Swine Waste Management Alternatives

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WASTE MANAGEMENT

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COOPERATIVE EXTENSION SERVICE • MICHIGAN STATE UNIVERSITY

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Waste management in swine facilities has become a more important consideration as a result of larger production systems, scarcity of labor, and more stringent environmental restrictions. An acceptable manure management program requires a well-designed manure handling system as well as sufficient land and equipment for terminal disposal of solid and liquid wastes. Swine manure can be handled as a solid or semi-solid, a slurry (feces, urine and wastewater), or a liquid, such as lagoon effluent or runoff from open lots.

Manure management objectives vary between producers. These may include (1) optimum nutrient utilization; (2) land, labor or capital minimization; (3) odor control; (4) animal or human health and performance, or (5) some combination of two or more of these. Differences in the mix of land, climate, capital, labor supply, and management skills between producers eliminate the possibility of a best manure management system for all.

The purpose of this fact sheet will be to outline the basic advantages and disadvantages of common swine manure systems and to provide information for system selection.

Common Swine Manure Management Systems

Hogs are raised in many different systems today. About 30% of the swine in the U.S. are raised on a concrete slab, 20% on slotted floors, and the rest in drylot or pasture. Production trends are towards slotted floor type confinement systems. Figure 1 shows a flow chart of common swine manure systems that will be discussed in this fact sheet.

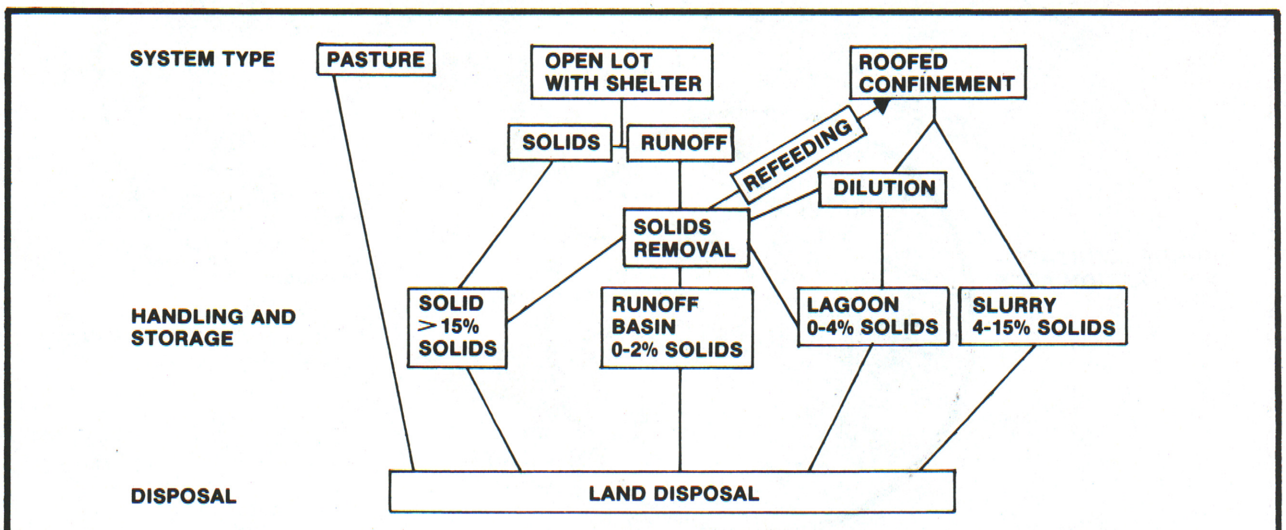

Figure 1. Flow chart of common swine waste management systems considered in this fact sheet.

Pasture Systems. Farrowing and growing operations on pasture have been popular in some areas for many years. Portable houses are normally used to provide seasonal shelter during inclement conditions. These are cleaned and moved to new pasture sites prior to farrowing or to introduction of another group of pigs on feed.

Waste management is essentially automatic in this type of system. If swine are provided sufficient land to sustain vegetation, manure is dispersed sufficiently to require no handling. Rotation of land areas and selection of locations away from steep slopes, streams and drainageways are required to minimize pollution hazards by direct runoff and to provide a lower disease transmission hazard. Pasture loading rates in humid areas should not exceed seven sows and litters per acre or 40 market pigs per acre.

Open Lots with Shelter. Open lot systems may use either paved or unpaved lots. In cool humid areas, housing is provided, while in warm areas, shades may provide sufficient protection. A paved open lot with shelter is shown in Figure 2. Open lots for feeding typically allow 4 - 6 sq. ft. of shelter per animal. For paved lots, an additional 6 - 20 sq. ft. is provided, whereas unpaved lots provide widely varying lot densities from 100 - 1800 sq. ft. per animal, depending on climate and soils.

Manure is generally handled as a solid from open lot systems. Paved lots are sloped for drainage and to assist manure collection. Lots are scraped periodically to reduce buildup of solids and to control odor and fly production. Scraped manure is either stockpiled for later field spreading or directly hauled to land. Manure from solids settling devices on runoff control systems is handled the same way.

Runoff from open lots contains high pollutant levels and needs to be managed to avoid polluting surface waters. In humid areas, a settling basin and a grass infiltration area appear to be the most acceptable runoff control system for most producers with open lots. Large facilities may require a detention basin to contain runoff water for later land disposal to meet environmental regulations.

Roofed Confinement. Manure may be managed as a solid, slurry (semi-solid) or liquid (low solids). Solid floors may be bedded for solid manure handling or may be used with gutters for hydraulic handling. Slotted floors are commonly associated with under-floor storage pits or with shal-

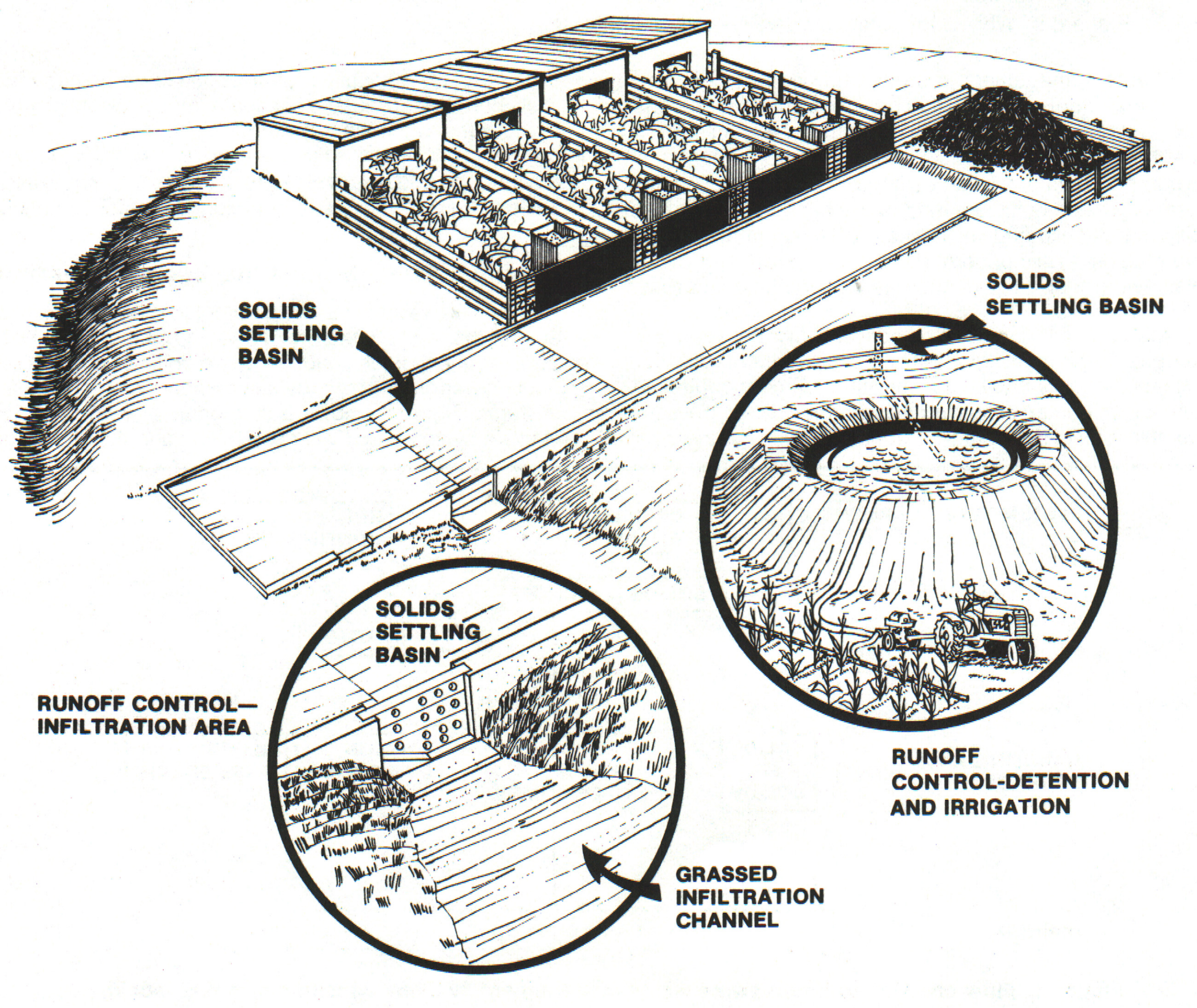

Figure 2. Paved lot with shelter, solid manure handling. Inserts show alternatives for runoff control.

low collection pits that are mechanically scraped or hydraulically flushed to outside storage structures. An example is illustrated in Figure 3.

Pit or storage volume is varied to provide a desired holding time. Critical storage intervals are through winter and early spring when field conditions do not allow spreading and through summer when cropland may not be available for spreading. Mechanical removal of undiluted manure with scrapers from shallow pits below slats has recently become popular. Manure is scraped at least daily to outside storage.

There are two types of solid concrete floor facilities with hydraulic discharge to outside storage or treatment. The narrow-gutter system with outside storage is one of the earliest systems used to hydraulically remove waste from buildings. Manure collected in the gutter (several days' quantity) is released manually to flow by gravity to the storage tank or lagoon. Frequently, storage is provided in either above- or below-ground structures, although earthen storage basins have been used.

The other solid floor system incorporates a shallow channel which is flushed periodically, commonly every 1-4 hrs. The flushing water transports the waste to an outside treatment center. A two-stage lagoon, as shown in Figure 4, is commonly used for flushing systems. For the anaerobic lagoon(s) to function with minimum odor, proper design includes adequate volume and dilution. Provision for irrigating lagoon wastewater on cropland is needed. In warm, dry areas where irrigation is used, fresh water flushing to a single cell lagoon is an alternative to recycling since added water is used as a resource. Design criteria and management requirements for anaerobic lagoons can be found in the *Livestock Waste Facilities Handbook*, MWPS-18, Midwest Plan Service, or in PIH-62, "Lagoon Systems for Swine Waste Treatment."

Waste Characteristics

Manure and wastewater generated from the swine housing systems previously described are highly variable with respect to nutrient strength, handling characteristics, odor levels and pollutant potential. Manure production values are listed in Table 1. Collection and pretreatment requirements can be approximated from Table 2.

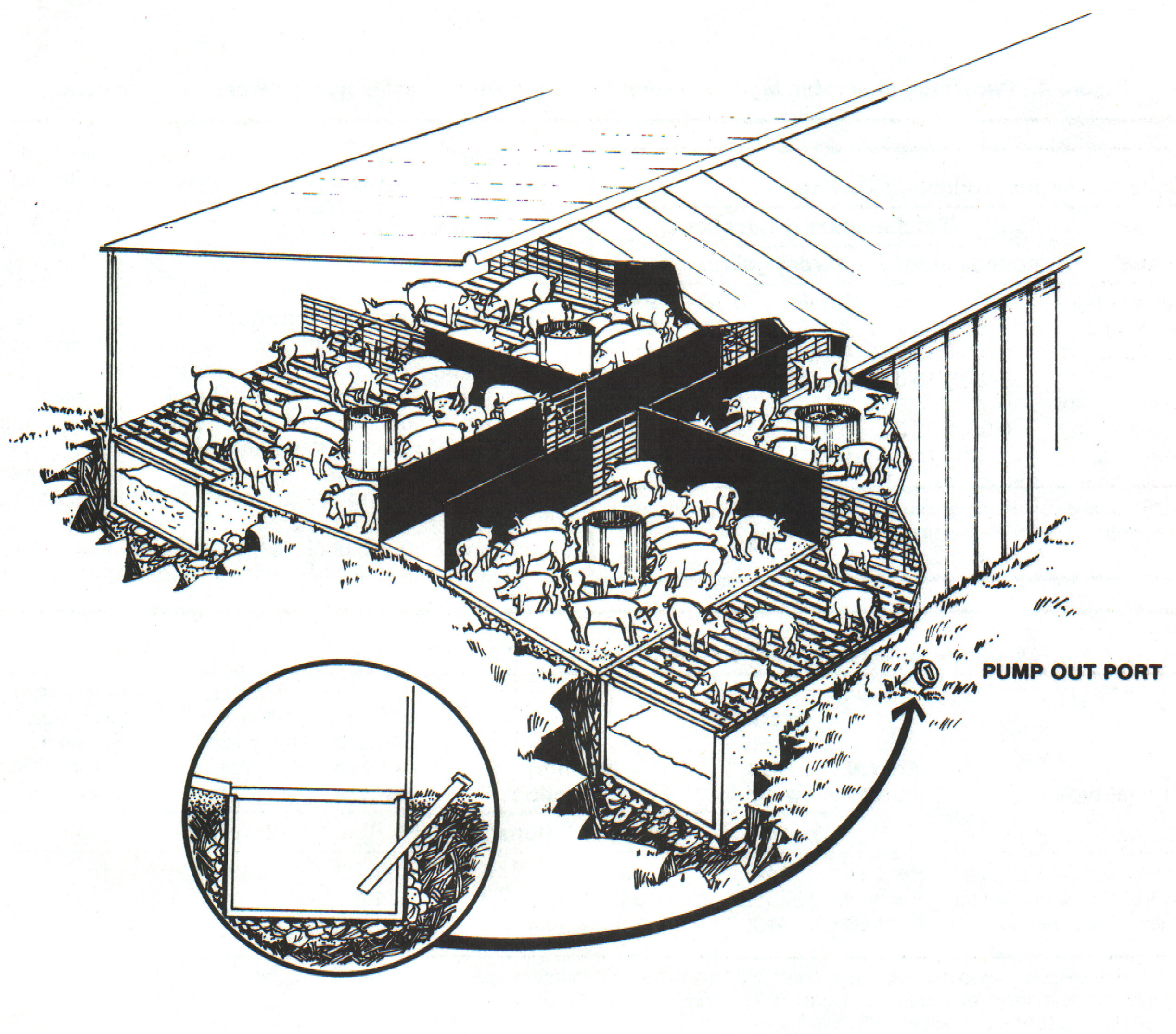

Figure 3. Confined, partially slotted floors, pit storage, liquid handling.

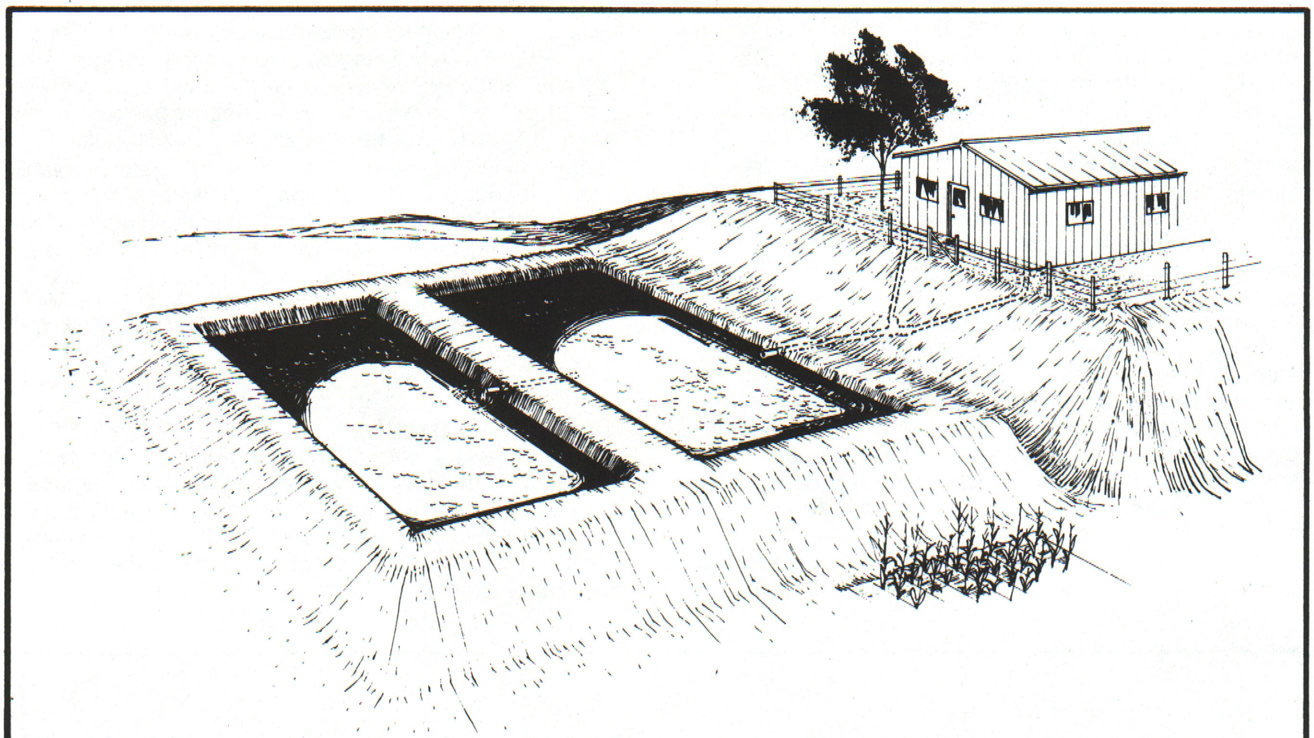

Figure 4. Two-stage anaerobic lagoon system for treatment of wastes flushed from swine building.

Table 1. Manure production - swine.*

Animal	Size pounds	Total manure production lb./day	cu.ft./day	gal./day	Water %
Nursery pig	35	2.3	0.038	0.27	91
Growing pig	65	4.2	0.070	0.48	91
Finishing pig	150	9.8	0.16	1.13	91
	200	13.0	0.22	1.5	91
Gestating sow	275	8.9	0.15	1.1	91
Sow and litter	375	33.0	0.54	4.0	91
Boar	350	11.0	0.19	1.4	91

*From Midwest Plan Service, MWPS-18. Values are for urine and feces only with no bedding or dilution water.

These values represent raw waste characteristics (feces and urine combined) for swine. Storage, treatment, dilution and runoff processes affect the form and content of the waste product handled.

Open Lot Manure Management

Manure scraped from open lots may vary from 15-30% solids, depending on climatic conditions. It is handled with front-end loaders, scrapers and blades. Conventional box or open tank spreaders are used to spread wastes on land.

Manure from open lots diluted with washwater or from runoff in settling basins may be too thin to handle as a solid and too thick to be handled as a liquid. Modified solids handling equipment can be used for such slurries. Front-end loaders with tipping buckets are generally used to scrape and load. Open-tank flail spreaders or rear-gated conven-

Table 2. Design values for waste collection and pretreatment.*

Animal type	Animal unit	Average unit live weight (lb.)	Manure† production (gal./day)	Manure† production (tons/yr.)	Nitrogen content of fresh manure (lb./ton)	Annual‡ nitrogen produced in fresh manure (lb./yr.)	Horsepower§ of aeration required for odor control (hp.)
Swine farrow-to-finish	Per sow	1417	14.2	21.6	11.4	248	0.07
Swine farrow-to-feeder	Per sow	522	5.2	7.9	11.4	91	0.03
Swine finishing only	Per head	135	1.4	2.1	11.4	24	0.01

*Swine calculations based on 9 pigs/litter, 2.2 litters/year, 50-lb. feeder pig, 220-lb. market hog, and 400-lb. sow and boar.
†Assumes manure production of 1 gal./100 lb./day.
‡Assumes 0.048 lb. nitrogen/100 lb./day.
§Horsepower of aeration based on 50% satisfaction of waste COD and aerator oxygen transfer rate of 3 lb. O_2/hp.-hr. Partial aeration for odor control only.

tional box spreaders can be used for transport and spreading.

Irrigation of liquid from runoff holding basins is required to eliminate direct discharges. Standard irrigation equipment can be used if solids have been removed with a solids settling system ahead of the basin.

Confinement Manure Management

Slurry (4-15% Solids). In systems where little or no extra water is added to the raw manure excreted by pigs, the manure is handled as a slurry. Slurries with up to about 15% solids can be pumped with special equipment, but 4-8% is most common. Solids will settle in storage, so wastes must be agitated before pumping.

Vacuum loading tanks are used extensively to remove swine manure stored in pits and tanks. The agitation capability of vacuum loading equipment is limited. If manure contains high solids, as found in growing and finishing buildings, access ports to the pit should be spaced approximately 20 ft. apart to assure good removal with vacuum loading equipment.

Units with mechanical scraping under slats as well as deep, narrow gutter units are constructed to transport slurry manure to outside storage. The outside storage structure may be either below-ground tanks, above-ground tanks, earthen storage, or lined earthen storage systems. If above-ground storage is used, a pump is required to pump raw waste into storage. The combination of the chopper-agitator pump and tanker seems to be growing in popularity for larger operations to replace vacuum loading units for handling from all types of slurry storage.

Slurry manure can be irrigated directly with little or no dilution with special pumping and agitation equipment. Odor potential is high. Application must be limited (less than ½ in. per yr.) to control nutrient overloading. Application of slurry on growing crops is not recommended since plants may be killed or severely damaged.

Liquid Systems (up to 4% Solids)

If sufficient water is added to manure, the resulting material can be handled as a fluid. Solids content should be less than 4%. Standard irrigation equipment can be used if precautions are taken. Screens over suction intakes or use of solids-handling pumping equipment may be necessary to prevent nozzle plugging problems with hair, grain hulls and other slowly degradable materials.

Handling large volumes of liquid waste material is generally more feasible in terms of labor, energy and investment with irrigation equipment than with hauling equipment. Land application with irrigation is gaining popularity because of problems with labor shortage, field accessibility, compaction and limited times for application in the spring prior to planting. In humid areas, lagoon effluent is sometimes applied directly to growing crops for better nutrient usage. In more arid regions, wastewater can be used as an irrigation resource, but application to growing crops requires caution.

Environment Requirement

Environmental concern has led to governmental regulations for control of water, land and, to a limited extent, air pollution. These will be discussed separately.

Water. Public Law 92-500 is the federal water pollution control legislation with the most direct effect on livestock operations. Production units impacting water quality are required to implement best management practices to eliminate direct discharges. Several states have established more stringent standards than federal requirements for livestock facilities. Indirect or intermittent discharges and runoff from land application sites are considered to be non-point sources. Swine producers should be familiar with 208 areawide water quality planning dealing with discharge control in their state to know how it will affect their waste management activities in the future.

Land. State and local agencies in some parts of the country control how and when animal waste is applied to land. Limitations on manure loading rates, timing and application on slopes or near watercourses have been placed on swine producers in some states.

Air. A few states have enacted odor regulations for livestock operations. Facility location control through zoning ordinances or construction permits is generally used to minimize future conflicts between livestock producers and surrounding neighbors. Limitations on location, timing and method of land disposal have been used to control odor. Several producers have been convicted of nuisance odors by jury trials even though evidence verified that recommended practices were being followed. The importance and value of good neighbor relationships and responsive communication cannot be over-emphasized.

Disposal Alternatives

Swine waste has long been returned to land as an organic fertilizer and soil amendment. Recent technical developments in waste management have made other disposal alternatives, such as refeeding, a possibility.

Land Disposal. Approximately 80% of the nitrogen and phosphorus and approximately 90% of the potassium in the feed ration is excreted by swine. Thus, swine waste makes an excellent organic fertilizer and soil amendment. Swine manure also has beneficial effects on the chemical, physical, and biological properties of soils.

Chemical effects. The principal chemical benefit of manure is the supply of the major plant nutrients: nitrogen, phosphorus and potassium. In contrast to commercial fertilizers, swine manure supplies organic matter and other chemicals necessary for plant growth to receiving soils. This supplement is usually considered beneficial in increasing the nutrient-holding and moisture capacity of the soil as well as in improving the physical structure.

Physical effects. If manure is applied to the surface of the soil, it will aid in preventing soil crusting. If mixed with the soil, it will decompose more rapidly, and the products of decomposition will improve soil structure and general physical condition. Thus, whether applied to the surface or mixed with the soil, it will help conserve water and soil by reducing runoff and erosion.

Biological effects. Manure is a source of food and, hence, energy, for soil microorganisms. These soil microorganisms have both direct and indirect beneficial effects on the physical, chemical and biological properties of the soil.

Refeeding — Land Application. Refeeding systems have offered an alternative manure management technique for a few producers. The most common system used is removal of coarse solids in raw manure with a liquid-solids separation device. Coarse materials which are screened are stockpiled and fed to ruminants after some disinfection phase.

More sophisticated systems grow bacteria from waste through aerobic or oxidative treatment. The resulting bacterial mass is used as a high protein feed source. A third system, and perhaps the most practical, is the mixing of

Table 3. Land required for terminal application as determined by using various pretreatments and nitrogen application rates.*

Unit	Average unit weight (lb.)	Pit storage (20% N loss)			Anaerobic lagoon (50% N loss)			Surface aerated lagoon (90% N loss)		
		Acres of land required based upon nitrogen application rate of 200, 400 and 600 lb./acre (assuming no field losses)								
		200	400	600	200	400	600	200	400	600
Farrow-to-finish (per sow)	1417	.99	.50	.33	.62	.31	.21	.13	.06	.04
Farrow-to-feeder pig (per sow)	522	.36	.18	.12	.23	.11	.08	.05	.03	.02
Finishing only (per head)	135	.10	.05	.03	.06	.03	.02	.01	.01	.01

*Table presented for illustrative purposes. Nitrogen loss values are representative of typical data ranges. Local values should be used for actual design purposes.

swine manure and high cellulose materials like cornstalks or other crop residues to produce manure silage. The resulting product is usually fed to ruminant animals.

Refeeding is not an ultimate disposal system because a significant proportion of the original waste material must eventually be returned to the land.

Pretreatment — Land Application. Raw manure may be pretreated prior to land application to reduce the biological strength, the nutrient concentration or the odor-producing potential. Several attempts have been made to design treatment systems to allow final discharge to a stream. Even though this may be accomplished, the cost and operation requirements are very high when compared to land application.

Pretreatment of waste generally decreases land disposal problems. Pretreatment may lower nutrient and pollution potential of manure. Odor potential at disposal sites can also be reduced. The relative amount of land required for raw waste compared to effluent from either anaerobic or aerated lagoons for several systems is found in Table 3.

Factors Affecting Rates of Application

Several factors affect the amount of manure that might be applied to land. They are: (1) the use to be made of the land—whether it is to be used for crop production or for manure disposal only; (2) if used for crop production, the kind of crop to be grown; (3) the characteristics of the soil including texture, depth and fertility status; (4) topography as it affects runoff and erosion; (5) the season of the year in which the manure is to be applied; and (6) possibility of environmental pollution, particularly the contamination of surface and groundwater by excessive leaching or runoff.

Crop production is not the only factor to be considered in determining the amount of manure that might be applied to any particular soil. Another very important factor is the possible environmental effect, particularly contamination of surface or groundwater. The two nutrients contained in manure which are most likely to cause non-point source problems in water are nitrogen, particularly in the nitrate and ammonia forms, and phosphorus. A high ammonia level in surface water is toxic to fish. Very high nitrate levels can be toxic to animals, and high concentrations or accumulations of nitrates and phosphate in surface water can result in eutrophication (excessive growth of algae or other plants because of overfertilization).

Phosphorus is mainly in the organic form in swine manure. Phosphorus availability is directly related to the rate of manure decomposition and is much slower than that of nitrogen. Potassium in swine manure is an inorganic salt that is easily leached and is readily available for plant use. Swine manure also contains many minor elements in very small quantities that are released as the manure decomposes.

Manure nutrient losses occur with land-spreading by either leaching of soluble constituents or volatilization. These losses can be minimized if the material is applied to the land as soon as possible and incorporated into the soil.

Nutrient Utilization of Manure by Crops

For efficient use of nutrients, apply manure to match crop fertilizer requirements. Manure nutrients, especially nitrogen, are used more efficiently by grasses and cereals than by legumes. Refer to PIH-25, "Fertilizer Value of Swine Manure," in the *Pork Industry Handbook* for a guide to land application.

Application

Manure is usually applied by one of the following:

- Broadcast (top dress) with plow-down or disking
- Broadcast without plow-down or disking
- Knifing (injection under the soil surface)
- Irrigation

Rapid incorporation of manure will minimize nitrogen loss to the air and will hasten biological activity to release nutrients for plant use. Injecting, chiseling or knifing liquids beneath the soil surface will minimize odors and nutrient losses to the air and/or to runoff. Disking or chiseling land soon after surface application will also reduce odors generated from field-spread wastes and runoff transport.

Timing manure disposal activities can help minimize odor complaints. If possible, select dry, windy days for manure disposal. Pay attention to wind direction with respect to neighboring residences. Direct injection or rapid incorporation can be used advantageously where neighbors live close to a disposal site. Cooperative communication, sincere response to complaints and other good neighbor techniques can be as important as following good waste management practices!

Summary

Regardless of the collection, storage, treatment and handling methods used for swine manure, some end products remain. These end products may be either valuable resources or unwanted wastes to be disposed of economically and efficiently. The end use of swine manure often dictates the most appropriate waste disposal system. Consider the many variables before selecting a waste system. The cheapest method may not meet regulations or be acceptable to your neighbors. Some advantages and disadvantages inherent in common swine waste management systems are summarized in Table 4. Remember — all systems have some disadvantages, but some will work better than others for specific circumstances.

Table 4. Advantages and disadvantages of alternative waste management strategies.

Unit	Engineering considerations	Advantages	Disadvantages
Storage and Treatment			
Below floor slurry	Design dependent on depth, soil and drainage Volume based on storage length desired Pit access for equipment Agitation potential Pit ventilation	Easy collection and storage Minimum volume Maximum fertilizer value	Odors and gases Solids accumulation Solids agitation and removal problems
Remote storage slurry	Transfer from building to storage Cold weather operation Agitation Above ground, below ground or earthen structure	Manure gases minimized Adaptable to refeeding, methane, separation Maximum fertilizer value	Extra cost for storage and transfer Dependence on transfer system Solids removal
Anaerobic lagoons	Volume, depth and shape regulations Distance to neighboring residences Distribution to irrigable land Organic loading Dilution water availability	Storage and disposal flexibility Low solids liquid for simple irrigation and recycle for flushing system Low cost, low labor	Land requirement Odor potential Nitrogen loss Sludge buildup Recycle salt problems
Aerated lagoons	Volume, depth and shape Organic loading Mixing characteristics Constant or variable depth Power access	Minimum odor Reduced land requirement	High energy and maintenance cost Cold weather operation High nitrogen loss Increased solids buildup
Oxidation ditch	Detention time Aeration and recirculation Constant vs. variable depth Power interrupt strategy	Reduced odor Waste stabilized Refeeding potential Lowers odor and land requirement for disposal	High energy and maintenance cost Foaming Cold water operation Storage requirement increased
Solids separation	Control of moisture content Capacity Overloading Housing	Solids may be refed or spread Low odor Reduces loading on subsequent treatment Low solids liquid easier to handle	High cost of equipment High management requirement Storage and handling of solid material

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Table 4. Advantages and disadvantages of alternative waste management strategies.

Unit	Engineering considerations	Advantages	Disadvantages
Transfer			
Flushing-open gutter	Slope, width, length and cross section of gutter Flush volume and frequency Plumbing and pump selection Flush mechanism Recycle or fresh water Lagoon requirements	Lower construction cost Quick manure removal Lower odor and ventilation requirements Manure movement with animal access Animals attracted to gutter	Cleanliness dependent on proper design Possible disease hazard Lagoon requirement Equipment dependency
Flushing-below slat	All of those with open gutter Equipment for greater flushing action below slats	Reduced animal contact Retrofit to existing buildings Low odor and ventilation requirements	Cleanliness dependent on design Lagoon requirement Equipment and time dependency
Mechanical scraper	Length, width of scraped surface Power requirement Cable or chain unit Layout for efficient use of equipment Cold weather operation	Positive removal Handle in slurry form Low power requirement	Higher cost Equipment and time dependency Cold weather—ice
Deep narrow gutters	Maximum self-cleaning width Depth for storage Rapid outlet system Slope floor to gutter	Lower cost Retrofit existing buildings No mechanical problems	Floors not clean Design critical for self-cleaning Some manure gases prior to manure release
Disposal			
Solid spreader	Volume, capacity Semi-solids capability Match to power source Loader capacity and time availability	Equipment readily available High solids allows less volume handled Mobility Soil conditioner	Loading and unloading times high Spreading uniformity Potential for lower fertilizer value
Slurry (Surface application)	Volume, capacity Agitation capability Maximum lift Match size to power Soil conditioner Wheel loads	Equipment available Mobility to spread over large areas Fertilizer conservation Soil conditioner	Time and labor Operating cost Soil compaction Restricted application times Odor potential Land availability
Slurry (Subsurface injection)	Same as slurry above Power requirement Varying soil conditions Application rate capability	Maximize fertilizer Minimize odor Minimize runoff Soil conditioner	Same as slurry above, except odor Higher power requirements Operation in non-tilled fields
Irrigation	Solids handling characteristics Rate and pressure regulations Agitation Surface vs. sprinkler Dilution requirement Application rate and amount Timing of application	Low labor High capacity Low energy Supplemental nutrients and water	Limited area coverage Odor potential Topography and soils limited Tendency to overapply waste

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