPECT

GENERAL

Cost is somewhat related to both energy and non-water quality aspect, and these topics are discussed under two major headings. All of the information in this section relates directly to the technologies discussed in Section VII, Control and Treatment Technology. Consequently, an examination of Section VII is essential for proper interpretation of much of the material in this section.

COST

Investment and operating costs are classified according to the technology with which they are associated. Assuming sufficient information is available for each technology, these costs may be combined (as discussed in Section VII with regard to Table 39) to estimate the costs of various techniques for managing the wastes from any of the feedlot categories.

In general, any feedlot category can be managed by a technology combination consisting of runoff control, a complete or partial treatment technology, and land utilization. For example, the category "cow yard with milking center" could be managed by runoff control (diversion ditches and lagoon), activated sludge (partial treatment), and land utilization (spray irrigation of lagoon water and spreading of sludge on crops). Of course, land utilization alone may serve as the complete treatment. On the other hand, both land utilization and runoff control may be unnecessary for a category using total confinement and a complete treatment such as dehydration for sale.

Utility of the cost data is limited by two major factors. In the case of BPCTCA (see Table 39) technologies, these methods are widely practiced, and cost data is plentiful. However, there is a great deal of data scatter caused by differences in climate, soil, state guidelines, implementation philosophy, and other factors. The cost impact of pollution abatement is difficult if not impossible to separate from the feedlot cost structure. This is due in part to the fact that those owners which do document their costs may be producing more than one animal, or are engaged in other businesses, agricultural or otherwise. With the experimental technologies, there is poor cost definition due to the relatively undeveloped state of the technology. As these technologies become better developed, costs are better defined but are often proprietary and therefore unavailable.

For BPCTCA technologies, the cost data to follow were primarily collected first-hand during the study. They are, however, supplemented by data or correlations from the literature for comparison or were obtained by contacting the process developer whenever the data were not available in the literature.

Land Utilization

The cost of land utilization of feedlot wastes is a complex subject. Unlike a specific chemical or biological process for use with a particular type of animal wastes, land utilization is applicable, in some degree to all types of animal wastes, crops, soils and climates. All of these factors can vary greatly, with a corresponding variation in the methods and costs of land spreading. Although waste spreading systems can be characterized as either liquid or solid handling systems, both categories have innumerable variations depending on available equipment, farm and crop management schemes and personal preference. For all these reasons, it is virtually impossible to present economic data which have a broad applicability. However, to put the subject in perspective, the following discussion will indicate the major cost considerations and present some actual fertilization cost data for specific situations. Economic data for disposal rate (as opposed to fertilization rate, which is lower) applications are not presented because they would be misleading in that the disposal scheme is only in the early experimental stages of developement.

Value of Animal Waste as a Fertilizer - The major factors affecting the value of animal wastes as a fertilizer are:

a. Value and quantity of nutrients in the wastes
b. Availability of nutrients to crops
c. Fringe benefits of animal waste utilization.

The value of fertilizer nutrients are generally based upon the increased value of the crop produced from fertilized land. This determination is difficult to generalize about or even estimate for specific situations. This is because of:

a. The condition of manure in terms of nutrient content and balance as applied is highly variable.

b. The type of soil, the method and time of application as well as the climate directly affect how much of these nutrients will be aviailable to crops.

c. The type of crop and requirements for specific nutrients and ratios of nutrients directly affects actual utilization of fertilizers by the crop.

d. Each crop has a different value and therefore will show a different return on the basis of nutrients used.

Animal wastes, unlike inorganic fertiizers, do not release all of their nitrogen to crops immediately. This is because much of the nitrogen in animal wastes is in an organic form and must first be reduced to ammonia before it is converted to nitrate for crop uptake. Inorganic fertilizers are applied in the form of nitrates or ammonia thus making them available to the crop immediately.

It is generally concended that only half of the nitrogen in animal waste is released in the year of application with only half of the remainder being released in the next year. This again complicates determining the nutrient value of the wastes.

The most common fringe benefits of animal waste utilization on land are increased tilth, increased water retention, and decreased runoff nutrient losses. Each of these is difficult to evaluate without data for each specific instance.

Cost of Hauling and Application - The general scope of the information to follow is for transferring the waste from the collection point to cropland. The collection point may be a stockpile, a deep pit, a lagoon, or some functionally similar facility. The data are classified as:

- Solid manure
- Liquid manure
- Irrigation

The data are presented in both tabular and graphical form and also in the form of examples. They are generalized to represent any animal category whereever possible. The data collected first hand for this report are supplemented with data from the literature for comparison. The correlations must be regarded as representing typical rather than average data, because individual points show wide variation depending on local economics, state guidelines, type of soil (sand, clay, rocky, wet, etc.), moisture content of waste, crop management approach, climate, and other factors. In addition, the particular operation may be barely adequate or overdesigned.

Solid Manure - Figure 60 represents investment in equipment for loading, hauling and spreading. Often, the same equipment is also used for pen cleaning. Most of the data derives from beef cattle feedlots. In reducing these data, a partly biodegraded, semi-dry waste rate of eight pounds per animal per day was assumed. The correlation is based on work by Butchbaker extended by data collected for this report.

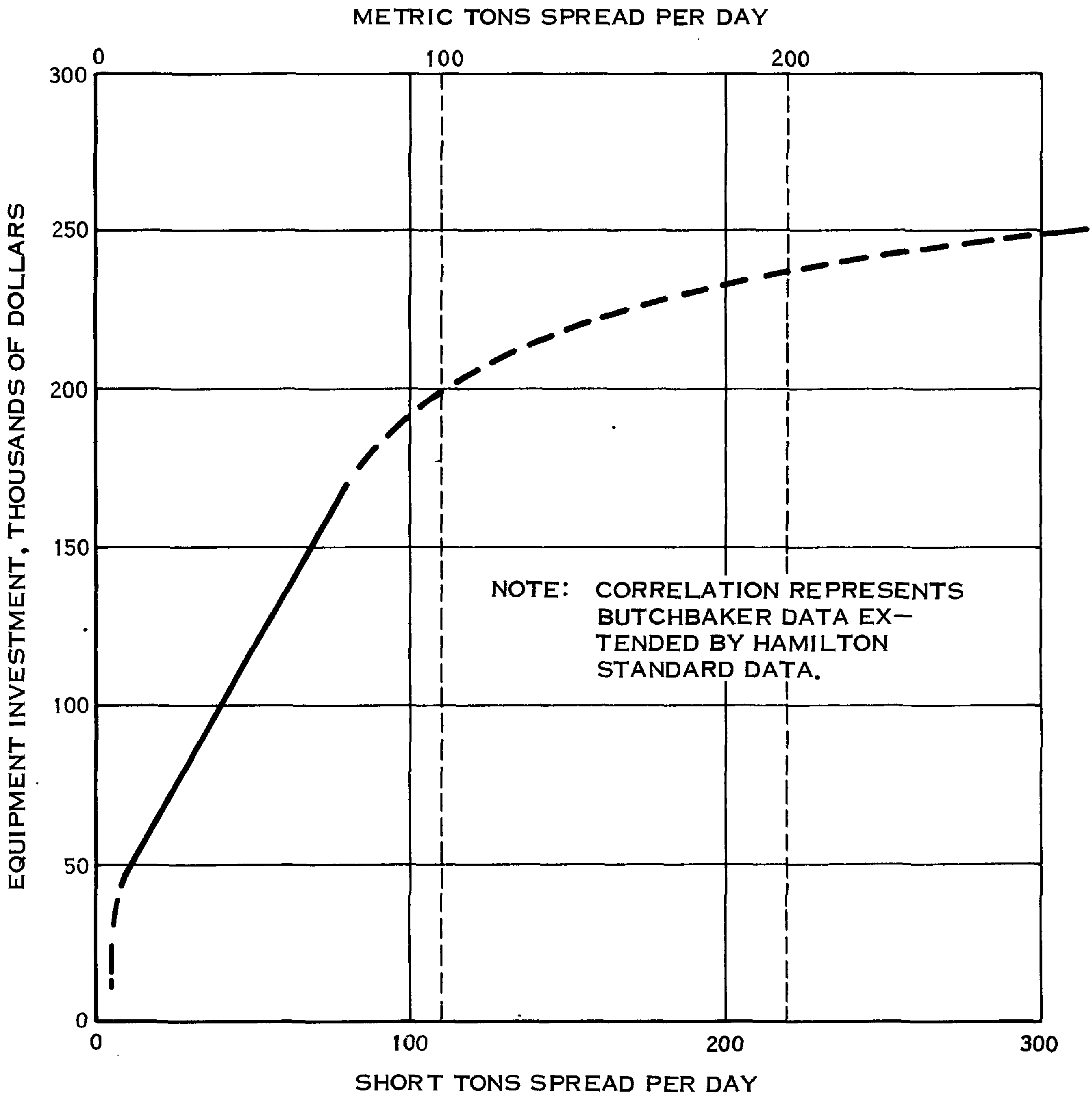


FIGURE 60. LAND UTILIZATION INVESTMENT COST — SOLID MANURE

The following equipment investment cost ranges for individual pieces of equipment were noted:

Loader:	\$5000 (100,000 turkeys) to \$38,000 (27,000 beef cattle)
Truck:	\$3000 to \$7300
Spreader:	\$2000

Figure 61 shows ranges of typical operating costs exclusive of pen cleaning and stockpiling (which are considered part of the animal husbandry function rather than waste management). All of the costs include loading. They may be paid either by the feedlot owner himself, or by a neighboring farmer to the feedlot owner or to a contractor.

A surcharge of 2.8 cents per kilometer (5 cents per mile) is sometimes added for contract hauling beyond some minimum distance such as nine kilometers (five miles).

Liquid Manure - Investment costs for managing liquid manure are shown in Figure 62. These costs include pump, container, and locomotion but do not include the cost of the manure pit or other waste storage container. The pump may be an ordinary manure pump or chopper pump. The container may be a tank spreader, tank truck, or vacuum wagon. Locomotion may be self-propulsion or supplied by a tractor. Individual equipment costs collected for this report are as follows:

Manure pump:	\$1450 - \$1600
Chopper pump:	\$1800 - \$2000
Tank Spreader:	\$1000 - \$3200, 11,355 liters (3000 gal.)
Self-propelled spreader:	14,000, 5.44 metric ton (6 ton, all weather)
Vacuum wagon:	\$1500 - \$3000, 7,949 liters (2100 gal.)
Tractor:	\$2000 - \$12,000

Operating costs associated with spreading liquid manure from beef cattle are shown in Figure 63.

Irrigation - Runoff water collected in holding ponds or lagoons is often used for crop irrigation. Investment costs for three types of irrigation systems are shown in Figure 64 based on the literature. In addition, the following data, collected for this report, may be useful:

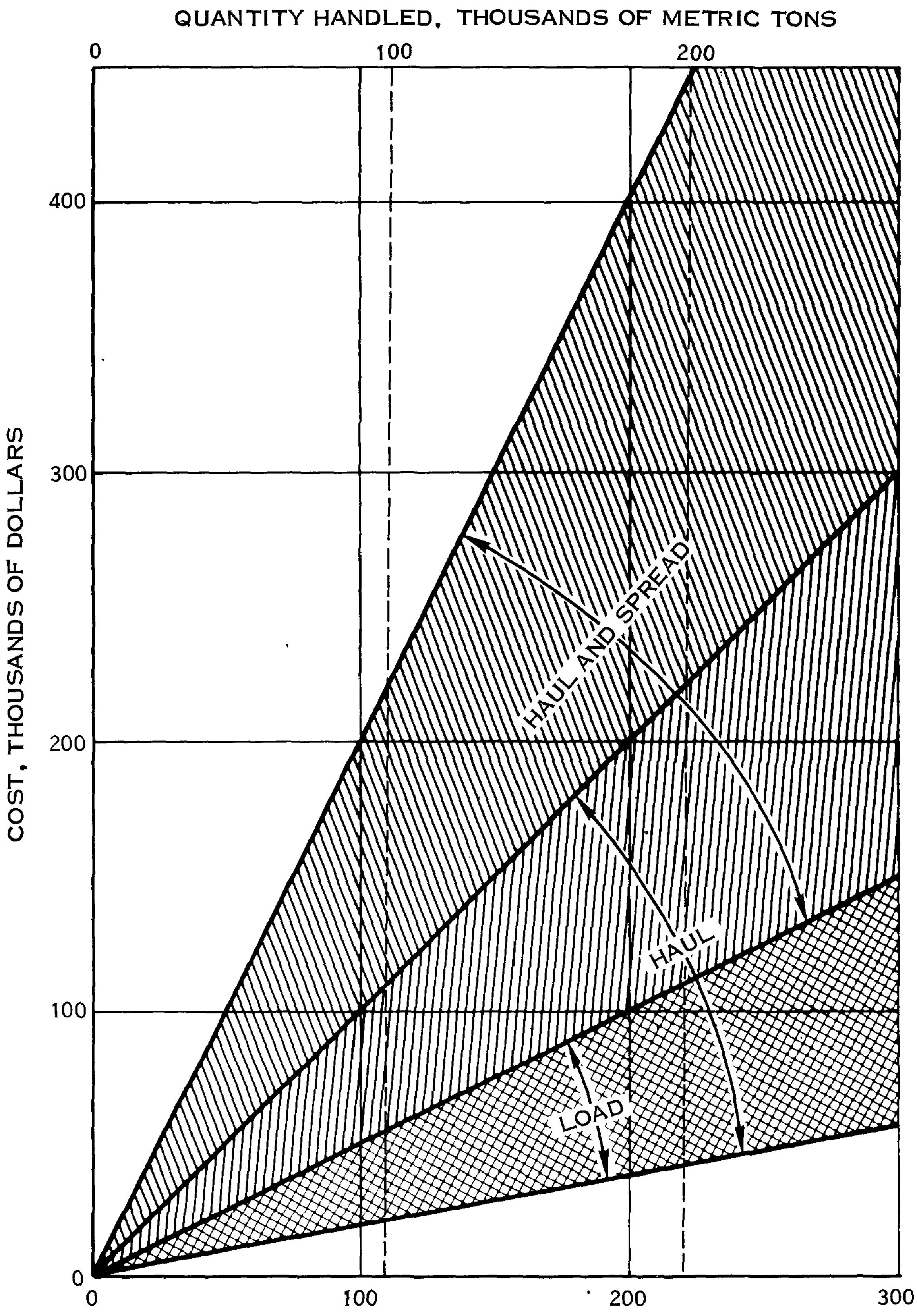


FIGURE 61. LAND UTILIZATION OPERATING COSTS—SOLID MANURE

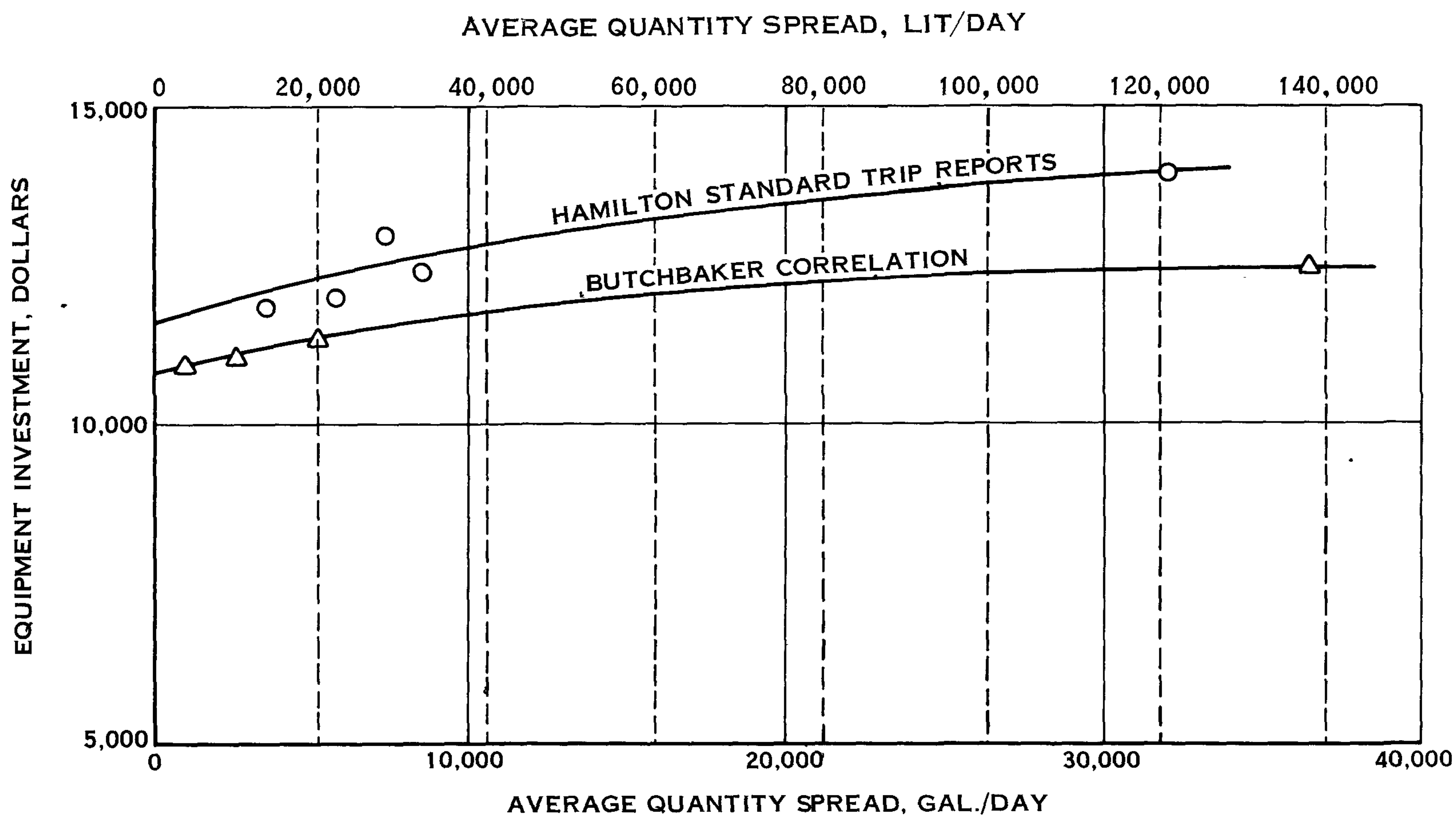


FIGURE 62. LIQUID MANURE MANAGEMENT — INVESTMENT COST (INCLUDES PUMP, CONTAINER, LOCOMOTION)

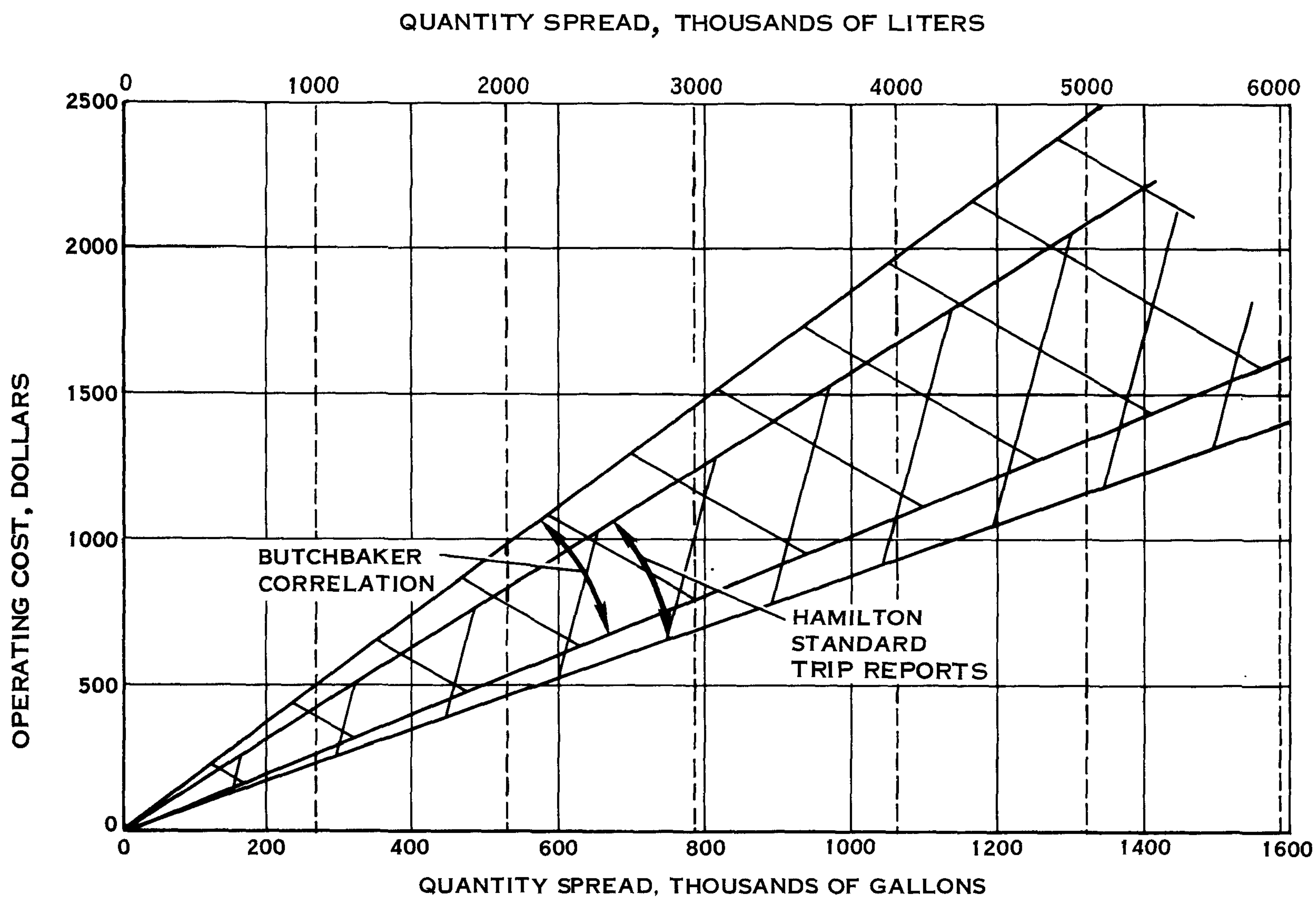


FIGURE 63. LIQUID MANURE MANAGEMENT - OPERATING COST

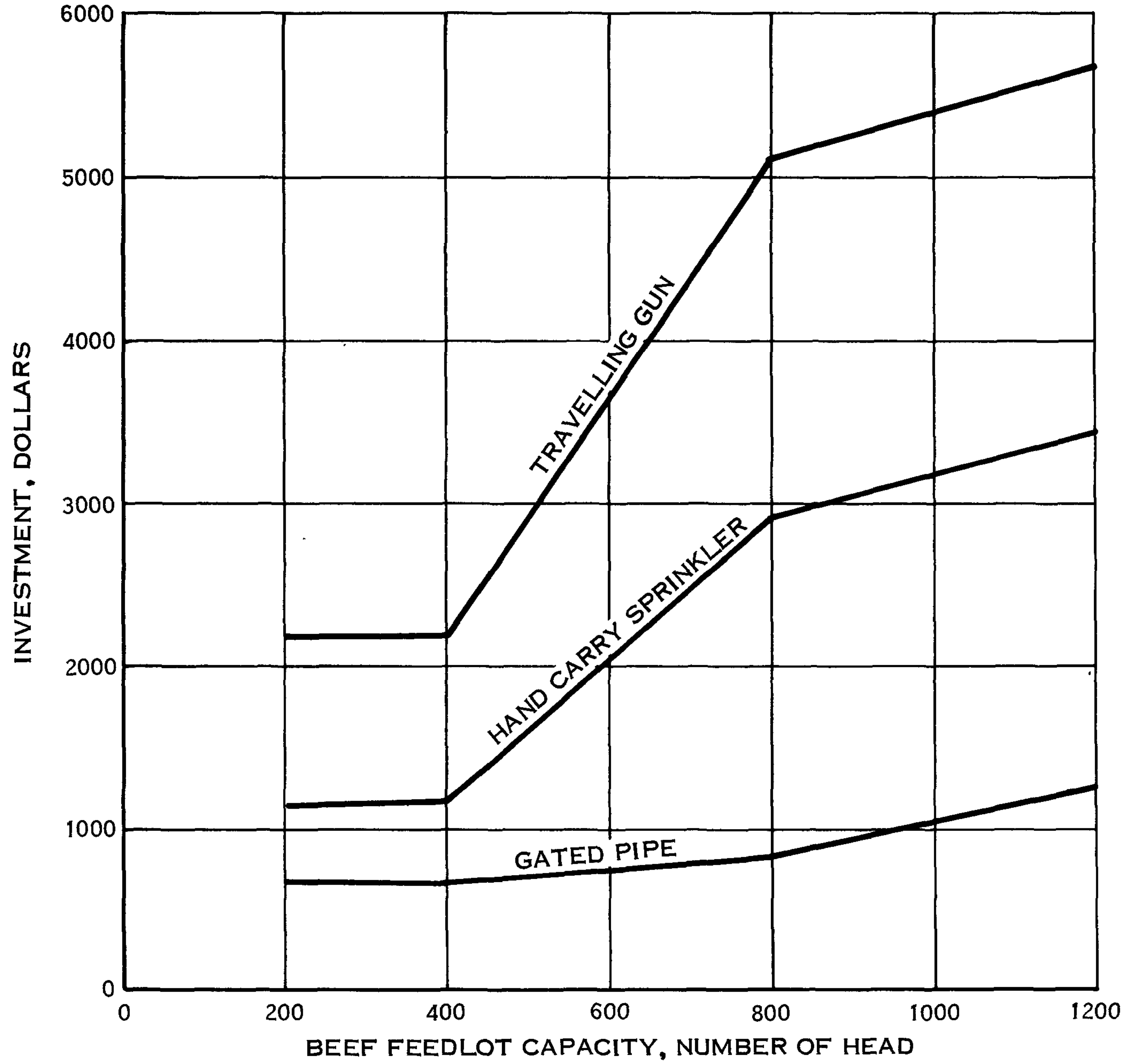


FIGURE 64. IRRIGATION EQUIPMENT – INVESTMENT COST

Pump system:	$5300 - three pumps totalling 158 liter/second (2500 gallons per minute)
Gated Pipe:	$0.50, 10 cm diameter (4 in.) to $1.00, 15 cm diameter (6 in.)
Sprinkler System (including pipe valves):	$9200 (22,000 beef cattle)
Travelling gun:	$6900 (75 dairy cattle) to $17,000 (3500 hogs)
Center pivot system:	$12,000 (1000 beef cattle) to $32,000 (10,000 beef cattle)

Irrigation operating costs, taken from the literature, are shown in Figure 65.

Examples - Because the cost data are sketchy (from a statistical standpoint), the following examples of actual operations are provided:

1. Management of Farm Animal Wastes, ASAE, 1966, pub. no. SP-0366, Pg. 122 - Spreading of liquid hog manure from under slotted floors.

Average analysis of manure was:

0.56% N
0.30% P_2O_5
0.25% K_2O
94% HH_2O

Waste was spread (application rate not specified) on cropland (corn and soybeans) for October 15 through June 15 and on non-cropland for June 15 through October 15. Equipment required was a tank spreader and pump and a tractor. The cost of the tractor was assumed to be chargeable to normal farm operation and was ignored. Costs were given as follows (1966 figures increased 5%/year to apply to 1973 dollar value).

The return on investment was calculated by comparing it with the cost of the same amount of nutrients in the form of inorganic fertilizers. As stated previously, this is not considered valid in that the nitrogen in manure is not immediately nor completely available for crop growth and the nutrient balance in manure may not be optimum. For this reason the return figures are not included in this report.

2. Management of Farm Animal Wastes, ASAE, 1966, pub. no SP-0366, Pg. 126.

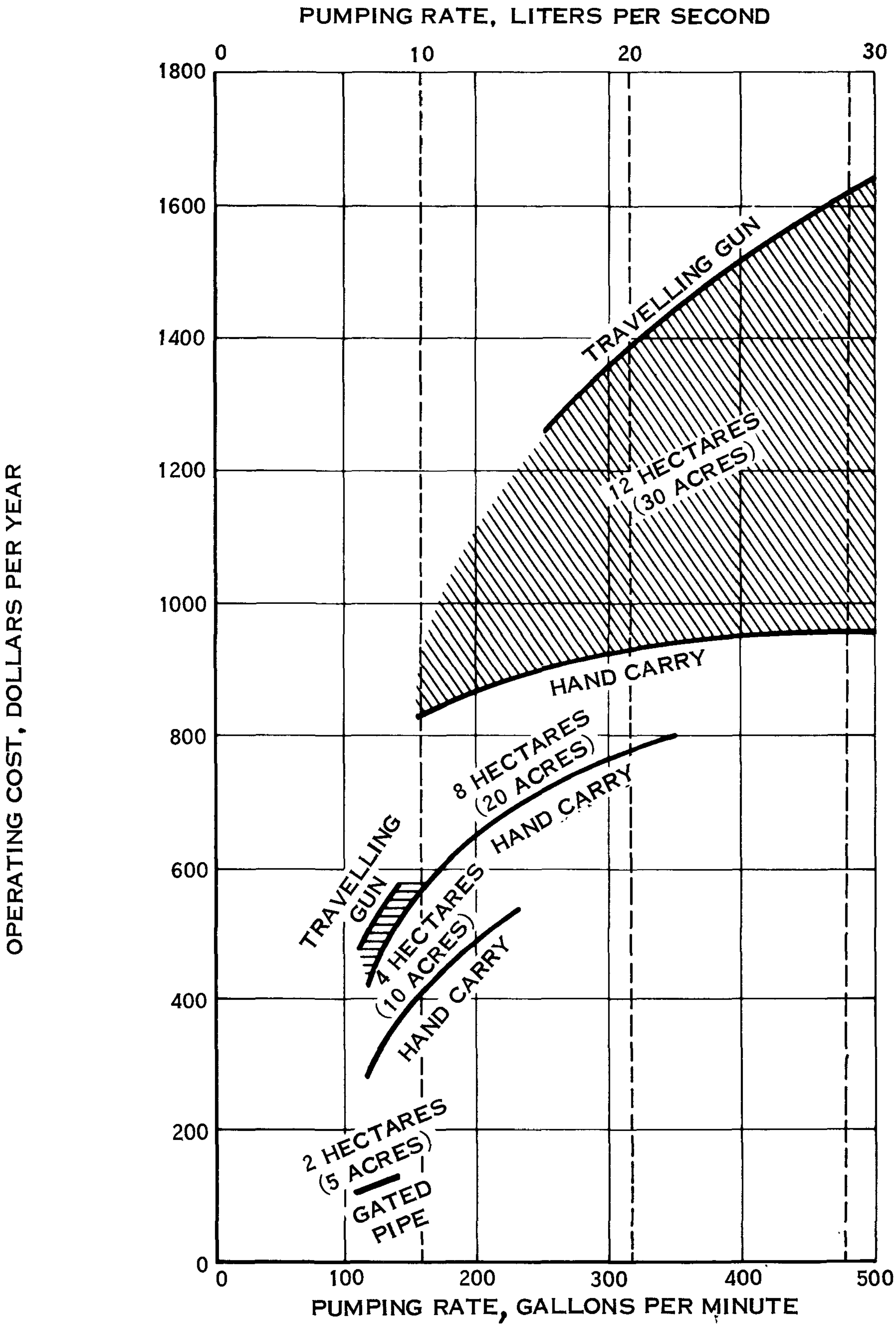


FIGURE 65. IRRIGATION EQUIPMENT — OPERATING COSTS

The economics of this article are based on a "paper study" only, but they do include an estimate of the value of manure relative to inorganic fertilizer which attempts to account for the relative fertilization efficiency of manure versus inorganic fertilizer.

Value of Manure as Fertilizer

a. Manure nitrogen kg for kg (lb for lb) is 50% of the value of inorganic fertilizer nitrogen.

b. Manure phosphorus kg for kg (lb for lb) is 67% of the value of inorganic fertiizer phosphorus.

c. Manure potassium kg for kg (lb for lb) is 75% of the value of inorganic fertiizer potassium.

Equipment Costs (liquid manure system only)

(1966 figures increased 5%/yr. to apply to 1973 dollar value)

Equipment	Capital Cost - $	Fixed Annual Cost - $	Operating Cost $/kkg spread ($/ton spread)
Vacuum Wagon			
2839 liters (750 gallons)	$1500	262	0.61 (0.55)
5678 liters (1500 gallons)	$2250	394	0.37 (0.34)
Tank Wagon & Pump			
5678 liters (1500 gallons)	$4300	875	0.42 (0.38)

3. Animal Waste Management, Cornell University, 1969, (conference) Pg. 393.

This study incorporates costs for hauling and spreading dairy wastes in New York as well as data from experimental plots at the Cornell Research Farm. The study is fairly extensive. All test plots used for crop evaluation, with or without manure application, received the same amount of supplementary inorganic fertilization. The value of manure usage was based on increased crop yields of plots which received manure versus those which did not.

A summary of data from the study follows (1969 figures increased 5%/year to apply to 1971 dollar value).

Cost of hauling and spreading

Free stall barns	\$2.33/kkg ($2.11/ton)
Stanchion barns	\$3.86/kkg ($3.50/ton)

Crop increases for manure versus no manure

Ranged from 0.4% for oats to 6.6% for alfalfa.

Value of crop increases

Ranged from \$1.56 return to \$0.29 deficit. (The deficit figure appears because of compensating estimation to allow for below average crop management).

4. A Beef Feedlot in Iowa

This is a 405 head, slotted floor/deep pit beef facility. On the average, the pit contents are pumped out 2.5 times per year and spread on 24 to 28 hectares (60 to 70 acres) of corn and alfalfa cropland. The data is as follows:

Labor:	315 man hours/year
Application rate:	82 kkg/hectare/year (37 tons/acre/year)
Capital equipment	
Pump:	\$1600
2 tank spreaders:	\$4000

Three \$12,000 tractors are used during this operation; however the spreading task represents only a small portion of their use. The slotted floor facility cost \$27,5000 in 1970. This is a cost of \$68 per head.

5. A Beef Feedlot in Iowa

This is a 500 head slotted floor/oxidation ditch beef facility. The ditch effluent flows into a pit followed by two lagoons in series. Lagoon contents are spread on 48.6 hectares (120 acres) of corn cropland in the spring and fall. The data is as follows:

Labor:	100 man hours/year or (at \$2.25/man hour) \$225/year
Application rate:	94 kkg/hectare/year (42 tons/acre/year)
Capital cost:	\$1500 vacuum wagon

The complete facility cost was $60,000 in 1970 or $120/head.

6. A Beef Feedlot in Texas

This is an 80,000 head capacity open dirt feedlot. Pens are scraped twice each year. The feedlot pays 55 cents per kkg (50 cents per ton) to farmers who spread the manure on cropland at a rate of 11 kkg per hectare (5 tons per acre) or higher. A private contractor hauls and spreads the manure at a cost of $1.21 per kkg ($1.10 per ton) plus 3.6 cents per kkg per km (5 cents per ton per mile). Farmers using the manure report higher silage yields of 60.5 versus 44.8 kkg per hectare (27 versus 20 tons per acre).

7. A Swine Feedlot in Illinois

This is a 4800 head, slotted floor/deep pit, swine facility. On the average, 25% of the pit volume (about 15% of the solids) overflows to a lagoon. Manure pumped from the pit is spread on 192 hectares (475 acres) of corn. The data is as follows:

Labor:	0.25 man years/year
Application rate:	60,750 l/hectare or 6500 gal/acre/year (135 kg or 120 lbs of nitrogen per acre)
Capital Cost:	
Vacuum tank wagon	$3000
Tractor	$10,000 (50% usage)

8. A Turkey Feedlot in North Carolina

This company raises 2.5 million turkeys per year in open lots. No costs are available on waste control on the range land; however, the company also operated a few experimental full confinement houses. Litter and manure was removed and spread on farm land by a contractor. A house containing 10,000 birds is cleaned once each year at a cost of 88 cents per kkg (80 cents per ton). The total tonnage is about 45 metric tons (50 tons).

Composting

Detailed capital and operating costs are not available. However, the total cost of processing manure by composting was estimated by operators at between $0.55 and $13.23 per kkg ($0.50 and $12.00 per ton) of product.

Dehydration

Investment Cost -

1. Purchased Equipment - $30,000 for a rotary drum dryer that produces 0.22 kkg (0.2 tons) per hour of dried waste.
2. Buildings - None required, system usually installed outdoors.
3. Land - Minimal, 6.1 m x 12.2 m (20' x 40') plot required per machine.
4. Site Work - Purchase price includes price of dryer, shipping, concrete pad, and auxiliary equipment.

Operating Cost -

1. Materials and Supplies - None required for refeed program unless excess is bagged and sold. Maintenance costs are $0.55/kkg ($0.50/ton).
2. Utilities -Electrical - 22 KWH/kkg (20 KWH/ton) at $0.23/KW equals $0.55/kkg ($0.50/ton)
   -Fuel - 36.0 lit/hr x 5.5 hr/kkg x $0.05/lit equals $9.90/kkg (9-1/2 gal/hr x 5 hr/ton x $0.20/gal equals $9.50/ton)
3. Labor - 5.5 hr/kkg at $2.50/hr equals $13.78/kkg (5 hr/ton at $2.50/hr equals $12.50/ton)
4. Indirect costs - Depreciation and interest cost based on $30,000 purchase price of 5 years at 9-1/2% interest and operating 60 hours per week for 50 weeks per year is $13.89 per kkg ($12.60 per ton).
5. Total Cost - Cost per kkg (ton) of dried material is:

Materials and Supplies	$0.55	($0.50)
Utilities	11.03	($10.00)
Labor	13.78	($13.50)
Indirect	13.89	($12.60)

TOTAL $39.25 per kkg ($35.60 per ton)

Conversion to Industrial Products

Processing costs are not available. Product value has been stated to be $12.86 per cubic meter ($0.03 per board foot) for low density material and $0.05 per unit for brick.

Aerobic Production of Single Cell Protein

Cost information is not avialable. The maximum value of the product is about $0.18 per kilogram ($0.08 per pound) of protein or $0.09 per kilogram ($0.04 per pound) of product. Costs for processing the manure into reusable nutrients must therefore fall below these figures.

Aerobic Production of Yeast

No figures are available, but in its current configuration, the process appears to be excessively expensive.

Anaerobic Production of Single Cell Protein

Investment Cost - In the 45,000 kg/day (100,000 lb/day) system, the capital costs consists of the sum of the slurry system, fermenter system, centrifuges, dryers and power generator for a total estimated capital cost of approximately $550,000.

Operating Costs - For labor, supplies, maintenance and repairs, taxes and insurance and financing, operating costs are estimated to be $168,000/year for an operating cost of $20.40/kg ($18.50/ton) for a product worth $44.10/kkg ($40/ton) based on 1971 feed grain prices.

Feed Recycle Process

Investment Cost - Cost of a plant to process 90.7 kkg (100 tons) (dry basis) of manure per day has been estimated at about $250,000. A plant this size would service about 35,000 head of cattle.

Operating Cost - Operating cost for a 90.7 kkg (100 ton) per day plant was estimated at $1000/day for direct costs and (based on a five year write-off) $200/day indirect costs. Value of the product is estimated at $4400/day for the 90.7 kkg (100 ton) per day plant.

Oxidation Ditch

Investment Cost -	Purchased Equipment	- $50 per head of cattle
	Building	- $65-75 per head
	Land	- Cost of land negligible to other costs
	Site Work	- Included in cost of equipment

Operating Cost - Based on 10 year equipment depreciation, operating cost on a non-feed basis is estimated at $0.13 per day per animal.

Investment Cost -

1. Equipment: Program A equipment (see Section VII) is described in detail in Reference 113. Program B equipment cost, adjusted for a recent increase in aeration requirement, if $9700, based on a maximum capacity of 1000 hogs. The Program C cost of $110 (to treat runoff from 0.336 hectare, 0.83 acre, or 166 beef cattle) is probably high because of high prototype equipment costs. Program E equuipment is described in Reference 117; cost is roughly $155 per cow capacity.

2. Buildings: Buildings are not required.

3. Land: Land requirements are very low. The general order of magnitude for the demonstration units previously described is an area of 7.6 meters by 22.9 meters (25 feet by 75 feet).

4. Site Work: Excavation for tank foundations is required. In some of these processes, the top of the tank is at ground level.

Operating Cost -

1. Supplies: The only raw material is chlorine, which may not be needed, depending on the degree of treatment required.

2. Utilities: All of the activated sludge processes need aeration power. Estimated annual costs are $1255 for Program B and $900 for Program D.

3. Labor: Although these processes are capable of full automation, they will require significant attention for monitoring and maintenance.

4. Total: Total operating costs are estimated at $0.60 - $0.70 per hog capacity for the Program B operation (based on 8% ammoritization) and at $0.60 per animal fed for the Program C operation (based on 6% ammoritization). Figure 66 demonstrates that standard municaipal sewage treatment costs are not applicable, because the processing rate for feedlot installations is generally well under 3.785 million liters (one million gallons) per day.

Wastelage

Emphasis has been placed on technical evaluation of the concept, rather than on cost analysis.

Anaerobic Production of Fuel Gas

Investment cost for one concept is estimated at $16,500,000 with annual operating and maintenance costs estimated at $5,812,000. These figures are based upon local experience and manufacturer list price. Prices are for a plant capable of producing 840,000 cubic meters (30 million cubic feet) of synthetic natural gas per day and requiring a cattle base well in excess of 500,000 head. These values yield a cost to produce of approximately $2.14/100 cubic meter ($0.60/1000 cubic foot).

Another system results in production costs of approximately $1.54/100 cubic meter ($0.43/1000 cubic foot).

These figures would place methane produced in this fashion in a competitive position vis a vis imported liquified gas and, possibly even, domestically produced gas.

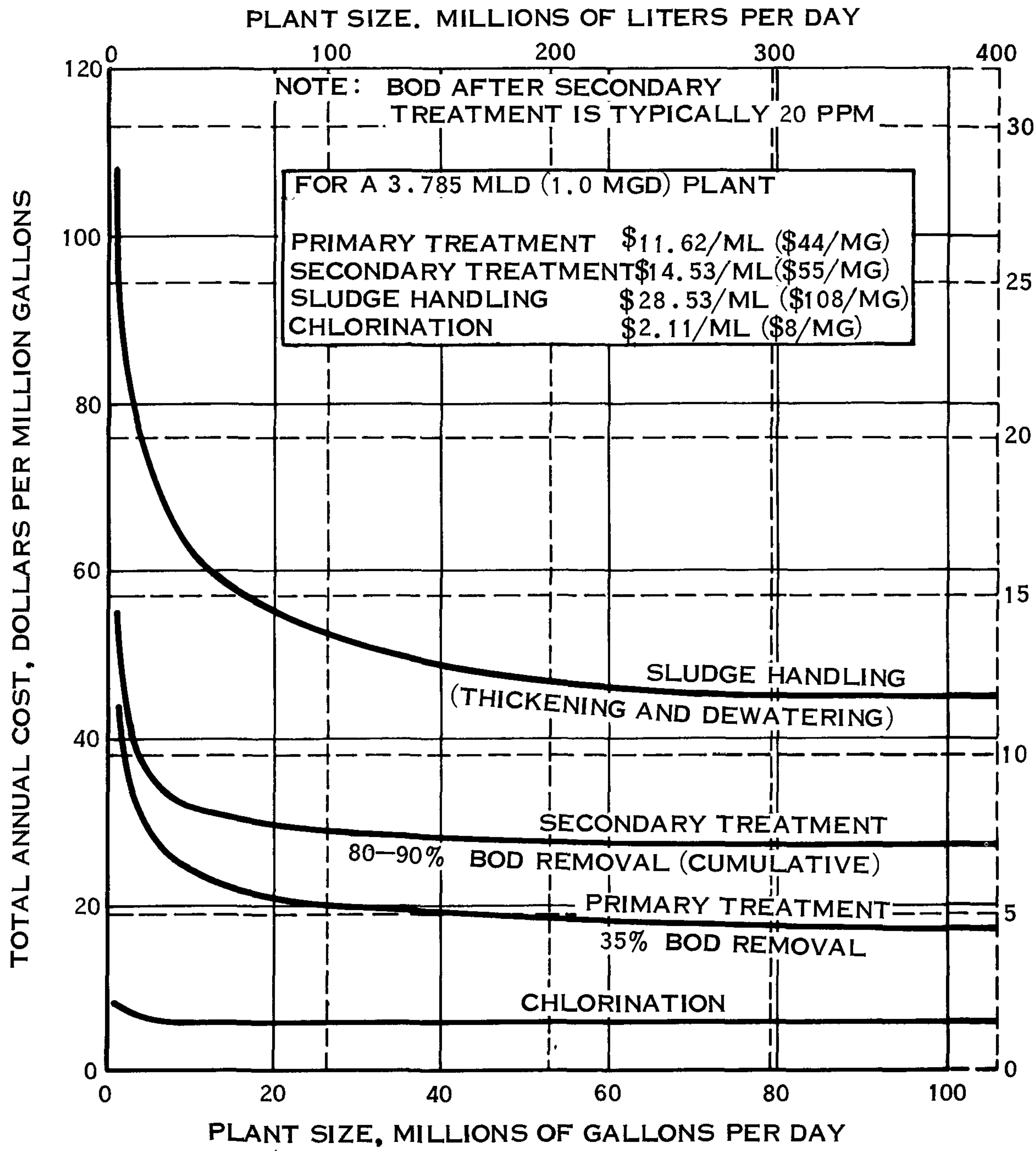


FIGURE 66. COST OF SEWAGE TREATMENT UNIT OPERATIONS (1970 BASIS)

Reduction by Fly Larvae

Cost estimates have not been made. The value of the protein product has been estimated at $230/kkg ($209/ton), based on soy bean meal (44 percent protein) at $176/kkg ($160/ton). Operating cost has been claimed to inclde only part time attention from someone with no special skills.

Biochemical Recycle Process

Each 100 cow unit - 4.54 kkg/day (5 ton/day) sells for under $20,000 including a 2.4 x 2.4 x 3.0 meter (8 x 8 x 10 foot) weatherproof enclosure. Land usage is negligible, and site work consists of a concrete slab.

Total operating cost is not available. Materials costs include $0.60 per day for 1.6 kg (3.5 lbs.) of alum. The electric power requirement is 50 KWH per day, costing about $1.25 per day.

Conversion to Oil

Aerobic Production of Single Cell Protein - Despite use of the Operating costs of this complex process would be very high, especially with the pre-drying operation. The value of the product does little to offset these costs. Consequently, conversion to oil does not appear to be economically attractive.

Gasification

The gasification process is not developed enough for meaningful capital and operating cost estimates. Synthesis gas as an ammonia plant intermediate is estimated to have a value of $13.78/kkg ($12.50/ton).

Pyrolysis

The basis for the following capital and operating costs is as follows:

Reference 154	40,000 head capacity or 907 kkg manure per day (1000 ton manure per day)
Reference 155	181 kkg (200 ton) per day capacity (40% moisture, 30% ash)
Reference 156	30,000 head capacity.

Investment Cost -

1. Equipment:
   Reference 154: $5,5000,000
   Reference 155: $624,000

2. Building and Site Preparation: These are undefined additional costs.

3. Land: 3.6 - 4.1 hectares (9 - 10 acres).

Operating Cost -

COST ITEM	ANNUAL COST Reference 154	Reference 155	Reference 156
Fuel	$ 182,000	$ 0	-
Labor	180,000	131,000	-
Maintenance	220,000	25,000	-
Taxes and Insurance	275,000	31,200	-
Depreciation	550,000	62,400	-
Capital Charges	330,000	75.000	-
Other	110,000	12,500	-
Total	2,477,000	337,100	$1,148,400
Offsetting Costs	464,000	379,700	-
Net Cost	2,013,000 (cost)	42,600 (profit)	-

Incineration

There is no activity on this technology as it applies to animal waste.

Chemical Extraction

Economic information is proprietary.

Hydrolysis and Chemical Treatment

Investment Cost - The only avialable capital cost information is that projected for Program A operation (see Section VII). The actual operation was not implemented as intended and was later suspended. Projected system capacity was 2,724 kg (6,000 lb.) batches of wet poultry manure, with a processing time of one hour, or a capacity of 22.7 kkg (25 tons) of raw manure per day.

Installed equipment cost was estimated at $49,700, including $7,000 for a steam boiler. Pollution abatement equipment was an additional $10,900. An additional $7900 was required for an automatic bagging operation, including screw conveyer, hopper, and bagging line, and fork lift. Cost of a building was estimated at $25,000.

Operating Cost - Operating cost information is not available. Cost would include either fuel for the steam boiler in the case of steam hydrolysis, or a chemical (probably potassium hydroxide) for chemical treatment.

Runoff Control

The major cost item for runoff control is the holding pond. Costs of dikes, berms, ditches, settling diversion terraces, and settling basins are small by comparison. In fact, these features are often included in the cost data for ponds and lagoons. The reader is therefore referred to cost data under the heading "Lagoons".

Barriered Landscape Water Renovation System

Meaningful cost information is not yet available. Purchased equipment includes pumps, sprayers, lines, valves, and plastic sheeting. Buildings are not needed, and land requirements are much less than for spray irrigation. Site work includes excavation up to 0.6 meters (two feet), backfill and mound buildup (with soil, sand, or a mixture), and a collection channel and sump if water is to be recycled. A plant cover is desireable.

Operation is largely automatic, and maintenance is low. Electrical power is needed for pumping. Periodic limestone replacement is needed, and molasses or other supplemental energy source may be used to promote anaerobic microorganism growth.

Lagoons

Investment cost for lagoons is shown in Figures 67 and 68. The data apply to all types of lagoon, including holding ponds. In addition, associated runoff control features such as settling basins are often included. Figure 67 indicates the characteristic data scatter caused by variations in local economics, soil characteristics, topography, and individual state requirements.

An enlargement of the boxed portion of Figure 67 is shown in Figure 68. The actual ASCS data points, which fall within the indicated oval envelopes, were taken from ASCS files and represent individual designs meeting all government guidelines. The Butchbaker correlation represents an average of typical installations, while the data points gathered for this report are actual installations. The George correlation represents lagoons built on a slope by constructing an earthen dam. Lagoons built on a flat or less ideal topography would cost more.

Lagoon costs are often presented for specific animals. The following tabulation of investment cost is an example from the literature. Costs are on a 1966 basis. The same author suggests an annual cost of 14 percent to cover depreciation, interest,

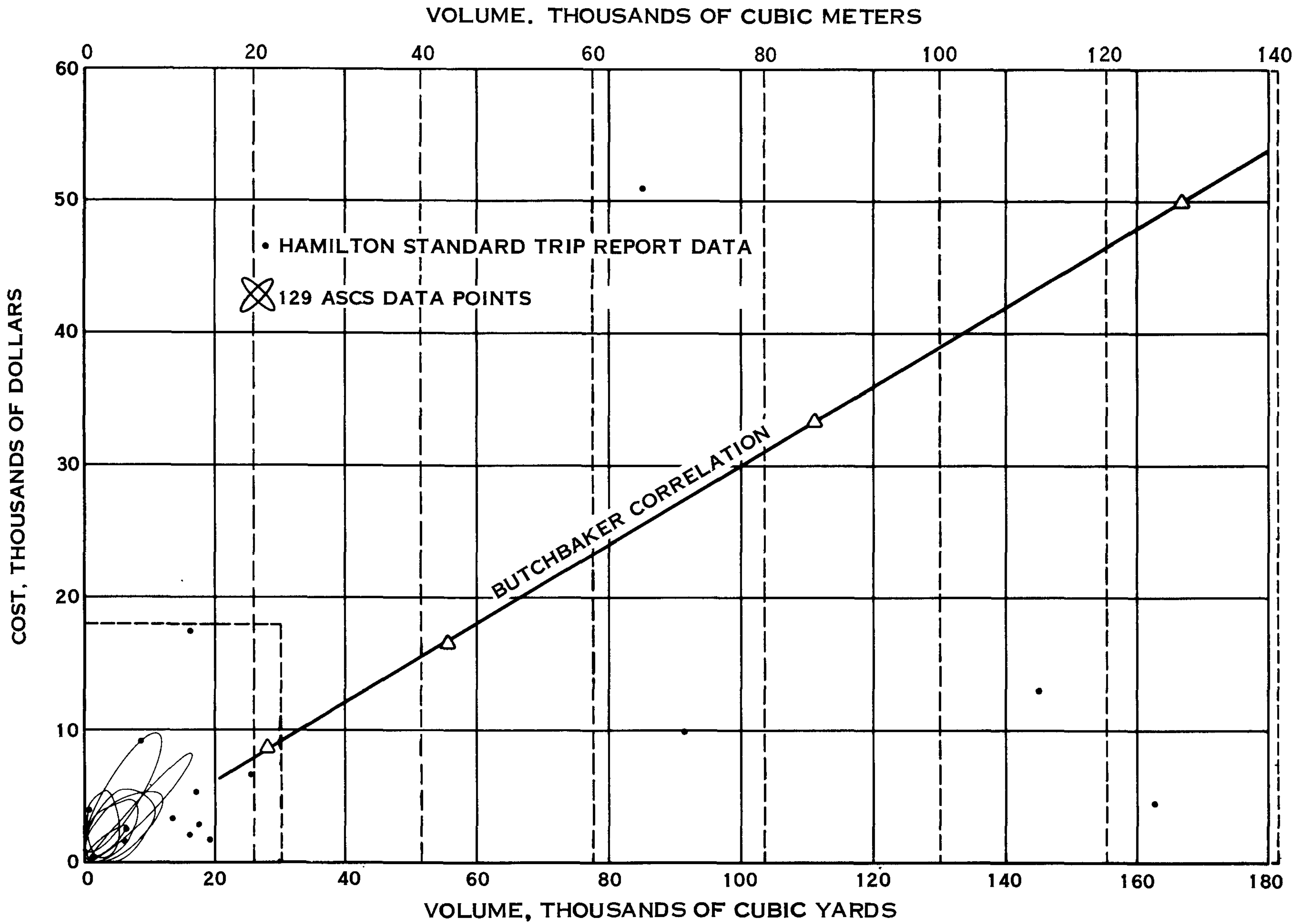


FIGURE 67. LAGOONS AND PONDS — INVESTMENT COST

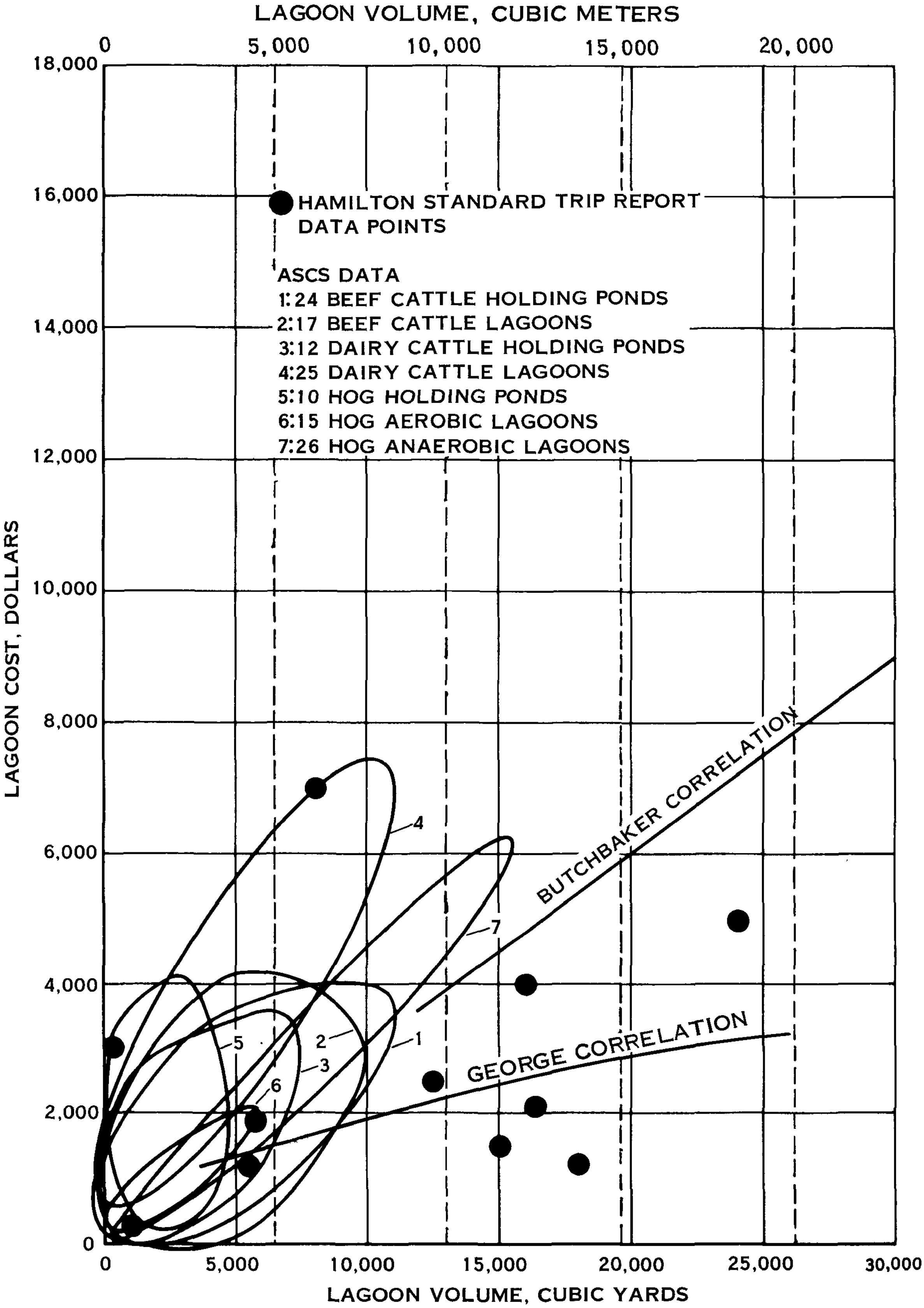


FIGURE 68. LAGOONS AND PONDS — INVESTMENT COST (DETAIL OF FIGURE 67)

taxes, insurance, maintenance, and repairs.

	Hogs Produced Per Year		
	500	1500	2500
Earth Moving	$889	$2667	$4445
Fencing	137	219	277
Sealing (tile)	120	120	240
Total	1146	3006	4962

Evaporation

Cost of evaporation ponds is included under "Lagoons".

Trickling Filters

Investment Cost - No cost estimates have been made for commercial sized trickling filters for treating animal wastes. Municipal sewage plant trickling filters can be used as a guide.

Purchased Equipment - Sedimentation tanks, trickling filter (including distributer), pumps, and valves. Sizing is usually based on hydraulic loading. The following guidelines have been developed based on the laboratory work.

Trickling Filter Type	Source of Waste Water	Sizing Guideline for Costing	More Information
Stones	Dairy Cows	21-77 ft^3/cow or 45-170 ft^3/lb BOD/day*	Reference 232
Bark	Poultry	14-17 ft^3/lb BOD/day	Reference 233
Inclined Plane	Swine Waste Lagoon	30-250 ft^2/gpm*	Reference 234
* Depending on desired BOD removal efficiency			

Sedimentation Tank	Source of Waste Water	Sizing Guideline	More Information
Primary	Dairy Cow Barn Flushing	200 ft^3/cow	Reference 232
Final		114 ft^3/cow	

Buildings - Housing to maintain 7.2°C (45°F) minimum waste water temperature required.

Land - Much less than required for spray irrigation disposal.

Site Work - Equipment foundations and building erection.

Operating Cost - Operation is largely automatic. Maintenance is normally low, but upsets can clog the trickling filter. Electric power is needed for pumps. Labor costs include periodic sedimentation tank cleaning.

Spray Runoff

A 4.4 hectare (10.9 acre) spray runoff system incurred the following investment costs:

Earth moving	$1188
Concrete ditch	698
Pipe	2445
Valves	316
Grass seed	177
Fertilizer	131
Total	$4965

These costs do not include labor. In addition, modifications to obtain recycling capability will cost $1276. Operating costs include power or fuel for the pump and harvesting the grass. Operation is largely automatic, and maintenance is low.

Rotating Biological Contactor

The RBC is potentially valuable only where land availability is severely limited. At the present time, this not generally the situation at feedlot locations. Land spreading, spray irrigation, and lagoon treatment are therefore far less expensive than use of an RBC.

Water Hyacinths

Economic information is not available.

Algae

Proponents of this experimental technology claim that a full scale operation could be implemented for about $0.09 per kilogram ($0.04 per pound) of dry algae harvested.

ENERGY AND NON-WATER QUALITY ASPECT

Energy and non-water quality aspect are separate considerations, but both are related to cost. Technologies with high energy input tend toward high investment costs and high operating costs. As pointed out in the following discussion, however, a high energy input technology may be a low net energy user. Often, those technologies such as conversion to oil that have high energy input and low net energy consumption are expensive, relatively complex, and potentially heavy polluters. Byproducts can be disposed of without pollution, and air pollution can be controlled, but this requires additional expense.

With the exception of some runoff control situations, every non-polluting waste management technology uses energy from electric power or consumption of a common fuel. For technologies such as land utilization, the energy is used mainly for transferring or transporting the waste material. For others, energy provides the mixing or aeration needed for efficient biological treatment of the waste. For still other technologies such as dehydration and pyrolysis, energy input forces rapid physical or chemical changes in the waste material.

Nevertheless, almost all of these technologies should receive an energy credit that tends to offset the energy input. Thus, land utilization of wastes results in reduced requirements for chemical fertilizer, saving the energy needed to produce, distribute, and spread the fertilizer. Similarly, technologies that convert manure to feed supplements reduce the energy that would otherwise be expended in planting, fertilizing, harvesting, and processing such crops as soybeans. Processes such as gasification can extract the energy they need from the product they make and still have enough product left to act as an energy source for other industries. Thus, energy input for the process may be high, while net energy consumption is low, or the process may actually convert the waste to an energy producing product.

In addition to useful products, many of the waste management technologies produce byproducts of questionable value. This sludge, fiber, ash, or other residue often has value as a soil conditioner and can sometimes be used in other applications. Thus these by-products of the waste management technologies may be disposed of without affecting the water quality of natural waterways.

Technology Characteristics

In the rest of this section, each technology is considred with regard to energy usage and non-water quality aspect. Table 41 summarizes these considerations, noting whether net energy consumption is high or low, thus providing an indication of the ultimate impact of the technology on our energy resources.

Land Utilization - Energy used for loading, hauling, spreading, pumping, and spraying solid or liquid wastes is offset by reduced fertilizer needs and consequent saving in energy for producing, transporting, and spreading the fertilizer. Net energy usage is therefore low. There are no byproducts, and odor is non-objectionable if suitable techniques are used.

Composting - Energy is needed for periodic turning of the composting material, but input energy is still relatively low. Porper operation minimizes odor, and there are no byproducts. The product is a useful soil conditioner.

Dehydration - The product is useful as a fertilizer or feed supplement, but net energy to remove the water is still relatively high. Proper design minimizes odor, and there is no by-product.

Conversion to Industrial Products - This is basically a pyrolysis process with a useful product. The gases evolved in the process may be used as fuel to supply the heat required, so that net energy consumption is potentially low. Positive measures to prevent odor are required.

product as a feed supplement, net energy usage is relatively high due to the number of steps in which forced air aeration is required. There are no odor or byproduct problems.

Aerobic Production of Yeast- The comments for the preceding technology also apply to yeast production.

Anaerobic Production of Single Cell Protein - Energy input to this process is relatively low, and the feed supplement produced represents an energy credit. Even if dehydration of the product is desirable, the fuel gas byproduct is adequate to supply the required energy.

Feed Recycle Process - This process is basically a low energy physical-chemical separation, and the product represents an energy credit. The process is free of objectionable odors, but a practical use or means of disposal for the fiber byproduct must be found.

Oxidation Ditch - Despite potential value of the resulting sludge as a feed supplement, net energy for mechanical aeration is high. There is no odor problem.

Activated Sludge - Energy for aeration is high. There is no odor but byproduct sludge must be used as a soil conditioner or for land fill.

Wastelage - Input energy is very low, there is no byproduct, and odor is controlled.

Anaerobic Production of Fuel Gas - Input energy is relatively low, and the product has a high energy value. Byproduct sludge may be used as a soil conditioner.

Reduction With Fly Larvae - Energy input for mixing and air circulation is moderate, and energy for drying is offset by the high protein value of the product. Pending further development, net energy usage is regarded as low. Byproduct compost may be used as land fill or as a soil conditioner.

Biochemical Recycle Process - Expensive equipment is used to achieve low energy aeration. There is no odor, but a practical use must be found for the fiber byproduct.

Conversion to Oil - The energy requirement is high, but the product itself has a high energy content which can be used for the process. Thus, net energy usage is potentially low, although practical use of the product as a fuel is in some doubt.

Gasification - High input power is offset by potential use of the product as a fuel and primary use of the product to save the energy associated with a major step in the production of ammonia. The synthesis gas product must be considered toxic, and byproduct ash requires disposal.

Pyrolysis - The endothermic reaction requires high input energy, which may be supplied by burning byproduct gases. The byproduct ash must be disposed of or used (see "Conversion to Industrial Products"). Odor must be controlled.

Incineration - The waste material itself provides much of the energy required for incineration of wet waste. Positive control of air pollution is required, and ash requires disposal. There is no product, although utilization of the heat released may be possible.

Hydrolysis and Chemcial Treatment - Energy for steam hydrolysis can be minimized by use of regenerative heat exchangers and is somewhat offset by the nutritional value of the product. Energy for the chemical treatment approach is low, except possibly for the energy associated with producing the chemical. Pending further development, net energy usage is regarded as low.

Chemical Extraction - This process appears to use low energy physical-chemical separations. Energy for drying the product is somewhat offset by its nutritional value. Disposal of the liquid byproduct is a problem.

Runoff Control - No energy is required. Solid and liquid byproducts are disposed of by land utilization. There is a potential for groundwater contamination or objectionable odor.

Barriered Landscape Water Renovation System - Energy for pumping is low. There is no product or byproduct, and odor is limited.

Lagoons for Waste Treatment - Aerated lagoons are really an activated sludge technology. Other lagoons have neglibible energy requirements for maintenance. Poor design or operation can result in stream pollution or objectionable odor. Solid and liquid byproducts are disposed of by land utilization.

Evaporation - Except for solar energy, there is no energy input. Poor management can result in stream pollution or odor generation. Sludge generally requires disposal by land utilization.

Trickling Filter - Despite the high recycle rate, pumping energy is relatively low. The process should be odor free, but solid and liquid byproducts require disposal.

Spray Runoff - This is essentially a trickling filter technology using a living medium. Consequently, grass must be harvested in addition to water disposal. However, due to potential contaminants on the grass surfaces, its use as a feed needs to be demonstrated.

Rotating Biological Contactor - This is essentially a form of trickling filter.

Water Hyacinths - Energy for harvesting and preparation is hopefully offset by nutritional value of the product.

Algae - The algae technology is similar to that of hyacinths.

ENERGY AND NON-WATER QUALITY ASPECT

Technology	Net Energy Usage	By-Product
Land Utilization	Low	None
Composting	Low	None
Dehydration	High	None*
Conversion to Industrial Products	Low	None*
Aerobic SCP Production	High	None*
Aerobic Yeast Production	High	None*
Anaerobic SCP Production	Low	None*
Feed Recycle Process	Low	Fiber
Oxidation Ditch	High	Sludge, liquid
Activated Sludge	High	Sludge, liquid
Wastelage	Low	None*
Anaerobic Fuel Gas	Low	Sludge
Fly Larvae Production	Low	Compost
Biochemical Recycle	Low	Fiber
Conversion to Oil	Low	Ash
Gasification	Low	Ash
Pyrolysis	Low	Ash
Incineration	Low	Ash
Hydrolysis	Low	None*
Chemical Extraction	Low	Liquid
Runoff Control	Low	Liquid, solids
BLWRS	Low	None
Lagoons for Treatment	Low	Sludge, liquid
Evaporation	Low	Sludge
Trickling Filters	Low	Sludge, liquid
Spray Runoff	Low	Grass, liquid
Rotating Biological Contactor	Low	Sludge, liquid
Water Hyancinths	Low	None*
Algae	Low	None*

*Note: Unless otherwise specifically indicated ash, salts or similar system residuals, if any, are not fully established at full scale.

TABLE 41

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 for feedlots, is generally based upon the average of the best existing performance by feedlots of various sizes, ages, and unit processes within its category or sub-category. This average is not based upon a broad range of feedlots within the feedlot industry, but is based upon performance levels achieved by exemplary ones. The technology applied by these feedlots to achieve these effluent limitations is termed Best Practicable Control Technology Currently Achievable.

Consideration has also been given to:

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

Best Practicable Control Technology Currently available emphasizes treatment technology applied at the end of the normal feedlot processes but includes the control technologies within the feedlot itself when the latter are considered to be normal practice within the industry.

A further consideration is the degree of economic and engineering reliability which must be established for the technology to be "currently available". There should be a high degree of confidence in the engineering and economic viability of the technology, at the time of commencement of actual construction of the control facilities, resulting from general use or from pilot plants and demonstration projects.

EFFLUENT ATTAINABLE THROUGH THE APPLICATION OF THE BEST PRACTICABLE CONTROL TECHNOLOGY AVAILABLE

For the purposes of this Section, wastewater refers to (1) rainfall runoff, and (2) flush or washdown water for cleaning animal wastes from pens, stalls, milk center areas, houses, continous overflow watering systems or any similar facility. Based upon the information contained in Section III through VIII of this report, a determination has been made that a total effluent elimination is attainable through the application of the Best

Practicable Control Technology Currently Available. The effluent limitation shall be "no discharge" of wastewater pollutants to navigable water bodies for runoff from any and all precipitation events up to but excluding the incremental runoff from a climatic event in excess of the 10 year, 24 hour rainfall event as established by the U.S. Weather Bureau for the region in which the point source discharge is located; applicable to the following animal types and all identified subcategories thereof cited in Section IV: beef cattle, dairy cattle, swine, chickens, turkeys, sheep, and horses. The animal type, ducks and the subcategories thereof, is an exception in that there is an effluent discharge with pollutant limitations as shown:

Effluent Characteristic	Limitation
BOD_5	Maximum for any one day 1.66 kg per 1000 ducks (3.66 lb/1000 ducks)
	Maximum average of daily values for any period of 30 consecutive days .91 kg per 1000 ducks (2.00 lb/1000 ducks)
Coliform bacteria	At any time not to exceed 400 fecal coliform per 100 ml during the months May to October and 2000 fecal coliform per 100 ml during the months November to April.

IDENTIFICATION OF THE BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

Best Practicable Control Technology Currently Available for the feedlot industry is containment of all contaminated liquid runoff resulting from rainfall, snowmelt, or related cause, and application of these liquids, along with the generated solid wastes to productive cropland at a rate which will provide moisture and nutrients that can be utilized by the crops. The technology for containment and application to cropland can achieve the stated goal of "no discharge" to navigable water bodies. To implement this technology requires the following:

a. Provisions for the containment of all contaminated runoff, liquid manure, and seepage in order to prevent the uncontrolled discharge of these liquids across the feedlot boundaries and through the feedlot surface. Among the alternatives for containment may simply be a holding pond, or perhaps a lagoon or oxidation ditch that provides biological pre-treatment to the wastes in order to reduce the land required for application, or may be, in applicable geographic regions, an evaporation pond with collection of solid residues for application to the land.

b. Provisions for applying liquid and solid wastes to cropland for the efficient utilization of the contained moisture and nutrients by the crop. The solid wastes may be subjected to a pretreatment of dehydration or composting where these wastes must be stored, transported, and sold for use on land not immediately available to the feedlot.

c. As part of the above containment and land utilization concepts, where necessary, provisions should be made for efficient site selection; diversion of outside runoff away from or around the feedlot using berms, dikes, or ditches; inclusion of emergency dewatering capability for runoff storage structures to minmize problems encountered with multiple precipitation events.

The Best Practicable Control Technology Currently Available for the animal type, ducks, consists of primary settling, aeration, secondary settling, and chlorination prior to discharge.

The technologies described above are all presently found in commercial practice and are described further in Section VII.

RATIONALE FOR THE SELECTION OF THE BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

The Best Practicable Control Technology Currently Available for the feedlot industry is dependent upon the ability of avialable cropland to receive feedlot wastes and efficiently recycle them into useable crops. Both the amount of waste and their strength, as well as the type of crop produced, are direct functions of climatic conditions which vary exceedingly with location and time of year. In addition, the local variation in soil condition and topograpny will affect the application of the technology, as will traditional agricultural practices. Because of these highly variable circumstances, the application of the Best Practicable Control Technology Currently Available must be tailored on an individual basis to the local prevailing situation. This should be done in accordance with the advice of the knowledgeable technical experts available to the agricultural community.

Age and Size of Equipment and Facilities There are no inherent technical restrictions in the application of the Best Practicable Control

Technologies Currently Available based upon feedlot age and/or size. Regardless of age or size of the facility for any given animal type, the essential characteristics of both the waste products and their means of production and treatment are the same. However, smaller sized feedlots may incur higher costs of implementation per unit of production than larger feedlots. These smaller feedlots may be less profitable and more affected by these costs; however, they do account for a significant percentage of the industry.

Total Cost of Application in Relation to Effluent Reduction Benefits

As noted above, because of the total size and diversity of the feedlot industry, its geographical distribution, and the associated variations in climate, topography and soil conditions, a completely reliable estimate of total investment costs required of the industry in achieving the specified effluent limitation is beyond the scope of known information. However, based upon what may be synthesized from available information, between $0.5 and $1.0 billion approximates the range of total investment for the remaining costs to be incurred. Furthermore, the selection of the Best Practicable Control Technology Currently Achievable was based upon the existence of feedlots representative of all sizes and types presently applying this technology in all parts of the country, and the lack of available alternative technologies. Of importance is that among the smaller, less commercial types of feeding operations, relatively less implementation of runoff controls has taken place for any type of storm condition. Consequently, the 10 year, 24 hour rainfall event serves as a reasonable baseline upon which to develop a nationally uniform runoff control requirement for all operations which conforms to the purposes of the Act ad which available data indicates is economically within reason for the industry to implement. There is, therefore, a high likelihood of achieving the elimination of pollutant discharge to navigable water bodies which would warrant this investment.

Processes Employed

The processes employed in the feedlot industry are described in Section IV of this report, and result in the industry categorization and sub-categorization described in that section. All of the feedlots within s sub-category use the same or similar production methods which result in discharges which are also similar. There is no evidence that operation of any current production process or sub-process will substantially affect capabilities to implement the Best Practicable Control Technology Currently Available.

For ducks, the treatment technology is based on processes employed at the present time by nearly 50% of the industry in response to state regulations.

Engineering Aspects of Control Technology Applications

These technologies have a long history of application and represent, to a great extent, the prevalent agricultrural practices prior to the 1940's. These technologies are presently in full scale use on commercial operational feedlots with a high degree of reliability and technical efficiency.

The amount of wastes that must be contained and/or stored in order to implement zero discharge is dependent upon the length of the crop growing season and the amount of contaminated runoff which occurs during the storage period and must be determined individually for each local situation.

With respect to duck growing operations, data were insufficient for detailed effluent analysis of even the most efficient treatment systems. The limitations therefore are based upon biological treatment (with equivalent of a five day contact time) followed by settling and chlorination to a BOD reduction of 90 percent; which when applied to an average raw waste load of 20 lb BOD per 1,000 ducks per day results in an effluent of 2.0 lbs BOD per 1,000 ducks per day. The current New York State limiation of 50 mg/l BOD results in a similar effluent quality when related to a flowrate of 4.0 gallons per duck per day (as currently achieved by several wet lot and dry lot operations). Coliform levels were established following a review of limits recommended by the National Technical Advisory Committee which was established under the Water Quality Act of 1965. The median in-stream coliform limit of 70 MPN (Most Probable Number) for shellfish water was the recommended level. The Environmental Protection Agency manual, Recommended Uniform Effluent Concentration provides for fecal coliform levels of 400 counts per 100 bml (months May to October) and 2,000 counts per 100 ml (months November to April). The former number particularly will protect watercourses for contact recreation. The in-stream limit of 70 MPN would also afford this prctection but may require extreme levels of chlorination of effluents which can create problems if chlorine residuals inhibited beneficial in-stream aquatic organisms. Consequently, the effluent limits for fecal coliform were selected.

Process Changes

These technologies are completely end-of-process technologies and will, therefore, not require any process changes to the feedlots within the industry.

Certain areas (particularly nrothern, humid regions) of the country have climate conditions which are such as to require a runoff control system which contains both a peak event (specific storm) and a period of precipitation storage during which time ground is frozen or too wet for usual land utilization practices. Other areas (such as the southern regions) require more dependence on a specific design event since access to land for waste disposal is normally available. In either case, if a design event is known, minimum runoff control requirements can be readily implemented.

Non-Water Quality Environmental Impact

The application of the waste products from feedlots to the land for the efficient production of crops is judged to have no additional impact upon the environment than does the use of chemical fertilizers for the same purpose. Where wastes are stored in an exposed manner under anaerobic conditions, there will be unpleasant odors and this situation should be limited to circumstances where potentially affected local populations are sufficiently removed.

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 by 1 July 1983 has been determined by identifying the very best performance by a specific feedlot within its category of sub-category. The technology applied by these feedlots to achieve these effluent limitations is termed Best Available Technology Economically Achievable.

Consideration has also been given to:

a. The age of equipment and facilities involved.
b. The process employed.
c. The engineering aspects of the application of various types of control techniques.
d. Process changes.
e. The cost of achieving the reduction in effluent resulting from the application of the technology.
f. Non-water quality environmental impacts (including energy requirements).

In-process control options which have been considered in establishing the effluent limitations have included:

- Alternative water used
- Water conservation
- Waste stream segregation
- Water re-use
- By-product recovery
- Re-use of waste wa#er constitutents
- Waste treatment
- Good housekeeping.

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

For the purposes of this Section, wastewater refers to (1) rainfall runoff, and (2) flush or washdown water for cleaning animal wastes from pens, stalls, milk center areas, houses, continuous overflow watering systems or any similar facility. The effluent limitation reflecting this technology for all animal types and all identified subcategories thereof cited in Section IV: beef cattle, dairy cattle, swine, chickens, turkeys, sheep, horses, and ducks, is "no discharge" of wastewater pollutants to navigable water bodies for runoff from any and all precipitation events up to but excluding incremental runoff from a climatic event in excess of the 25 year, 24 hour rainfall event as established by the U.S. Weather Bureau for the region in which the point source discharge is located.

IDENTIFICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

In addition to the technologies cited as Best Practicable Control Technology Currently Available, there are technologies which are either not fully available for general use or sufficiently demonstrated to provide a high degree of confidence in the engineering and viability of the technology. These technologies are included under the category of Best Available Technology Economically Achievable because they offer an opportunity for a future choice toward providing increased flexibility and economic viability.

These technologies are presently being demonstrated in field operation on a feedlot or at a university with wastes collected and utilized in a manner representative of a commercial situation. Hardware components, configuration, and controls accurately represent full scale operation. At the present time, sufficient confidence in the systems appears to exist to warrant investment by industry for commercial application. The following technologies are thus designated Best Available Technology Economically Achievable in addition to those technologies described in Section IX.

Wastelage - A technology in which cattle manure is ensiled along with standard feed ingredients and refed to cattle. This is a partial treatment utilizing 40% - 50% of the available waste. The required land for spreading of the remaining waste is reduced and there is the potential for reducing the cost of production. The technology of wastelage has been demonstrated over the past eleven years with a total of over 300 head of cattle. The lack of Food and Drug administration (FDA) approval for the use of manure or the products from manure for refeeding is a restraint upon the large scale commercial acceptance of this technique.

Dehydration With Refeed - A technology in which poultry manure is thermally dried and used as a feed ingredient in the diet fed to poultry. This is a partial treatment utilizing 50% - 75% of the available waste. The land required for spreading of the remaining waste is significantly reduced and there is the potential for reducing the cost of production. The technology has been demonstrated by refeeding for over one full year with a 400 bird flock of laying hens. The lack of FDA approval for the use of manure or the products from manure for refeeding is a restraint upon the large scale commercial acceptance of this technology.

Oxidation Ditch With Refeed - A technology which utilizes the mixed liquor from cattle and swine oxidation ditches as an animal feed ingredient. This is a partial treatment utilizing about 40% of the oxidation ditch effluent. The required land for spreading of the remaining waste is reduced and there is the potential for reducing the cost of production. This technology of oxidation ditch mixed liquor refeed has been demonstrated over the past two years in five feeding trials and over 400 animals.

Activated Sludge - A technology for the treatment of dairy wastes at thermophilic temperatues with extended aeration which produces a reuseable water and a soil conditioner. The soil conditioner is a wet product which must be disposed of by application to the land or further processed for storage, transportation and sale for use on land not immediately available to the feedlot. This is a proprietary process which is presently being demonstrated on an 80 head experimental dairy farm.

Complete Confinement Dry Lot Duck Process - A technology in which ducks are produced in complete confinement with the entire growing cycle within one building. There are no outside duck runs. The water usage is a minimum, and water is recycled.

The housing is partially solid floor with waste gutters under a screen floor. Gutter wastes are flushed out of the building with recycle water, and solid wastes with litter are scraped for removal. The flush water passes through a "clarifier" where the solids are settled and pumped to holding ponds. The liquid effluent from the clarifier is treated in an aerated lagoon and then in a settling pond prior to being used for recycle flush water. The excess recycle flush water is used to irrigate pasture or cropland. The solids from the manure holding ponds and the scraped solids from the houses are spread on cropland for fertilizer. This system has been practiced by a commercial duck grower without the flush recycle and will be expanded to include recycle flush in some buildings if state authorities approve the plans.

Recycle Water Wetlot Duck Process - A technology in which ducks are produced on outside duck runs with the effluent water subjected to treatment and then reused. The treatment consists of primary settling followed by aeration and final settling. Subsequent to final settling, the water is chlorinated and pumped to a storage pond which is used to feed the duck runs. Make-up water from wells is added to the storage pond as necessary. Once a year the duck run and settling ponds are dredged to recover settled solids for land spreading. This system is presently being implemented by a commercial duck producer in a major duck production region.

RATIONALE FOR THE SELECTION OF BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

The factors considered in selecting the effluent limitation for the animal types, beef cattle, dairy cattle, swine, chickens, turkeys, sheep, and horses, is the same as described in Section IX.

With respect to runoff, a number of feedlot operations have controls which serve not only to implement the concepts addressed as Best Practicable Control Technology Currently Available, but also accomplish a higher degree of control than normally encountered. That is, runoff controls are sufficient to eliminate discharge of runoff from a storm equivalent to a 25 year, 24 hour event. As a matter of initial design, consideration of the runoff from this event is about 10.0 percent more than for a 10 year, 24 hour storm. As with control requirements for the smaller event, however, practical application is such that any one of a number of in-place systems would meet the storage requirement: (1) design for the 25 year event; (2) design for net storage structure performance to control the 25 year event, e.g., a design storage period and a peak flow storage; (3) an extended (one to several months) design storage period.

The additional degree of runoff controls thus required for Best Available Technology Economically Achievable will provide a logical endpoint for pollution control of runoff. Beyond the 25 year, 24 hour situation, rainfall is likely to fall into the area of "natural diaster" or outright flooding for which practical application of controls at the individual farm level is neither economical nor technically viable. Moreover, the relatively modest additional storage or containment requirement further enhances the likelihood that "slug" flow discharges from a series of very small rainfall events will be minimized.

The effluent limitation of "no discharge" to navigable water bodies for the duck feedlot industry is based upon the existence of commercial operations presently in the process of implementing the described technologies on a commercial basis. These examples include both dry and wet lot production which are the major processes practiced by the industry. There is some technical risk associated with these technologies which will be resolved when they are in complete operation. These technologies are being implemented by these commercial operations by changes to existing facilities.

SECTION XI

NEW SOURCE PERFORMANCE STANDARDS

NEW SOURCE PERFORMANCE STANDARDS

Introduction

A new source is defined to mean "any source, the construction of which is commenced after the publication of proposed regulations prescribing a standard of performance". Technology to be utilized for new sources has been evaluated by considering the best in-process and end-of-process control technology identified as Best Available Technology Economically Achievable in Section X and considering the utilization of alternative production processes and operating methods.

The following specific factors have been taken into consideration in the determination of performance standards for new sources:

a. The type of process employed and process changes
b. Operating methods
c. Recovery of pollutants as byproducts.

New Source Effluent Limitation

For the purposes of this Section, wastewater refers to (1) rainfall runoff, and (2) flush or washdown water for cleaning animal wastes from pens, stalls, milk center areas, houses, continous overflow watering systems or any similar facility. The effluent limitation for new sources is no discharge of wastewater pollutants to naviagable water bodies for runoff from any and all precipitation events up to but excluding the incremental runoff from a climatic event in excess of the 25 year, 24 hour rainfall event as established by the U.S. Weather Bureau for the region in which the point source discharger is located.

End-of-Process Technology

The initial end-of-process technology utilized should be that defined as Best Practicable Control Technology Currently Available for all animal types except ducks, for which the Best Available Technology Economically Achievable should be utilized. It should be kept in mind that at a future time some of the technologies defined as Best Available Technology Economically Achievable and those listed below as Experimental Technologies, may provide a more effective and economical production-treatment system:

- Aerobic Fermentation and Refeed
- Algae Culture and Refeed

- Anaerobic Fermentation and Refeed
- Anaerobic Production of Fuel Gas
- Barriered Landscape Water Renovation System
- Biochemical Recycle Process
- Chemical Extraction and Refeed
- Conversion to Industrial Products
- Conversion to Oil
- Fly Larvae Production and Refeed
- Gasification
- High Rate Land Disposal
- Hyacinth Culture and Refeed
- Hydrolysis and Chemical Treatment
- Oil Pooduction by Pyrolysis
- Spray Runoff Treatment
- Trickling Filter Treatment

The above technologies are further described in Section VII.

In-Process Technology

The in-process features which should be considered for all new sources should include:

Site Selection - Considered on a national and local basis, the factors to be considered are: suitability of the geographic area for the production of specific animals, local topography, climate, location of receiving surface waters, availability of cropland, soil conditions, sub-surface water location and quality, population locations, and the prevailing wind direction.

Method of Production - The method should be best suited to the animal type and site location. This involves choice between open or confined housing, liquid or solid waste management systems, type of waste management pre-treatment, good housekeeping practices, and the use of recycled water. The above technologies are described further in Section IV and Section VII of the report.

SECTION XII

ACKNOWLEDGEMENTS

The Environmental Protection Agency expresses appreciation for the support in preparinq this document provided by Hamilton Standard Division, United Aircraft Corporation which program was directed by Mr. Danield J. Lizdas, Project Manager, assisted by Mr. Warren B. Coe, Lead Project Engineer. The major contributinq Project Engineers were Messrs. Eric E. Auerbach, Arthur K. Davenport, Donald R. McCann and Michael H. Turk.

Special recognition is offered to the consultants who provided invaluable technical assistance as cited:

Dr. Dan M. Wells, P.E.
Director, Water Resources Research Center
Texas Tech University
Lubbock, Texas (Beef Cattle)

Dr. Raymond C. Loehr, P.E.
Diector, Environmental Studies Program
Cornell University
Ithaca, New York (Dairy Cattle)
(Chickens)
(Ducks)

Dr. Frank J. Humenik
Professor, Department of Agricultural Engineering
North Carolina State University
Raleigh, North Carolina (Swine)

Dr. John M. Sweeten
Agricultural Engineer
Animal Waste Management
Agricultural Extension Service
Texas A and M University
College Station, Texas (Sheep)

Dr. Joseph G. Berry
Department of Animal Sciences
Purdue University
West Lafayette, Indiana (Turkeys)

Appreciation is expressed to Mr. Jeffery D. Denit, Chief, Impact Analysis Branch, Technical Analysis and Information Branch, Effluent Guidelines Division, who served as Project Officer and provided supervision, guidance and assistance throughout the conduct of the project.

Intra-agency review, analysis, and assistance was provided by the Feedlots Industry Working Grou/Steering Committee comprised of the following EPA personnel:

Mr. Ernst P. Hall, Effluent Guidelines Division
(Committee Chairman)

Mr. Lynn Shuyler, Office of Research and Development
Mr. William LaVeille, Office of Research and Development
Mr. Donald Anderson, Office of Research and Development
Mr. Ronald R. Ritter, EPA, Region VII
Mr. Norman Klocke, EPA, Region VII
Mr. Osborne Linquist, EPA, Region VI
Mr. Gary Polvi, EPA, Region VIII
Mr. John Rademacher, Office of Enforcement and General Counsel
Mr. Robert McManus, Office of Enforcement and General Counsel
Mr. Harold Trask, Office of Solid Waste Management

Countless feedlot owners and managers, university professors and proponents of a variety of waste management techniques contributed significantly to the project by hosting site visits or discussing their areas of specialty. Although listing all of their names would be too lengthy, their assistance is gratefully acknowledged.

The Agency further expresses appreciation to the secretaries and support staff of the Effluent Guidelines Division who contributed immeasurably in producing this report: Jane Mitchell, Linda Rose, Kit Krickenberger and Gary Fischer.

Acknowledgement and appreciation is also given to the following individuals who played a vital role in the site visits by making detailed visit arrangements and accompanying the Hamilton Standard personnel and Project Officer on most of the visits:

Brad Nicolajsen, Region IV EPA
Ozzie Linquist, Region VI EPA
Paul Glasscock, County Agent, Hillsbourough County, Florida
Dr. Larry Baldwin, University of Florida
Dr. Roger Nordstedt, University of Florida
James Frank, Illinois EPA
James Hunt, Indiana Department of Health
Norman Klocke, Region VII EPA
Gary Polvi, Region VII EPA
Norbert Thule, Kansas Department of Health
Bob George, University of Missouri Agricultrural Extension Service
Ubbo Agena, Iowa Department of Environmental Quality
Lanny Icenogle, Nebraska Department of Environmental Control
Leland Jackson, Nebraska SCS
Phillip O'Leary, Wisconsin Department of Natural Resources

Dr. Lynn Brown, University of Connecticut
Dr. R. G. Light, University of Massachusetts
Dr. W. Urban, Cornell University Duck Research Facility
Ken Johanson, Cornell University Duck Research Facility

SECTION XIII

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SECTION XIV

GLOSSARY

INTRODUCTION

The terminology listed herein is intended as an effort to maintain uniformity of understanding in terms used throughout this report. Where applicable, terms and definitions from related fields were adapted.

Standard procedures determining the analytical terms defined herein may be found in Standard Methods, American Public Health Association, New York.

TERMS AND DEFINITIONS

Additives: Microamounts of drugs included in a ration.

Aeration: The bringing about of initmate contact betwen air and a liquid.

Aeration Tank: A tank in which sludge, sewage, or other liquid waste is aerated.

Aerobic: Growing only in air or free oxygen.

Aerobic Bacteria: Bacteria which require the presence of free (dissolved or molecular) oxygen for their metabolic processes. Oxygen in chemical combination will not support aerobic organisms.

Aerobic Decomposition: Reduction of the net energy level of organic matter by aerobic microorganisms.

Algae: Primitive plants, one or many-celled, usually aquatic and capable of synthesizing their foodstuffs by photosynthesis.

Alkalinity: A quantative measure of the capacity of liquids or suspensions to neutralize strong acids or to resist the establishment of acidic conditions. Alkalinity results from the presence of bicarbonates, carbonates, hydroxides, volatile acids, salts, and occasionally borates, silicates and phosphates. Numerically, it is expressed in terms of the concentration of calcium carbonates that would have an equivalent capacity to neutralize strong acids.

Anaerobic Bacteria: Bacteria that do not require the presence of free or dissolved oxygen for metabolism. Strict anaerobes are hindered or completely blocked by the presence of dissolved oxygen and in some cases by the presence of highly oxidized substances such as sodium nitrates, nitrites, and perhaps sulfates. Facultative anaerobes can be active in the presence of dissolved oxygen but do not require its presence. See aerobic bacteria for comparison.

Anaerobic Decomposition: Reduction of the net energy level and change in chemical composition of organic matter caused by micro-organisms in an anaerobic environment.

ASCS: Agricultural Stabilization and Conservation Service.

Backgrounding: The preparation of calves for feedlot by feeding a high roughage ration from the weight of from 182 to 204 kilograms to 272 to 295 kilograms (400 to 450 pounds to 600 to 650 pounds).

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

Barrow: Castrated male pig.

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

Beet Concentrate: A protein supplement that is added to the cereal grains or other carbohydrate source in the ration to adjust the protein content to the desired level for the sex and age of the animal.

Beef Yearling: Bovine being fed for beef between 1 year and 2 years of age.

BOD (Biochemical Oxygen Demand): An indirect measure of the concentration of biologically degradable material present in organic wastes. It is the amount of free oxygen utilized by aerobic organisms when allowed to attack the organic matter in an aerobically maintained environment at a specified temprature (20°C) for a specific time period (5 days). It is expressed in milligrams of oxygen per kilogram of solids present (mg/kg = ppm = parts per millions parts).

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

Biological Stabilization: Reduction in the net energy level, and the tendency to purify, of organic matter as a result of the metabolic activity or organisms.

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

Boar: Male pig.

Bovine: Member of the family Bovidae, which are hollow-horned ruminants that have been domesticated and used for meat and milk and hides.

Breeding Herd: Animals that are maintained for the purposes of producing offspring.

Breeding Stock: Usually poultry that are maintained for production of hatching eggs.

Broiler: Chickens of either sex specifically bred for meat production and marketed at approximately 8 weeks of age.

Bull: Male Bovine.

Bulk: Fibrous portion of the ration.

Bunk Feeder or Feed Bunks: A trough that is constructed for the purpose of feeding cattle.

Calf: Young bovine, usually up to weaning or even up to 1 year old. May be called short yearlings.

Cellulose: Plant cell walls that are formed by the combination of many molecules of glucose.

Cereal Grain: The seeds of plants that are high in starch and eigher low or relatively low in fiber.

Chemical Oxidation: Oxidation of organic substances without benefit of living organisms. Examples are by thermal combustion or by oxidizing agents such as chlorine.

COD (Chemical Oxygen Demand): An indirect measure of the biochemical load exerted on the oxygen assets of a body of water when organic wastes are introduced into the water. It is determined by the amount of potassium dichromate consumed in a boiling mixutre of chromic and sulfuric acids. The amount of oxidizable organic matter is proportional to the potassium dicromate consumed. Where the wastes contain only readily available organic bacterial food and no toxic matter, the COD values can be correlated with BOD values obtained from the same wastes.

Chick: Young poultry.

Coagulant: A material, which, when added to liquid wastes or water, creates a reaction which forms insuluble 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.

Cock: Male chicken.

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

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.

Crossbreeding: The crossing of two purebred animals to produce a hybrid offspring.

Dehydration: The chemical or physical process whereby water, which is in chemical or physical combination with other matter, is removed from it.

DES: A synthetic femal sex hormone used to improve the feed efficiency and fattening of steers.

Digestion: Though aerobic digestion is being 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 or organic solid materials by bacterial action alone is never accomplished.

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

Droppings: Animal waste or fecal matter.

Effluent: A liquid which flows from a containing space.

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

Evaporation Rate: The quantity of water that is evaporated from a specified surface per unit of time, generally expressed in inches or centimeters per day, month, or year.

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

Excrete: To throw off waste matter by a normal discharge.

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

Facultative Decomposition: Reduction of the net energy level of organic matter by microorganisms which are facultative.

Farrowing: The act of giving birth to pigs by the sow.

Farrowing Crate: Equipment to house a sow at farrowing time to prevent her from crushing the young offspring.

Feces: Excrement from the bowels consisting of food residues, bacteria, and intestinal excrement.

Feeder Cattle: Cattle that are to be placed in feedlots for the purpose of fattening.

Feeder Pig: Pigs that are to be placed in finishing lots for the purpose of fattening.

Feed Supplement: Materials included in the ration to provide needed nutrients to balance the ration for the specific sex and age of the animal.

Fertilizer Value: The potential worth of the plant nutrients that are contained in the wastes and could become available to plants when applied onto the soil. A monetary value assigned to a quantity of organic waste represents the cost of obtaining the same plant nutrients in their commercial form and in the amounts found in the waste. The worth of the waste as a fertilizer can be estimated only for given soil conditions and other pertinent factors such as land availability, time, and handling.

Filtration: The process of passing a liquid through a porous medium for the removal of suspended or colloidal material contained in the influent liquid by a physical straining action. The trickling filter process used in waste water treatment is a method of contacting dissolved and colloidal organic matter with biologically active aerobic slime growths, and is not a true filtration process.

Finish: Feeding animals to improve the quality of lean meat, by storage of fat between the bundles of fibers, often called marbling.

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

Forage: A crop that is grown for the feeding of the entire plant rather than just the seeds.

Gilt: Young or immature female pig.

Hatchery: A business or building engaged in the hatching of chicks or the production of baby chickens.

Haylage: Silage made from hay.

Heifer: Young or immature female bovine.

Hen: Mature female chicken.

Hog: A domestic swine weighing more than 54.5 kilograms (120 pounds).

Hydraulic Collection and Transport System: The collection and transportation or movement of waste material through the use of water.

Incineration: The rapid oxidation of volatile solids within a specially designed combustion chamber.

Infiltration: The process whereby water enters the environment of the soil through the immediate surface.

Infiltration Rate: The rate at which water can enter the soil. Units are usually inches of water per day.

Influent: A liquid which flows into a containing space.

Inoculum: Living organisms, or an amount of material containing living oragnisms (such as bacteria or other microorganisms) which are added to initiate or accelerate a biological process (e. g., biological seeding).

Lagoon: An all-inclusinve term commonly given to a water impoundment in which organic wastes are stored or stabilized, or both. Lagoons may be described by the predominant biological characteristics (aerobic, anaerobic, or facultative), by location (indoor, outdoor), by position in a series (primary, secondary, or other) and by the organic material accepted (sewage, sludge, manure, or other).

Lamb: Young or immature sheep.

Layer: A mature hen that is producing eggs.

Laying Houses: Where laying hens are kept.

Liquification: Any of several processes whereby solids are converted to liquids. Suspended solids may be liquified by the biochemical action of microorganisms, or by the physical-chemical process of dissolving. Liquification is often used as a term for the operation whereby water or agitation or both are used to convert semi-solid manure into thick slurries or somewhat thinner solid suspensions.

Liquid Manure: A suspension of livestock manure in water, in which the concentration of manure solids is low enough so the flow characteristics of the mixture are more like those of Newtonian fluids than plastic fluids.

Litter: Particles of solid material, usually organic but not readily decomposable, used as holding for poultry.

Manure: The fecal and urinary defecations of livestock and poultry. Manure may often contain some spilled feed, bedding or litter.

Manure Pit: A storage unit in which accumulations of manure are collected before subsequent handling or treatment, or both, and ultimate disposal. Water may be added in the pit to promote liquification.

Methemoglobinemia: Nitrate/Nitrite poisoning.

Milking Parlor: A confined sanitary area where cows are milked mechanically.

Milo: A grain sorghum classed as cereal grain, grown in the more arid parts of the country. May be included in the ration to replace corn.

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 lagoon.

Oxidation Pond: Synonymous with aerobic lagoon.

Pasture: An area where the animals are premitted to harvest the forage freely.

pH: The symbol for the logarithm of the reciprocol of the hydrogen ion concentration, expressed in moles per liter of a solution, and used to indicate an acid or alkaline condition. (pH 7 indicates neutral; less than 7 is acid; greater than 7 is basic.)

Percolation: The movement of water through the soil profile.

Percolation Rate: The rate, usually expressed as a velocity, at which water moves through saturated granular material.

Pig: The young of the hog.

Playa: An undrained basin in an arid region that sometimes becomes a shallow lake on which evaporation leaves a deposit.

Pollution: The presence in a body of water (or soil or air) of substances of such character and in such quantitiies that the natural quality of the body of water (or soil or air) is degraded so it impairs the water's usefulness or renders it offensive to the senses of sight, taste, or smell. Contamination may accompany pollution. In general, a public health hazard is created, but in some cases only economy or esthetics are involved as when waste salt brines contaminate surface waters or when foul odors pollute the air.

Poult: A young immature turkey.

Pullet: An immature female chicken.

Putrefaction: A process of decomposition in which, as a consequence of the breakdown of proteins, end products with offensive odors are formed.

Ram (Buck): A mature male sheep.

Range: Open pasture, usually considered to be the western portion of the United States, where cattle and sheep are raised on native grasses grown on rather rough terrain.

Residues: Minute amounts of a drug remaining in tissue following administration of the drug to an animal.

Roughage: Foodstuff high in fiber.

Ruminant: A herbivore that has three forestomachs that digest cellulose located ahead of the true stomach, or abomasum.

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.

Seepage: The movement of water through the ground surface; influent seepage is movement of water from surface bodies of water into the soil; effluent seepage is discharge of water from the soil to surface bodies of water.

Self Feeding: The practice of having feed available to the animal at all times.

Septic Tank: A single-story settling tank in which the organic portion of the settled sludge is allowed to decompose anaerobically without removal or separation from the bulk of the carrier water flowing through the tank. Only partial liquifaction and gasification of the oragnic matter is accomplished, and eventually, the undecomposed solids will accumulate to the extent that solids removal is necessary,

Settleable Solids: Those suspended solids contained in sewage or waste water that will separate by settling when carrier liquid is held in a quiescent condition for a specified time interval.

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.

Silage: Cellulosic material that is placed in an air-tight container and undergoes fermentation.

Slatted (Slotted) Floor: A confinement system that has a floor with openings that permit the feces and urine to be worked through and into a lagoon or ditch below.

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-solid liquid mass.

Sow: A mature female hog.

Steer: A castrated male bovine.

Suspended Solids: Solids that either float on the surface of, or are in suspension in water, sewage or other liquid wastes, and which are largely removable by laboratory filtering.

Swine: Pigs or hogs.

Tilth: State of soil aggregation.

Total Solids: The residue remaining when the water is evaporated away from a sample of water, sewage, other liquids, or semi-solid masses of material and the residue is then dried at a specified temperature (usually 103°C).

Urine: A watery solution voided by animals. Urine contains the end-products of nitrogen and sulfur metabolism, salts, and pigments.

Volatile Acids: Low-molecular-weight organic acids, used as control parameters in anaerobic digestion. A low figure for volatile acids (400 - 2000 mg/lit), under normal conditions, would indicate that digestion is proceeding satisfactorily.

Volatile Solids: That portion of the total or suspended solids residue which is driven off as volatile (combustible) gases at a specified temperature and time (usually at 600°C for at least one hour).

Wastelage: A combination of manure and forage placed in a silo followed by fermentation.