Chapter 4

Swine Manure Management

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Production of pork is a major agricultural enterprise in the United States, and a majority of the production occurs in the Midwest (Ohio to Nebraska and Minnesota to Missouri) and North Carolina. Seventy-nine percent of the hogs and pigs marketed in 1987 (96.6 million head) were produced in the north-central region of the United States (Bureau of the Census 1989). Iowa has ranked first in hog inventory since 1980, and in 1987 was estimated to have 25.6 percent of the December 1 inventory of 53,795,000 hogs and pigs on farms. Inventory on farms tends to fluctuate between 50 and 70 million swine in a 4- to 7-yr cycle.

In 1980, 21 percent of the growing-finishing pigs (pigs raised from 12 to 100 kg for meat production) and 45 to 50 percent of the nursing and nursery pigs in the United States were housed in confinement facilities (that is, liquid-manure systems; VanArsdall and Nelson 1984). With the large influx of new confinement construction, especially the construction associated with contract production units in North Carolina and Iowa, it is logical to predict a major increase in the percentage of manure captured and stored as a liquid or semiliquid.

The Corn Belt States are expected to remain the primary hog production area, although some shifts within the area will occur. Because of historically lower feed grain prices and lower human population densities, pork production is expected to expand west of the Mississippi River, especially in the western (Kansas, Colorado, and Wyoming) and southwestern fringe (Oklahoma) areas of the Corn Belt (Hurt et al. 1992).

Expansion will be governed in part by individual state laws or constitutional amendments regarding corporate ownership of livestock. These laws can vary tremendously from one state to the next. Currently, Nebraska has an amendment to its constitution restricting nonfarm corporate ownership of livestock destined for slaughter while Wyoming is using municipal bonds as a source of financing to attract corporate production units. Similar differences exist among other states.

One of the primary issues associated with the production of pork and expansion of production is the disposal of the animal manure and the odor associated with animals and manure storage facilities. Traditionally, swine manure has been returned to the land in some manner in the production areas; however, land application has come under attack in rural areas because of the odor problems during application. Estimates are that swine manure production accounts for 12 to 15 percent of the total livestock waste produced annually in the United States (VanDyne and Gilbertson 1978).

Today's swine production systems have become larger, more specialized, and more dependent on purchased feed supplies than in the past. Environmental problems associated with swine production during the 1950's and 1960's were often overlooked. However, swine production was characterized by small, individual systems that relied on recycling of animal manures back to the land as a major nutrient source for the farm. In the last 20 yr, many structural changes have occurred in the industry. These changes have caused concern over the environmental effects of swine manure management. The industry is rapidly consolidating. A recent University of Missouri study (Rhodes 1990) indicates that larger production systems are growing the fastest in terms of percent market share. This study shows that only the farms with annual sales of over 1,000 head are expanding. In 1988 large farms (those with more than 1,000 head) produced over 60 percent of the market hogs.

The environmental effects of swine manure storage systems and application methods are a concern, particularly with respect to surface water and groundwater quality and to air quality as affected by odors and gaseous emissions from large-scale swine production operations.

Manure Production and Composition

Swine manure composition may be estimated from various sources (Midwest Plan Service 1985, American Society of Agricultural Engineers (ASAE) 1990). Some estimates of swine manure's fertilizer components available to the plant are listed in table 15. In ASAE (1990), data are given for estimates of daily manure production for various species and means and standard deviations of physical and chemical characteristics of the manure. Swine are estimated to produce daily raw manure of as much as 8.4 percent of body

Table 15. Mean (in parentheses) and range of values for composition of swine manure from various handling systems

Handling system	Dry matter (percent)	Nutrients available to the plant			
		Ammonium N	Total N	P	K
For solid manure		---------- $g\ kg^{-1}$ ----------			
With bedding	15–20 (18)	2.7–4.0 (3.1)	4.0–4.9 (4.5)	1.4–2.6 (1.8)	2.2–3.7 (3.0)
Without bedding	17–20 (18)	2.2–3.6 (2.7)	3.1–4.5 (3.6)	1.0–2.0 (1.4)	2.2–3.3 (2.6)
For liquid manure		---------- $g\ L^{-1}$ ----------			
Anaerobic storage	2–7 (4)	2.5–3.7 (3.1)	3.4–6.6 (4.3)	0.7–1.6 (1.4)	1.2–3.0 (2.2)
Lagoon	0.3–2.0 (1)	0.2–0.6 (0.5)	0.4–0.7 (0.5)	0.05–0.2(0.1)	0.2–0.6 (0.4)

Source: Adapted from Sutton et al. (1983).

weight (urine and feces). Sweeten (1992) estimated the total production and nutrient content of swine manure in the United States in December 1988 to be as follows:

Number of head	55,299,000
Annual manure production (solids)	14.1 million Mg
Annual N production	0.66 million Mg
Annual P production	0.42 million Mg
Annual K production	0.66 million Mg

More recent calculations indicate that the annual production of P and K should be about 0.23 and 0.37 million Mg, respectively.

Since much of the nation's swine manure can be collected, stored, and spread on the land surface, this manure could be used as a substantial nutrient source for crops. In fact, if all U.S. swine manure was recovered and applied without loss of nutrients, it could supply the nation's corn crop with one-eighth of its N needs and one-fourth of its P and K needs. It is estimated that over 80 percent of the manure is generated in systems where manure could be collected. Manure handling and storage systems may remove a significant amount of N, but P and K are not likely to be significantly affected by treatment.

As of yet, swine production units are not geared toward retaining nutrients in swine manure. One reason for this is that land for manure application is limited. Many units use anaerobic lagoons to digest manure solids and allow the manure to be handled as a liquid. Anaerobic lagoons may volatilize 70 to 90 percent of the N in the manure. Manure N is converted to ammonia in these lagoons and is lost to the atmosphere. By volatilizing this N, anaerobic lagoons allow land requirements to be decreased to 10 percent of the land required for application of slurry manure.

Swine manure tends to be a relatively homogeneous material from production unit to production unit, unlike manure collected from ruminant animals. The swine in the United States are fed diets similar to those fed to poultry. The swine diet is formulated with corn or grain sorghum and soybean meal, and vitamins and minerals are added to prevent deficiency. In addition to Ca and P additions, Zn is added at 50 to 100 ppm, Cu at 5 to 10 mg kg^{-1}, and Se at 0.3 mg kg^{-1} (National Research Council 1988). As a percentage of the total mineral content in the diet, excreted swine manure is estimated to contain 86 percent of the Cu, 100 percent of the Zn, 79 percent of the Mn, 40 percent of the Ca, 74 percent of the Mg, 59 percent of the K, and 66 percent of the Na offered to the pig (Overcash and Humenik 1976). The FDA held hearings on the environmental impact of selenium additions to all animal diets (Muirhead 1992), and there are current regulations on the additions of Se in animal feed.

The major differences in composition of the manure are dependent on the methods of collection, dilution, and storage and are not diet dependent. About 85 percent of the N in a typical corn and soybean diet is digested (McConnell et al. 1972). The majority of the

N excreted from the pig is as uric acid in the urine and organic N forms in the feces. Phosphorus is excreted as phytic acid (an organic matrix derived from the undigested P in cereal grains) and as other complexes that result from growth and digestion processes. Phosphorus is excreted in both the feces and urine. About 40 to 60 percent of the P in a corn and soybean diet is digested (National Research Council 1988).

It is estimated that corn and soybean diets supply sufficient K for swine of all sizes, and therefore supplemental K is not normally recommended (National Research Council 1988). However, K additions may improve swine growth rate (Mabudiuke et al. 1980, Coffey 1987). Little data exist on the digestibility and retention of increased K in the diet. Thus, no predictions can be made as to the impact of supplemental K additions (generally as KCl) on the composition of swine manure.

Swine nutritionists are evaluating the results of using phytase enzymes in diets to enhance the digestion and use of phytase P in cereal grains. In cereal grains the majority of the P is bound as phytate (National Research Council 1988). This form of P is not readily available to nonruminants because they lack phytase, which cleaves the orthophosphate groups from the phytate molecule (Cromwell et al. 1993). Nutritional P needs in pigs are met by adding inorganic P sources to diets because only 15 percent of the P in corn and 25 percent of the P in soybean are available (National Research Council 1988). The addition of the inorganic P sources leads to 65 to 75 percent of the P being excreted in the manure (Lei et al. 1993). Addition of dietary phytase to swine diets will lead to enhanced use of phytate P from the cereal grains and reduce the addition of inorganic P sources. Improved use of phytase P is generally associated with improved protein use, which will reduce the amount of excreted P. In the Netherlands, it is estimated that N and P excretion by pigs can be reduced by 33 percent and 40 percent respectively by the year 2000 through advances in swine nutrition (Jongbloed and Lenis 1992).

Sodium chloride additions to swine diets have decreased over the years, partially in response to concerns about the fate of Na in stored manure. Generally sodium chloride is added to swine diets at the rate of 0.25 to 0.5 percent to prevent Na deficiency symptoms, with 0.25 to 0.3 percent being the most common addition rate. In anaerobic storage pits, Na levels in manure range from 5,000 to 9,000 mg kg^{-1} on a dry matter basis for dietary additions of 0.2 to 0.5 percent (Sutton et al. 1976). On average for all phases of production, it is estimated that 40-kg pigs produce 182 g of volatile solids per day, and the ratio of volatile solids to total solids equals 0.81 (Overcash and Humenik 1976).

The United States industry is improving the overall conversion efficiency of feed to meat of the swine herd. Better use of nutrients leads to a lower rate of converting food to waste. Current estimates of manure production and composition are based on feed-conversion efficiencies of 3.7 to 3.8 kg of feed per kg of meat. However, many producers have made large advances in production efficiency and now report conversions of 3.3 kg of feed per kg of meat or better. Recent advances in reproductive efficiency also have led to less waste generated from sows and boars as a percent of the total waste stream. Thus, previous estimates of waste production and composition may prove to be inaccurate estimators and in many cases will overestimate both the total volume of production and the composition of the waste produced.

Manure Management Systems

A major change in the structure of the pork-producing industry is also impacting the animal waste issue. While total pork production remains relatively constant in the United States (about 92 to 93 million swine were slaughtered in 1992), the number of farms selling hogs or pigs has declined from 1,273,000 in 1959 to under 200,000 in 1990 (Rhodes 1990). By the turn of the century, the number of farms selling pigs is expected to decline to slightly more than 100,000 (Hurt et al. 1992). In 1988 about 69 percent of the commercial hog slaughter in the United States was from 28,700 operations.

While many swine farms have all their production at one site, an increasing number involve two or more sites, either through production contacts or expanded ownership. Thus, the issue of swine manure is becoming an issue of point source production, especially as it relates to livestock ownership and responsibility for the collected material.

Swine manure is handled as a solid, a semisolid slurry, or a liquid, depending on the type of housing and manure handling system used. Each of these systems has some unique features that add complexity to the problems of manure handling and use, and some of these features are discussed in the text that follows.

Systems for handling solid manure

No more than 15 percent of United States swine are raised on farms using systems designed to handle solid manure. These systems are most commonly used in the western Corn Belt. Smaller production systems may make use of extensive housing systems in which small, roofed buildings are used to handle solid manure. Other small production systems may involve the use of pastures or open feedlots for distributing and handling manure.

In pasture production, manure is generally spread “naturally” by the swine as they graze. Rotation grazing will allow manure to be somewhat uniformly distributed in the forage area except for in watering and feeding areas. In this system little manure is collected and spread on other land. Some overloading of manure in specific areas can be expected if feed and watering systems are not moved frequently, since these areas collect a majority of the manure excreted. Pasture production systems are most common in states where smaller swine farms are more common. Certain areas within states, such as Henry County, IL, have been producing swine on pastures for many years. Pasture production is most common in the mid and southern Corn Belt. However, it is estimated that no more than 5 percent of swine are now raised on pasture.

Open feedlot systems are also common with small- to moderate-sized production systems. These systems are not covered by a roof, and the feedlot surfaces commonly have an accumulated manure layer on them. Solid manure is scraped from the feedlot surface periodically. Scraping frequency may vary from once or twice weekly to once monthly. Some manure is lost from the feedlot surface through runoff from rainfall or snowmelt. Unless some runoff containment system is in place, surface water contamination is possible if the runoff from the feedlot can enter a body of water before manure solids are settled or infiltrated into soils during transport in the runoff.

Research has shown that 5 to 20 percent of the manure deposited on an open feedlot can be expected to be transported from the feedlot via water runoff. The fate of manure nutrients is affected by whether or not a solid settling system is built to contain solids. Runoff losses are highest for K and lowest for P, assuming solids are retained in a solids settling system below the feedlot. Solid storage systems are required to store manure between land disposal events. These storage facilities generally consist of an on-grade concrete pad with low walls surrounding the pad to allow manure to be pushed into storage and removed with a blade or a front-end loader. The overall nutrient value of manure from solid systems is quite variable, and N losses during storage of 20 to 40 percent have been reported for these manure systems. Typical concentrations of N on a dry-weight basis for solid manure applied to land range from 0.45 to 0.55 percent for manure containing no bedding and from 0.25 to 0.50 percent for manure containing bedding.

Other solid systems besides open feedlot systems may also use bedding. The most common bedding material is straw, but wood chips or shredded newspaper are sometimes used. These systems may have totally or partially roofed pens in which bedding is added to absorb urine and to provide insulation for the animals inside unheated buildings. Manure and bedding is periodically removed from the pens, and the pens are rebedded to keep animals clean and comfortable. Once removed, the mixture of manure and bedding can be stored on concrete pads with optional low outside walls to help contain the mixture. Stored manure can be stacked in a pile with a front-end loader or stacking elevator.

Solid manure can be applied to the field using regular box spreaders or side-discharge flail-type spreaders. Some box spreaders require an end gate to prevent leakage of the material from the rear of the spreader during transport.

Systems for handling slurries

Most large-scale swine production systems have totally roofed confinement systems. Bedding is purposely not used so that the manure can be handled as a slurry or as a liquid. Manure converted to a slurry is not diluted much, since little water is added in the conversion process. Liquid manure, however, has been diluted quite a bit since significant water is added to assist with manure transport, treatment, and land application. Slurry manure systems are most common in the north-central region, where manure can be recycled back to cropland and where cool temperatures are not as conducive for lagooning swine manure.

Slurry systems commonly use several types of storage structures. The most common system is the below-floor pit covered with a slatted floor. Until recently, a high proportion of all swine confinement systems using slurry manure used a deep-pit storage system. However, in recent years, there has been more concern over air quality problems in buildings resulting from long-term manure storage in the building. Alternatives to an indoor storage system are in-ground storage tanks remote from the building, aboveground storage tanks, and earthen structures. In-ground tanks may be covered or uncovered, but if left uncovered, they must be isolated with a safety fencing to prevent accidents. Uncovered tanks unfortunately can collect significant snow during winter. Round tanks are becoming more popular as remote tanks, since the shape has structural advantages and these tanks are more easily agitated. Aboveground tanks can be constructed from various materials, but concrete and glass-fused steel are the most popular. Earthen structures provide the lowest cost storage system, but adequate soil investigation and construction controls are necessary to minimize groundwater pollution hazards.

Equipment for handling slurry manure is designed for agitation, pumping, transport, and spreading. Vacuum loading tankers are designed for several functions. However, some systems require more agitation and pumping capacity than available with vacuum loading equipment. Agitation equipment usually consists of a propeller or open impeller. Pumps must be able to chop and pass large-diameter solids in the manure. Tank-type manure spreaders can be mounted on trailers or trucks for field distribution of manure. Direct-injection equipment for immediate incorporation of manure is now common. Direct-injection allows immediate covering of the manure to prevent N loss by volatilization, reduces the potential of surface runoff of N and P, and significantly reduces odor potential.

Manure is most often applied to cropland near the swine production unit. A majority of slurry storage systems can store manure for 120 to 180 days, meaning that manure applications to fields are needed two or three times per year. This sometimes leads to problems with having land available for manure application in the middle of the growing season or during winter. It is estimated that 50 to 60 percent of producers use slurry manure handling systems. These units are most common in the Corn Belt. A slurry manure should be stored for at least 180 days before application in the Corn Belt. The longer storage period minimizes manure application problems, and full-year storage is becoming more popular.

Systems for handling liquid manures

Hydraulic flushing systems have been successfully used for 20 yr for quick, efficient removal of manure from swine confinement buildings. Flushing systems require the use of larger manure storage systems, since significant amounts of dilution water are added to the manure during flushing. Anaerobic lagoons are used extensively for storage and treatment and, in many cases, as a recycling system. Recycled treated lagoon water is often used to minimize storage requirements. In areas where lagoon water can be used for irrigation throughout the year and where adequate fresh water is available for flushing, recycling is not generally practiced. Anaerobic lagoons are also popular for swine production systems in areas with a limited land base, since high losses of N can be expected in anaerobic lagooning systems.

Anaerobic lagoons convert manure to a liquid that is low in solids, allowing easier transport and application. Conventional irrigation equipment can be used to apply anaerobic lagoon liquid to land. Even though higher volumes of waste are produced with these systems, the cost and labor requirements for application of liquid manure are lower than for slurries or solids.

Aerated lagoons can also be used as a storage and treatment system for flushing units. Odors are minimized and recycled water is safer in terms of disease prevention, but the cost of mechanically aerating a swine lagoon is relatively high. Capital requirements and energy and maintenance costs have been high enough to prevent this use of aerated lagoons from becoming common on swine farms, even though aerated lagoons are commonly used for this purpose in municipal and industrial sewage treatment systems.

Odors, potential leakage, overflow, and over application of lagoon effluent are the major environmental concerns associated with anaerobic lagoons. Proper design, loading, and management are required to minimize odor problems. Soil investigations and proper construction techniques are required for groundwater protection. Adequate irrigation equipment is needed to dewater lagoons on a regular basis and to distribute the water over farmland. Nutrient management plans should specify loading rates to properly use the manure product.

Anaerobic lagooning systems do lose significant amounts of N to the atmosphere, but P and K are not lost. It is estimated that 80 to 90 percent of the input N is lost to the atmosphere through ammonia volatilization. A high proportion of the P is contained in sludge from the lagoon. Periodic cleanout of this sludge is required for continued efficient operation of the lagoon. These P-rich sludges should be applied to land with caution so that high levels of P buildup will be prevented.

The majority of the systems using anaerobic and aerobic lagoons are used in warm climates. The majority of large operations (1,000 head per year) are using anaerobic lagoon systems to minimize land application areas. These operations are concentrated in the Southeast, the southern Corn Belt, and the southwest Plains. It is estimated that 20 to 30 percent of the manure from swine production is processed in liquid manure systems.

Manure Handling and Disposal

The major concerns associated with managing manure from swine are related to runoff control from open feedlots, storage requirements, and land application of manure collected from confinement facilities. The runoff control issues for handling this type of manure are very similar to those for handling other types of manure.

Storage and land application problems from confined production units occur due to the large volumes of water often associated with the material. Depending on method of collection and storage, the collected material can contain from 90 to 99.9 percent water at the time it goes into storage.

Generally, growing-finishing pigs weighing 21 to 100 kg can be expected to generate 0.39 to 0.45 kg of waste per day on a dry matter basis (Brumm et al. 1980). This manure contains 1.9 percent P, 7.2 percent N, and 3.2 percent K as byproducts of digestion. Depending on the phase of production and the specific production practices of the pork producing unit, the manure may also contain significant amounts of Cu, which is added to the diet as copper sulfate at up to 250 mg Cu kg^{-1} to promote growth. Swine manure may also contain antimicrobial drug residues, which are added to the diet to enhance growth and improve health (Brumm 1978).

Copper levels and drug residues in manure have in some instances limited the uses of the manure. For instance, manure high in Cu is undesirable for anaerobic storage because it reduces biological activity (Brumm 1978), and manure high in antimicrobial drug residues is undesirable for pilot anaerobic digesters designed to generate methane because of the limited biological activity in the methane generator (Fischer et al. 1978).

Refeeding of collected swine manure to swine has been researched and has been tried on several commercial swine units. However, the large volumes of water associated with typical manure collection has meant that dewatering of some type must be used to generate a material that is easily handled. Refeeding swine manure to a different species (generally beef cattle) has been successful on a limited scale. The possibilities of high concentrations of Cu or other potentially toxic elements or drug residues has limited refeeding to beef animals during their growing stage. This limitation has generally minimized the concern of residues entering the human food chain as a result of refeeding. In general, the primary safety concerns associated with using animal manure as animal feed involve potential harmful residues of pesticides, drugs, toxic minerals, and other toxins, and the hazard of disease transmission (American Society of Animal Science 1978).

Some sow herds are fed dewatered swine manure as a means of enhancing colostral immunity for newborn pigs. Refed manure, however, has been recognized as a possible source of internal parasite reinfestation and dysentery spread. Reuse of stored swine manure as either a source of water for flushing or as a nutrient source in the diet has caused concern regarding animal health. Anaerobic storage in either deep pits or lagoons does not affect the survival of roundworm eggs, *Treponema hvodvsenteriae,* and *Salmonella* spp.

Swine manure that contains small or no amounts of antimicrobial drug residues can be used to generate methane. In general, successful methane generation relies on thermophilic bacteria for the conversion of organic wastes to volatile fatty acids and then to methane. With much of the pork production in the United States occurring in the north-central regions, extensive investments in insulated and even heated facilities have been necessary for this bacterial process to be possible during winter weather.

During methane production only 40 to 60 percent of the volatile solids are converted to methane; 1 m^3 of methane is produced per 0.61 kg of volatile solids converted in the digestion process (Sweeten et al. 1981). The conversion of the organic wastes to methane does not decrease the need for disposal of byproducts. Removal of carbon as methane from the waste stream does not decrease the amount of N, P, K, or other significant elements in the digester effluent.

Land Application of Manure

Problems

Decisions on the best ways to apply swine manure to land are complicated by compromises between achieving best soil erosion control and best conservation of nutrients in manure and use of these nutrients by growing crops. For a long time, extension specialists have recommended that manure applied to the soil be incorporated into the soil surface within 24 hr after land application. This practice can significantly reduce odors and can minimize ammonia volatilization so that N in manure is conserved. Fall application of manure to cropland following harvest is often recommended because the risk of damage from soil compaction is minimized. Spring applications are usually accomplished prior to tillage and planting. Frequently in the spring, soils receiving the manure are close to saturation, resulting in significant compaction from spring application. Also, labor availability often favors fall application.

Many producers, as part of their approved conservation plan with the Natural Resource Conservation Service (formerly the Soil Conservation Service), have agreed to significantly restrict or stop any fall tillage practices as a means of maximizing residue cover at the time of spring planting. Thus, land application and tillage in the fall, long an accepted best management practice for manure application, may result in a violation of the NRCS plan and a reduction in government payments under provisions of the 1985 Food Security Act and the 1990 Food Agriculture Conservation and Trade Act. Direct injection by means of tanker wagons equipped with injection devices has become a common technique for land application in much of the Midwest. However, the injection process disturbs the soil as much as major tillage operations.

Limiting fall applications of manure in the future is likely to have an impact on the cost of storing manure. Currently, most regulations require 90 to 180 day storage capacity for collected animal manure. This requirement capacity generally is based on the growing season for the area or state, on the assumption that manure will be applied to land in the spring or fall. If fall application is no longer feasible due to soil conservation concerns or possible runoff concerns, the length of storage may need to be increased to 270 to 360 days. Longer storage not only increases cost but also increases the workload in the spring when many producers are already very busy.

Some farmers may be able to find use for swine manure in the summer. The traditional corn and soybean farmer who also raises pork may need to add some forage crop to provide a land base for summer applications. Forage crops, however, are generally not useful on swine farms, but producers may have to find a use for these crops in the future.

Impact of manure on the soil

Although manure can be used to supply adequate nutrients to grain crops, it is usually difficult to determine the exact nutrient content of the manure. Sutton (1992) stated that the potential fertilizer value of swine manure may range from $2.50 to $3.50 per market hog sold. He outlined some of the potential problems that need to be addressed concerning the use of swine manure as a fertilizer. Currently, there is no rapid, inexpensive method for testing manure before it is applied to land. Without knowledge of the nutrient content prior to application, it is difficult to apply proper rates to meet the soil fertility requirements. Even if proper rates could be determined, application methods can cause poor or inconsistent distribution of manure in a field.

Nitrogen is often thought to be the primary nutrient available in manure. However, there are proportionally larger amounts of P and K available than N because of the losses of N during storage. Little information exists regarding N losses during storage, but studies show that these losses range from 10 to 90 percent. Application of manure in quantities required to meet the N requirements of corn or other grain crops can lead to excessive supplies of both P and K in the soil. The manure value of a fertilizer must be based on the nutrient supply from all elements and therefore must be based on effective testing of the composition of the swine manure. Midwest Plan Service (1985) provided estimates for N losses during storage and land application, and some of these estimates are shown in tables 16 and 17.

Table 16. Nitrogen loss during storage of manure from different manure handling systems

System	Type of manure	Nitrogen lost (percent)
Daily scrape and haul	Solid	15–35
Bedded manure pack	Solid	20–40
Anaerobic pit	Liquid	15–30
Aboveground storage	Liquid	10–30
Earth storage	Liquid	20–40
Lagoon	Liquid	70–80

Source: Midwest Plan Service (1985).

Table 17. Estimates for the amount of nitrogen that is lost within 4 days of applying swine manure

Application method	Type of manure	Nitrogen lost (percent)
Broadcast	Solid	15–30
	Liquid	10–25
Broadcast/immediate	Solid	1–5
cultivation	Liquid	1–5
Direct injection	Liquid	0–2
Sprinkler irrigation	Liquid	15–35

Source: Midwest Plan Service (1985).

There are various techniques for estimating the amount of available nutrients from manure applied during the year or during a previous year. This estimate will vary greatly with the type and form of manure applied to land. With solid manure or open-lot manure, little N is found in the ammonia or ammonium form, since much of the N in this form has been volatilized prior to land application. Slurry manures may have at least 50 percent of the total N in ammonium N form, which is readily available following application.

The key to estimating N availability after application rests on the mineralization decay rate expected from the breakdown of organic solids after land application. For swine manure, the estimated first-year contribution from organic N in manure can vary from 25 to 50 percent of the total organic N. This is a function of the breakdown rate of solids in the soil, which is a function of particle size, shape, temperature, moisture, and other environmental factors, including the level of antibiotics in the manure. However, with modern feeding systems, manure particle size is small, and mineralization rates approaching 50 percent of the organic N in the first year may be expected. The second-year rate is usually about half of the first-year rate (or approximately 25 percent), and the third-year rate is about half the second-year rate (12.5 percent). Little additional N contribution is expected from swine manure 3 yr after application.

In addition to providing nutrients for the crop, swine manure and other manures are an energy source for microbial activity that promotes soil structure and aggregation and therefore soil quality; however, the mechanism of the process and the ideal application rates have not been identified. The lower N contents reported in lagoon systems may be adequate for maintaining and promoting microbial action in the soil. Soil aggregation and a stable soil structure would improve the infiltration process, decrease surface runoff, and enhance the effect of other soil conservation practices. Manure application just for the purpose of enhancing the soil, however, may not provide sufficient economic incentive for the use of manure.

Management processes for preventing N loss from manure applied to soil are not well understood. Losses of N (as ammonia, nitrous oxide, or methane from the soil) diminish the value of the manure and also may add to the abundance of greenhouse gases in the lower atmosphere. Preliminary studies indicate that the amount of N lost after application is substantial.

Application rates to the soil are dependent upon the soil, crop, climate, manure composition, and mineralization rate. Proper manure application methods and rates should be incorporated into best management practices designed to manage both crop residue levels and soil quality. The amount of land area needed for the effective use of manure will depend upon the composition of the manure and the treatment of the manure after application. Nitrification inhibitors are sometimes used to arrest the rate of mineralization; however, they have not been fully evaluated under field conditions and the results have been variable among different studies. More research is needed to fully understand the most effective manure application methods and rates for different crops and soil conditions.

Disposal of dead animal carcasses

Along with the usual manure problems associated with pork production, a new concern is the disposal of dead animal carcasses. In many states, the legal requirements for disposal call for incineration, burial, or pickup by a commercial rendering service. However, the number of dead-animal rendering services in the United States has declined significantly (Fats and Proteins Research Foundation 1992).

Because of decreased access to rendering services, increased charges for rendering services, frozen ground in winter months, and high fuel costs associated with incineration, many pork producers are evaluating composting of swine carcasses as a disposal alternative. Research information in support of this practice is limited, however, and it is unclear what the legal aspects of this practice are with regard to current state laws and local health regulations.

Effects of Manure on Environmental Quality

Water quality issues

Environmental water quality problems resulting from swine manure use on land have been related to excess manure generation relative to land available for application and to inadequate manure storage and handling facilities. Excess manure application rates, runoff and leachate from manure application sites, and leakage and overflow from manure storage sites represent major environmental concerns. The problem of a manure surplus on swine production farms is exacerbated by low-cost commercial fertilizers, concentration of large (greater than 10,000 head) production units, reduced availability of labor, narrow profit margins, and higher priced land. Low-cost commercial fertilizers contain the essential nutrients (N, P, K) in a uniform mix and in a form more easily transported and applied to the field. Manure application requires many trips to the same field because of the large volume of water in manure. Concentration of large production units creates a surplus of manure relative to the land area for application without incurring large transportation costs. Often these facilities are located in areas with little land base for application, and other disposal methods must be used. Manure application requires labor, and on-farm labor sources are becoming less available. A smaller labor force coupled with the problem of application during the part of the growing season that is already busy leads to problems of effectively using manure. Crop production is on a narrow profit margin, and grain farmers want to decrease the potential risk by applying a nutrient source that will ensure adequate nutrient supply. The narrow profit margin coupled with the high price of land for either purchase or rent creates a situation in which manure is not an attractive nutrient source.

Population equivalent concepts are sometimes used to evaluate the potential for animal production systems to create water pollution problems. However, it is incorrect to assume that a large amount of manure generated by animals is an indicator of actual water pollution, since manure handling systems should be designed to prevent discharge of manure into water bodies. Manure generation is only an indicator of the total *potential* pollution. Modern manure management systems can and should be designed and operated to meet strict discharge guidelines.

Swine manure has several components that can pollute water. These include oxygen-demanding materials (organic matter), plant nutrients, and infectious agents. Color and odor are potential pollutants of secondary importance. Organic matter serves as an energy source for aerobic bacteria in a receiving stream. Increased bacterial metabolism resulting from a discharge of organic waste into a stream increases the oxygen depletion rate of the stream. If the rate of oxygen depletion exceeds the aeration rate of the stream, oxygen depletion occurs. Decreased or depleted oxygen levels can result in fish kills and anaerobic conditions in the stream or other water body.

Organic matter in wastewater has historically been measured as biochemical oxygen demand (BOD). This is a measure of the amount of oxygen required to metabolize waste during a specified time, usually 5 days. BOD is a measure of the organic “strength” of a manure; strength is measured by the oxygen demand during the 5 days.

Another measure of organic strength of a waste is chemical oxygen demand (COD), which is based on chemical rather than biological oxidation. COD will exceed the BOD value for animal wastes, since animal manure and other waste products contain organic materials resistant to aerobic bacterial degradation. COD/BOD ratios vary from 3.5 to 6.5 depending on species and feed rations.

Reduced organic substances such as ammoniacal N also increase oxygen demand. Relatively high ammonia concentrations are found in liquid manures, anaerobic lagoon effluent, and open feedlot runoff. Estimates of organic strength of different animal waste flows are available in many references (for example, Miner et al. 1966, Mielke and Mazurak 1976, Khaleel et al. 1978, and American Society of Agricultural Engineers 1990).

Figure 16 illustrates the relative strength of various types of waste. Note that raw manures have very high organic strengths compared to other common wastes. However, it should be noted that with the exceptions of accidental discharge or excessive precipitation, little, if any, waste should reach streams or other water bodies from animal production units that are environmentally safe.

Swine manures have high concentrations of plant nutrients. These nutrients are beneficial when properly recycled to land. These same nutrients, however, can pollute water bodies if manure is discharged into the water bodies. Nitrogen and P are the plant nutrients of primary concern. If they enter streams, these nutrients can stimulate the growth of aquatic plants, and these plants may have significant impacts on the acceptable water quality of that stream. In addition, high manure loading rates provide high levels of nitrogen, which can, in turn, increase nitrate concentrations of shallow groundwater.

Another potential water pollution hazard resulting from animal production is disease transmission of water-borne organisms. Several diseases can be transmitted in water from animal to animal and from animal to man (Hensler et al. 1970, Young 1974). Some examples include bacterial infections of *Salmonella, Listeria, Leptospiea, Vibrio, Brucella, Coxiella,* and *Chlamydia*. Other infectious agents such as *Mycoplasma*, fungi, and protozoa (*Cryptosporidium*) can also be transmitted in water. Managers of modern manure management systems must take into account the possibility of disease transmission through the environment and must therefore try to prevent improperly treated manure-laden runoff from reaching water bodies.

If swine manure is not handled and applied properly, it can be a threat to surface water and groundwater quality. Waste loading of swine manure discharges to groundwater or surface water is not well documented.

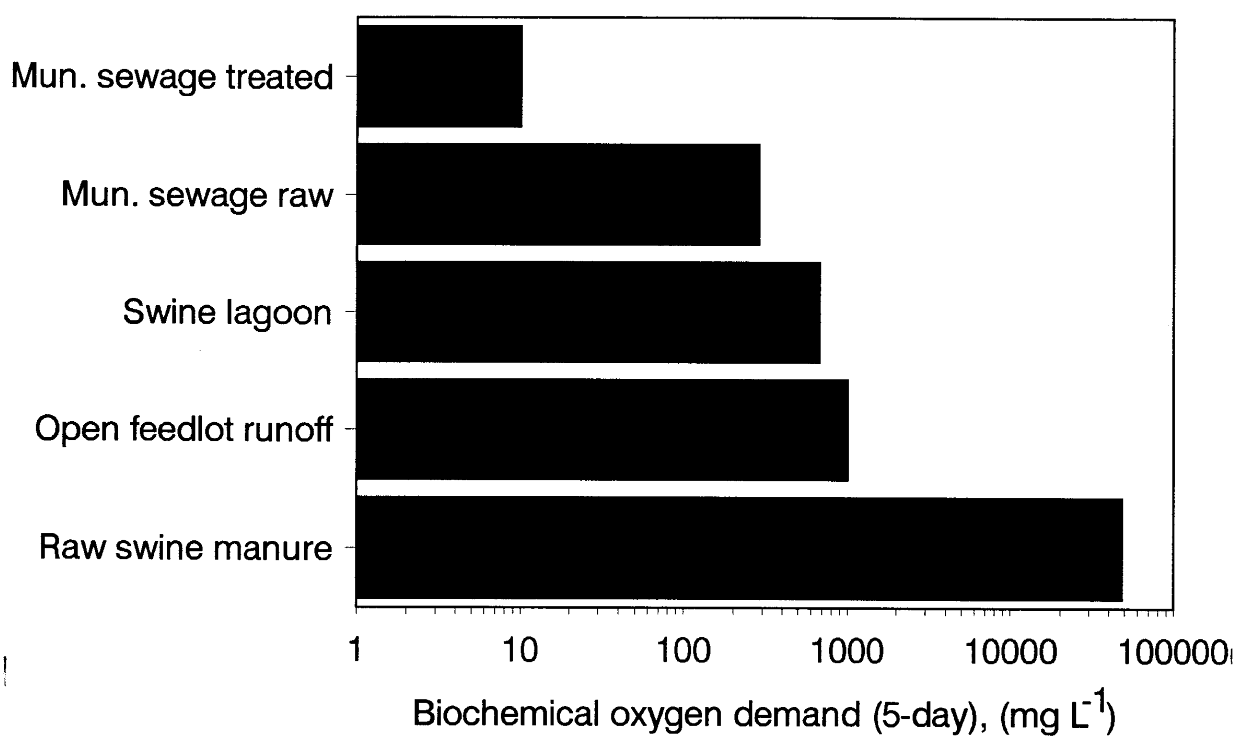

Figure 16. Biochemical oxygen demand of various wastes during a 5-day period

However, research indicates that little manure runs off land when the manure is applied properly. The worst-case scenarios for the incidence of surface runoff would be (1) rainfall occurring after manure is applied to frozen, snow-covered ground or (2) application of liquid manure by irrigation rates that exceed the infiltration rate of soil.

Environmental impacts of manure sites and application problems are just beginning to surface. Excess application rates in fields can lead to increased nitrate concentrations in shallow wells. In many areas, nitrate concentrations in wells often exceed 10 mg L^{-1}. The extent of these problems is not well known, and generally less than 20 percent of rural wells are expected to have nitrate problems; however, the soil above the well and the depth, aquifer material, and position of the well relative to any source will impact the nitrate concentrations.

Another water pollutant commonly associated with outdoor and unconfined animal production is increased sediment in surface water. Animal traffic in pastures, near and along streambanks, and on open feedlots can result in increased erosion in areas with animal production systems. Sediment is normally associated with cropland erosion, but in watersheds with significant permanent surface cover and high water quality, there is a potential impact for sediments from animal production systems to be a problem. Proper design and operation of feedlot runoff control systems and good pasture management can significantly reduce the problem.

Air quality issues

Odor control has become a major environmental concern of the swine industry. Swine producers have identified odor complaints as a major industry environmental issue. Because swine farms are larger and more concentrated, they have a larger potential odor problem. Neighboring residents have apparently become less tolerant of swine odors, since the frequency of lawsuits appears to be increasing. Fewer swine farms are in operation now than in the past, so now neighbors of swine farms are less likely to be associated with the swine industry.

Emission of gaseous wastes from production and manure storage systems has become a major environmental issue in Northern Europe during the past decade. Ammonia discharge from swine production systems is now being regulated in the Netherlands. Ammonia has been associated with acid rain problems in the region. Even though this has not yet been identified as a problem in the United States, there could be some future implications for the U.S. swine industry. Other gases, such as dinitrogen oxide (N_2O), methane (CH_4), and carbon dioxide (CO_2) are all associated with greenhouse effects. Production of these gases is increased through anaerobic treatment of swine manure.

Future Outlook on Swine Production and Research Needs

A study by the University of Missouri (Rhodes 1990) reports that over 50 percent of the nation’s hogs and pigs since the mid 1980’s have been marketed by farms producing more than 1,000 head per year. Nearly 70 percent of all market hogs in 1988 came from units producing greater than 1,000 head per year. In that year, 1,180 operations producing more than 10,000 pigs per year marketed nearly 19 percent of the nation’s commercial slaughter of domestic origin, while a subgroup of larger firms marketing more than 50,000 head produced nearly 6.6 percent of the total. A survey of swine operations in early 1989 found that 30 percent of all operators were planning to expand their farms (Rhodes 1990). Plans to expand were more common among large farms, farms with multiple production units, farms outside the north-central region, and farms having new facilities. Therefore, the structure of the swine production industry continues to change. New, larger farms are expanding outside traditional production regions. Projections are that farms with less than 2,000 head may not be economically viable in the near future (Rhodes 1990).

If the trend of increasing farm size continues, problems with animal rights and animal welfare may arise. In most European countries, an increasing percentage of the breeding herd is being given access to straw bedding during a portion of the gestation and lactation phases of production in response to concerns for the welfare of the swine. If the United States follows the European lead at some future time, either through legislative or consumer pressure, an entirely new set of problems will be created since little information is available regarding the composition, storage, or land application of the resulting high-residue manure material (that is, the manure mixed with straw).

Although another general trend in United States swine production is towards increased confinement production, there is a growing minority of small and not-so-small producers who are intensively producing pigs outdoors. Outdoor pig production allows them to escape some of the high investment costs associated with confinement production units. In addition to the obvious concern regarding surface runoff from these outdoor production farms, there is the issue of nutrient leaching from the intensive production area, especially if stocking rates result in total removal of all vegetation. The United Kingdom now considers some outdoor farms as “nitrate-vulnerable zones” (Worthington and Danks 1992).

Future research on swine manure management must focus on several issues. Manure quality must be enhanced or at least preserved during storage and handling. As discussed previously, quality is affected more by treatment than by diet. Methods that can provide a rapid evaluation of the quality of the manure must be developed. An accurate evaluation of the nutrient content of a manure will be useful in avoiding potential negative environmental impacts to either water or air quality.

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