9-1-1969

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AE-76
Sept. 1969

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Introduction

It presently seems that the public's demand for the control of pollution cannot and will not be denied, and the swine industry cannot revert to past systems of production to avoid the problem. This does not mean that it is "the end of the line" for the swine industry in Indiana, but it does mean that swine producers will have to do a more acceptable job of disposal in the future. All current systems of disposal have some undesirable characteristics, but with present day technology and some good management one can avoid many problems. Waste disposal is an integral part of the swine production unit and should be planned accordingly.

Much research is being directed to the problem of livestock waste management and disposal, and considerable progress is being made, but no simple solution to the problem has been developed. Of the twelve state agricultural experiment stations within the North Central Region of the United States, eleven now have active projects directed toward the determination of improved livestock waste handling and disposal methods. Seven have projects pertaining directly to swine wastes.

Manure Production, Value and Characteristics

Logically the first step in planning for handling, storage, and disposal of manure is to estimate the amount and value of manure to be produced. Table I gives the approximate daily production of manure by swine.

Some "rules of thumb" that are easily remembered and that provide for reasonable accurate estimation of manure production are as follows:

1. Manure production in gallons per day = I per cent of body weight

2. Manure production in pounds per day = 8-9 per cent of body weight

3. During the finishing period a hog will produce approximately 150 gallons of manure and urine.

Value - It is difficult to place an exact value on swine manure. Some have evaluated the manure in terms of the increase in production of crops to which the wastes were applied. Another way is to relate the value of the wastes to the cost of a quantity of chemical fertilizer that will provide the same quantity of nitrogen, phosphorous and potassium as Morris (II) has done. Table 2 gives a reasonable estimate of the value of swine manure, but these values can vary drastically depending on the assumptions made in the calculations.

Based on these calculations the value of the 150 gallons of manure produced by a hog during the finishing period is about 52 cents which is considerably less than was formerly believed.

The manure production and value figures do not include waste water, rain water, and wash water that may be collected and handled in the system. The volume water wasted by some fountains may be as high as the manure production. A reasonable estimate of rain water may be made by assuming 40 inches of annual rainfall, on uncovered finishing floors.

Excess waste water will probably improve the pumpability of the manure as a liquid but has little value and increases the amount of material to be handled.

Table 1. Daily manure production of swine

Animal Wt.	Solid Manure	Total [a] (Manure & Urine)		BOD [b] (5 day)	Population Equivalent [c]
lb.	lb.	lb./day	gal./day	lb./day	
50	2.7	4.2	0.53	.17	1.0
100	4.3	8.5	1.06	.32	1.9
150	5.8	12.8	1.59	.51	3.0
200	7.3	17.0	2.12	.68	4.0
Sow (Gestating)	8.0	24.0	3.0		
Sow & Litter	14.0	40.0	5.0		

a/ The dry matter content of the manure and urine is approximately 15-20 per cent. About 85 per cent of the dry matter is composed of volatile solids most of which could theoretically be biologically digested and 15 per cent non-volatile or ash that cannot be digested biologically or burned.

b/ BOD means biochemical oxygen demand as shown by a 5-day laboratory test. The total quantity of oxygen required to oxidize the daily manure produced by an animal is usually considered to be about two to three times this amount.

c/ Based on a 5 day BOD of .17 pounds per day for humans.

Table 2. Fertilizer value of swine manure

Element	% by wt.	lb./1000 gal.	% recovery	Comm. price	Value/1000 gal.
N	.56	44.8	50%	7¢/#	$1.57
P_2O_5	.30	24.0	67%	8¢/#	1.28
K_2O	.25	20.0	75%	4.2¢/#	.63
					$3.48

Methods of Handling and Disposal of Swine Manure

Many methods and combinations of methods are being investigated and tried for the disposal of swine manure. Some of the better known methods of disposal are as follows:

1. Spreading on agricultural land as a fertilizer
   a. as a solid
   b. as a liquid
2. Biological treatment
   a. anaerobic
      1. lagoons
      2. anaerobic digesters
   b. aerobic treatment
      1. oxidation ditch (Pas Veer Ditch)
      2. aerated lagoon
      3. other aeration methods
3. Dehydration
4. Incineration
5. Composting
6. Combination of methods

All of these systems have been used for the disposal of some types of waste materials, but very superficial study would indicate that some of these systems such as incineration and dehydration are probably not feasible for the disposal

of swine manure. Some of the other methods or combination of methods can be effectively utilized by swine producers. The type of housing system, location in relation to populated areas, topography, land area, and cropping system should be considered in selecting a system. When a system is considered, some thought should be given to question, "Will the system be an acceptable one to the sanitary and health authorities and to the public?" Systems that pollute streams, underground water supplies, and the air are not likely to be tolerated.

Spreading Manure on Agricultural Land as Fertilizer

At one time the use of livestock manure as a fertilizer was a profitable method of disposal, but with relatively low cost of commercial fertilizers there is no longer much, if any, profit in this practice. However, the manure will not simply disappear; therefore some provisions must be made for the disposal, and some cost is usually involved. As shown in Table 2 the value of 1,000 gallons of swine manure as fertilizer is approximately $3.48. Calculations indicate that a fairly large efficient operation could haul and spread the manure for about the same amount which makes the use of swine manure as a fertilizer a break-even proposition.

The use of manure as fertilizer is the only system of disposal that recovers any value from the product which offsets the cost of disposal. Therefore, although the use of manure as fertilizer may not be profitable it could well be the least cost system of disposal. Naturally land must be available for disposal, and the spreading must be done periodically to prevent excess accumulations. Land for disposal during the cropping season may be limited, and spreading the manure on frozen ground during the winter could lead to pollution problems.

At the present time a swine producer should have adequate land, preferably in an isolated location, available for the disposal of manure. With time it may be necessary to not crop some acreage to provide a disposal area. However, a small acreage can serve as a disposal area for a lot of manure. In some experiments, application rates as high as 200 tons per acre per year are being studied (12). This rate of application would require a different disposal plot each year. For continuous use the application rate should be limited to about 25 to 30 tons per acre or the manure from 40 to 45 hogs.

The odors liberated by spreading the manure has caused some very serious problems in some areas, and its use should be given careful consideration when establishing a new unit. Long term storage will permit the producer to select the most appropriate weather for spreading to minimize the odor problems. There have been some indications that the odors from liquid manure may be partially controlled by the addition of chemicals and/or masking agents to the storage tank prior to spreading.

Spreading manure as a solid - The primary problem with the disposal of swine manure on agricultural land in solid form is the handling of the manure. The consistency of the manure, particularly without bedding, makes it difficult to handle with the conventional manure handling equipment, and the addition of rain water on open floors adds to the problems of handling.

Normally solid manure handling is associated with open-front buildings with outside feeding floors, and generally some provisions are made to divert the rainwater away from the manure storage. This runoff frequently meanders away from the unit creating an odorous, unsightly area that is good for fly breeding and perhaps polluting some surface water. It seems logical to impound this runoff rather than letting it flow aimlessly around the farm and then run off into a stream. In this case the impoundment would be an anaerobic lagoon for the digestion of the organic material carried in the runoff water; only the solids would be hauled to field and spread in a conventional manner.

During cold weather the solids may be stored on an apron along the edge of a feeding floor. Although this area is somewhat unsightly, odors and fly breeding are not objectionable during the winter. However, during the summer the storage of solid manure is not advisable, and frequent hauling and spreading are necessary. This in turn requires land to be available during the cropping season for disposal of the manure. Frequent hauling reduces the efficiency of the handling system, and a producer cannot wait for the correct weather conditions to reduce odor problems.

When organizing a solid handling system, provisions should be made to divert and dispose of the runoff from open feeding floors, for manure storage during winter operation, and for mechanical loading of the manure. A wide apron along the lower side of a one-way slope floor will serve as a storage area from which the manure can be loaded with a tractor scoop. The apron should be sloped to drain the liquids from the storage and should be equipped with a bucking wall to help trap the sloppy manure in the scoop. Push-offs have been employed satisfactorily where the terrain permits installation without digging a hole for the spreader. Gutter cleaners have been used for loading the manure also, but the manure is extremely corrosive and equipment has a relatively short life.

Because of the undesirability of handling solid wastes and the problems associated therewith, most swine buildings are being designed for some form of liquid waste disposal. However, solid handling may still be practical where bedding is involved or where the small amount of manure to be handled will not justify the purchase of liquid manure handling equipment.

<u>Spreading manure as a liquid</u> - The manure, urine, and waste water produced in most hog houses that are not bedded are of a fairly pumpable consistency and can be handled efficiently as a liquid. Practically all enclosed and slotted floor buildings employ liquid manure handling. Even though outside floors collect rainwater that must be handled, many producers have constructed liquid manure pits in conjunction with outside feeding floors, provided bedding is not used.

Reliable liquid manure handling equipment is available on the market, and manure can be handled very efficiently from liquid storage to the field for disposal. When a liquid manure handling system is to be employed, the construction for long term storage is ordinarily suggested. This is easily constructed in conjunction with slotted floor systems at an economical price. Long term storage permits the handling and spreading to be done at the most suitable time for crop growth, farm labor and for minimizing odors.

Fly and insect breeding is not a problem in a properly constructed and managed liquid manure storage tank. While in storage, there is no serious odor problem, but when the tank is agitated and the manure is spread, there are very strong odors. There is some evidence that some of the odor may be controlled with the addition of chemicals to the storage tank prior to agitation and hauling. One trial using 10 pounds of ammonium nitrate per 1,000 gallons of liquid manure was reported to be highly effective.

Although specialized equipment is required for handling manure as a liquid, this system of disposal appears to be practical and efficient where large volumes of manure are to be handled (100,000 gallons or more). For smaller volumes the equipment expense is relatively high. However, it is conceivable that the equipment expense can be drastically reduced by owning the handling equipment in partnership with a neighbor. This type equipment is used only a few days a year and is considerably different than owning a corn planter in partnership.

More of the fertilizer elements are conserved in a liquid manure system than with a solid system of handling.

Biological Degradation of Swine Manure

The biological treatment of swine appears to be gaining some favor, but it is not a new system. Iowa, Illinois, Indiana, North Dakota and South Dakota are doing some experimental work on this process at the present time.

In general there are three biological processes: aerobic, anaerobic, and facultative. The classification of these three processes depends on whether free oxygen is available to support bacterial growth in waste materials. Aerobic bacteria require free oxygen for their growth and reproduction. Anaerobic bacteria obtain their required oxygen from the food which they consume; their growth is inhibited by free oxygen. Facultative bacteria grow both with and without free oxygen, and take on the characteristics of aerobic bacteria if oxygen is available and anaerobic bacteria if oxygen is not available.

Most wastes contain all three types of bacteria. If oxygen is available the aerobes grow and reproduce. If oxygen is not available, the anaerobic bacteria predominate. Aerobic bacteria breakdown wastes into water and carbon dioxide which are odorless. Anaerobic bacteria produce water, carbon dioxide, and methane which are colorless and odorless, but they also form hydrogen sulfide, ammonia, and mercaptan gases which are odorous in relatively low concentrations. Facultative bacteria produce many of the same gases. Free oxygen must be made available at all times by some system in the wastes for the aerobic bacteria to function at their best.

It is generally accepted that anaerobic bacteria, particularly the methane type, more completely degrade organic matter than aerobic bacteria, but aerobic bacteria have better odor characteristics.

Lagoons

The term "lagoon" has been used to define anything from a shallow pool of water to an anaerobic manure pit and is not very definitive. Apparently there is some confusion in the correct meaning of the term even as applied to sanitary engineering. Therefore, a better description of the predominant type of bacteriological action taking place in the lagoon should be included in the lagoon identification.

Starting with a pool of water the biological activity taking place in the lagoon will depend on the depth and the loading rate. In a lagoon all three types (anaerobic, aerobic and facultative) of bacteria may be present, but the predominant type will depend largely on the loading rate. A small deep heavily loaded lagoon will be primarily anaerobic; a shallow light loaded lagoon will be predominately aerobic. The facultative bacteria will function either as aerobic or anaerobic depending on the conditions and the presence of oxygen.

Most lagoons used for the disposal of livestock wastes are facultative and may take on the characteristics of either anaerobic or aerobic digestion. Since the facultative bacteria will operate in either the anaerobic or aerobic state, it then seems logical to classify the facultative lagoons as either aerobic or anaerobic for design and management purposes.

Most of the early lagoons for the disposal of swine manure were designed to operate anaerobically. Many of the designs were made on the basis of 80 cubic feet per hog capacity or less. Some of these lagoons were satisfactory, but others created a serious odor problem. Also the overflow from some lagoons into public ditches constituted stream pollution. Most experts have concluded that the early designs were not adequate for successful operation and presently suggest 3 cubic feet per pound of animal (9).

Two types of odor problems are encountered: a continuous vile odor generally beginning in early spring, and an intermittent odor becoming noticeable about sundown. The continuous odor

usually beginning in the spring is apparently the result of an "overloaded" condition. This condition is created by reduced biological activity during the winter with two possible developments when spring arrives: (1) bacteriological activity returns with a highly odorous lagoon, or (2) bacteriological activity remains low because of acid conditions. It has been reported by Berry (1) that in North Dakota lagoons have only a small amount of biological activity performing mainly as a storage for livestock wastes.

The effluent from lagoons is not of sufficient purity to be discharged into public streams, and some provision for disposal of overflow should be considered. The effluent could be spread on agricultural land or treated in a secondary aerobic lagoon.

For information on the design and management of anaerobic lagoons obtain a copy of AED-1, "Lagoon Manure Disposal," from the Agricultural Engineering Department, Purdue University.

The anaerobic lagoon is an inexpensive system of disposal of swine manure that requires little attention. However, it is possible that some odors may be emitted from the lagoon during parts of the year even with current designs. An anaerobic lagoon would be most suitable for operators too small to justify liquid manure handling equipment for impounding liquid runoff from solid manure handling systems and for remote locations.

Lagoons may be used for storage or for the final disposal of manure. Most of the fertilizer ingredients are salvaged if the lagoon is used for storage, but considerable odor may be dispersed when the manure is agitated and spread. Approximately 12 cubic feet of sludge per hog per year will accumulate in a lagoon used for final disposal.

For the swine production company that has a very large number of hogs per acre of land (over 45-50 per acre) anaerobic lagoons may not be advisable at all. Nearby residents may be irritated.

<u>Anaerobic Treatment</u> - Digesters are used for decomposing much of the domestic wastes in our municipal plants. This system is usually a carefully controlled one which requires expensive equipment and careful supervision. In this system, the temperature of the mixture is maintained at 95° to 105°F at which level methane is the main gas produced and most odorous gases are prevented from forming. The decomposition of the solids is far more complete by this anaerobic method than by the aerobic ones. The methane gas is often used by municipal plants to provide heat to generate steam for power and to heat the incoming sludge from the aeration chambers. (Raw incoming wastes are aerated for an hour or two producing a condition that promotes settling of the solids so much of the liquid can be discharged into a stream and the activated sludge can go directly to the digester.)

Gases Produced - The production of methane gas from animal wastes is possible. However, computations indicate that it would not be profitable for most swine producers. In such a system, solids are reduced to a small, stable mass in which little organic (volatile) matter remains. The small quantity of solids left could be readily spread on the fields or crops with little problem. It is difficult to maintain a sufficiently high temperature for an efficient operation. Anaerobic conditions occur at the lower temperatures and do a good job of decomposing the organic solids if given sufficient time. However, they are highly odorous because hydrogen sulfide, ammonia, mercaptan gases and other odorous gases are formed. In much of the research now in progress on this system, a combination anaerobic and aerobic lagoon is being tried. In such a system it is visualized that the desirable characteristics of both systems may be utilized. Thereby obtaining a greater reduction of the volatile solids and odorous gases.

<u>Aerobic Treatment</u> - With oxygen available in a waste and water mix, aerobic conditions prevail. By the aerobic process some of the volatile (organic) solids are reduced to carbon dioxide, water, nitrates,

and nitrites. The inorganic solids, called fixed solids, are essentially unchanged. Three or four years ago there were some who thought that by maintenance of aerobic conditions, it might be possible to decompose about 80 to 90 per cent of the volatile solids. However, more recent laboratory experiments indicate that only about 40 to 50 per cent of the organic solids are decomposed in three to six months. Figure 2 shows a curve taken from some aerobic treatment experiments by Irgens and Day (7) at the University of Illinois.

Time is the factor that alters the quantity of the solids that may be decomposed under proper conditions. For example, more of the solids will be decomposed in a long period of time than a short one. A kernel of corn is not in a readily usable form for the bacteria and takes a long time for the volatile portion to be thoroughly digested.

Aerobic Lagoons - Oxygen can be entrained in the waste and water in a shallow lagoon by the action of the wind and is produced by the algae present in a properly operating aerobic lagoon. However, this action is relatively slow and an aerobic lagoon must be shallow and loaded relatively lightly for the wind and the algae to provide the needed oxygen for the aerobic bacteria. Therefore, aerobic lagoons are relatively large in relation to an anaerobic lagoon for the disposal of a given quantity of waste. A lagoon must be shallow (5 - 7 feet) for this natural action to be effective.

Because of the large area required, the use of aerobic lagoons for the disposal of animal wastes has appeared to be an expensive system of disposal. This type of lagoon has been used with very favorable results for the disposal of domestic sewage for small municipalities. The odor level of a properly operating aerobic lagoon seems to be within an acceptable range and much better than that associated with anaerobic lagoons.

Aerobic lagoons should be constructed approximately 6 feet in depth and have an area of approximately 300 square feet per 100 pound hog (150-100 pound hogs per acre). Actually an aerobic lagoon would function as a faculative one and some anaerobic activity will also be present.

Mechanical Aeration - Because of the large area required for an aerobic lagoon and because of the favorable odor characteristics of aerobic activity, a considerable amount of work has been and is continuing to be conducted on the use of mechanical systems for entraining oxygen in waste and water mixtures to produce aerobic digestion.

The Oxidation Ditch System - A method of creating aerobic conditions for treating swine wastes which is mentioned most often is the oxidation ditch. The oxidation ditch is typically a "race tank" shaped ditch 2 feet to 3 feet deep, 4 feet to 10 feet wide, into which swine wastes with dilution water may be placed. The contents are stirred and aerated by a rotating aerator (see Figures 3 and 4) which "beats" oxygen from the air into the waste mix. The content should flow around the ditch about 1.5 to 2 feet per second to prevent the settling of solids.

The digested sludge is more stable and may be spread without causing as much odor nuisance if spread while aerobic. In summary, a good oxidation ditch treatment does the following: (1) eliminates odors associated with storage by maintaining an aerobic condition, (2) decomposes about 50 per cent or more of the volatile solids, depending on the detention time, and produces a more stabilized material that can be spread without causing much of an odor nuisance, (3) extends storage time as volatile solids are reduced by about 50 per cent, and (4) concentrates minerals in the dissolved form in the batch system. Conversely in the continuous system, the dissolved solids are carried out in the effluent.

Some disadvantages of the oxidation ditch are as follows: (1) storage may be more costly because it must be built for oxygenation of contents, (2) equipment requires periodic maintenance, (3)

operation costs are moderately high because the system must operate continuously, (4) foaming appears to be a major difficulty unless the system is properly designed and operated, (5) failure in equipment may cause the ditch to become anaerobic with worse odor conditions than with no treatment, (6) about 50 per cent of the solids must still be disposed of (alternatives are to dry on sand bed or in an evaporation pond) and (7) dilution is required for aeration. Results of research at the University of Illinois (4) indicate that the oxidation ditch should have a minimum capacity of about 10 cubic feet per 160 pound hog for a system operated continuously for thirteen weeks. There is little foaming for oxidation ditches with volumes this great or greater. BOD reduction was the most efficient at a loading of 12 cubic feet per hog.

A good "rule-of-thumb" for estimating power requirements for an oxidation ditch system is 1 H.P. per 100 head of finishing hogs. With an electricity cost of 1.5 cent per kilowatt hours, the cost of power for operating the system would be approximately 45 cents per hog finished. The depreciation, interest, repair, taxes, and insurance costs for operating the equipment would certainly be significant, but it is difficult to make a reasonable estimate of these costs with the limited information presently available.

Oxidation ditches are very similar to aerated lagoons in costs. Both require collection pits and lagoon combinations. The oxidation ditch requires a storage lagoon into which the effluent and sludge from the ditch may be discharged after treating. This lagoon needs to be almost as large as that required for aeration unless it is used as a storage only prior to spreading on land at convenience.

The Aerated Lagoon System - The principles of operation of the aerated lagoon are essentially the same as that of the oxidation ditch. The main difference is the container and type of aerator. In this system, a lagoon is used instead of a ditch and a floating aerator is used instead of a rotor aerator. Figure 5 shows a floating aeratcr in operation in a swine waste lagoon.

Two such lagoons have been built and used for research at Purdue University, one on the Dairy Farm and the other on the Swine Farm. They have been very satisfactory in their operation, except when the equipment malfunctioned. The malfunctioning which was experienced was mainly due to weeds being cut down into the lagoon and becoming wrapped around the impeller or permitting the lagoon to get too low which clogged the intake. Odors from these lagoons have been slight.

The advantages of the aerated lagoon are as follows: (1) larger volume with a lower initial cost giving longer detention time and possibly greater breakdown of solids, (2) foaming, if it occurs, is outside giving unlimited free board space, (3) in event of equipment failure, the anaerobic conditions are outside and the odorous gases produced at restart will probably not cause distress to the animals, (4) a combination anaerobic, facultative and aerobic decomposition processes breakdown a larger per cent of the volatiles, and (5) less aeration or free oxygen is probably required.

Disadvantages of the aerated lagoon for wastes are as follows: (1) manure must be carried or flushed into the lagoon, (2) may be more unsightly, (3) requires more outside space, and (4) more subject to freezing.

Aerated lagoons make it possible to control odors of the lagoon with a much smaller volume than is normally possible. Present recommendations for unaerated lagoons call for about 400 cubic feet of volume per hog finished per year. Charles E. Clark (2) sanitary engineer of the Illinois Department of Health, recommends an acre of lagoon, five to seven feet deep per 275 hogs. This is a volume of about 1000 cubic feet per hog. By the use of aeration devices, such as a floating aerator, the volume can be reduced greatly. Also, the

lagoon can be increased in depth and therefore reduced in size. For example, for these 275 hogs, the volume of the aerated lagoon could possibly be reduced to about one-fourth this amount and the depth could be three times as great.

Using these criteria (250 cubic feet per hog and an 18-foot depth), the size of the lagoon for 275 hogs would be slightly under 4000 square feet or one-tenth of an acre. However, to aerate this lagoon properly, a two horsepower floating aerator or its equivalent (one that supplies about 6 pounds of oxygen per hour) would be required.

A two horsepower motor requires approximately 2 kilowatt hours per hour. Then 2 kw. hrs./hr. x 24 hrs./day x 120 days = 5760 kw. hours which at 1.5 cents would give $86.40 power cost. This is slightly over 31 cents per hog for power costs. Equipment and installation for such a unit would be approximately $1500 which would add another $75.00 at 5 per cent interest plus depreciation at 5 per cent (for a four-month period). The additional cost is $150.00 per 275 hogs marketed. This gives a total cost of $236.40 or about 86 cents per hog marketed. This does not include the cost of aeration equipment for the sows which must be added to the total cost of operation.

An Aerated Lagoon and Irrigation System - A combination of an aerated lagoon with an irrigation system to remove the excess accumulation of water and solids appears to have much merit for the management and disposal of farm animal wastes. Although the work to date has been with dairy cattle manure at the Purdue Dairy Farm, there is no reason to believe that the system will not work for all animal wastes. Briefly the system works as follows:

Manure is scraped or flushed into an aerated lagoon where the organic matter is partially aerobically decomposed. The effluent from the lagoon is used to irrigate nearby crops or woodland. This effluent contains both liquid and solids which have been stabilized in the lagoon and are odorless. They are also "fine" and do not cause plugging of large (3/8") irrigation nozzles. The lagoon should have a volume of about twice that of the manure produced each year. If it is to intercept runoff from a large feeding floor, it may have to be larger. Figures 6 and 7 show a schematic of a combination aerated lagoon with an irrigation system used to spread the liquid and sludge on crop land.

As with any system, there are some alternate methods of management that may be worthy of consideration. For example, if one wishes to use only a "settled out" supernatant, a second lagoon for sedimentation may be desirable. Then with a submerged inlet to the irrigation system, only relatively clear supernatant is sprayed on the fields. Of course, in this latter system, one takes the chance of the system becoming anaerobic before irrigation. A small floating aerator prevents this and provides a final treatment but adds to the expense. Furthermore, solids accumulate more rapidly resulting in a shorter life of the lagoon.

The first method of irrigating directly from the primary lagoon removes suspended solids and thus retards sludge build-up. Therefore, the "life" of the lagoon is increased. Large, heavy particles settle to the bottom of the lagoon where they undergo slow decomposition. With the two-year detention, the possibility of breaking the organic matter down into water and carbon dioxide is greatly increased.

At the beginning of winter, the water should not be higher than about one-half to two-thirds capacity as protection against overflowing when irrigation is not possible. This also aids in the prevention of freezing. With the deep (15 foot to 20 foot) lagoon, it is not anticipated that freezing will be a severe problem in Indiana and in other areas with similar climates. However, if the lagoon does freeze for a month or two, it may still operate satisfactorily from the last of February to December and will

serve as a storage during the winter months. Aeration must be started as early in the spring as weather will permit. A woodland, crop or grassland may be used for irrigation purposes.

A check of the solids irrigated from the present lagoon at the Purdue Dairy Farm showed that the solids are 50 per cent organic and 50 per cent fixed or inorganic. This indicates that a 65 to 70 per cent reduction has occurred in the organic solids. This is a higher breakdown than normally considered possible. However, a large portion of the solids in this lagoon were placed in it approximately one year ago; thus, they had a longer detention time than the usual one or two months. Furthermore, some of these solids had undergone partial anaerobic decomposition in storage.

Based on the research evidence to date, it appears that in a period of one to one and one-half years up to 70 per cent of the volatile solids can be decomposed. This would be a reduction of about 60 per cent of the total solids. With the removal of the dissolved and some of the remaining suspended solids by irrigation, an aerated lagoon with a detention time of about two years may be expected to take care of the manure for some 10 years or more without objectionable odors.

Other Aeration Methods - There are several methods of aerating wastes that may have essentially the same effect on the systems as the rotor or floating aerator. These two methods involve "mechanical beating and shearing" of the water and wastes and appear to be some of the more efficient. Other methods that one may wish to consider are (1) compressed air, (2) high speed rotary fans, (3) rotating disks, (4) sprays and pumps, (5) moving wires, and (6) rapid sand filters.

Combination Aerobic and Anaerobic Lagoon - A system of disposal of swine wastes that appear to have much merit, but which has not been completely researched, is that of a combination aerobic and anaerobic lagoon. To be effective, this lagoon requires a chamber for anaerobic decomposition and a chamber for aerobic decomposition. It appears possible that the bottom of a relatively deep (15 feet to 20 feet) lagoon would remain unstirred and unaerated and become that anaerobic chamber. By placing a floating aerator with a baffle plate below the intake in the lagoon, the top would become the aerobic chamber. Any gases such as ammonia and hydrogen sulfide that are produced at the bottom would be intercepted in the top aerobic layers and converted into odorless compounds or dissolved in the water and thereby prevented from escaping into the air.

In many respects, this lagoon would be similar to the aerated lagoon. However, it would have an additional advantage of the decomposition from both aerobic and anaerobic bacteria. Therefore, less solids would be left in the system to be disposed of on the land or by other means.

If the "deep" lagoon functioned as an aerobic lagoon only, it would still have a distinct advantage of less area being required. A complete system using such a lagoon would probably require a second lagoon to catch the overflow from the first lagoon permitting the sludge to settle. The effluent could then be used for irrigation purposes, or if it is high enough in quality, it could be disposed of in a stream. However, this is not a recommended practice and may soon be stopped.

Combination of Storage Pits Plus Lagoons - A system that is being tried by some producers and one that appears to have considerable merit is a combination of pits to store the solids until spreading is convenient plus lagoons for the liquids. One method of operating this system is to construct an overflow in the pit that permits the liquid to flow out to the lagoon once the storage becomes full of both the liquid and solid mixture. Experience has shown that the solids generally settle to the bottom with the liquids remaining on top.

Therefore, the problem of separating them is an easy one. Such a system accomplishes several things which are as follows: (1) reduces the needed storage capacity, (2) reduces the size of lagoon needed, (3) permits a more flexible schedule for spreading, (4) improves the quality of manure; however, some nutrients are lost in the liquids going to the lagoon, (5) lessens lagoon odors, (6) it may be usable for a much greater period if only liquids are permitted to flow to the lagoon, (7) yields much higher quality effluent which may be more permissible to be discharged into a natural drainage ditch, and (8) irrigation from the lagoon is possible to recover some of the nutrients.

As with all systems, there are a few disadvantages. Some of these are as follows: (1) solids in the storage are likely to become somewhat compacted and may require considerable stirring and mixing before they can be readily pumped by a vacuum wagon, (2) some nutrients are lost to the lagoon, and (3) dual costs exist for both a lagoon and storage. With a lagoon and storage combination, it is recommended that a storage of at least one-half gallon per hog per day be provided for growing-finishing hogs. This is about 1 cubic foot for each 16 hog days assuming a 96-day feeding period or this would be six cubic foot per hog for the entire time. The remainder of the wastes and liquids would be discharged to the lagoon.

The lagoon size could be cut to about one-fourth to one-third of the regular recommended lagoon. Perhaps the size could be reduced to about 100 cubic feet per hog finished. However, keep in mind that the larger the lagoon, the better. Therefore, if the area where the lagoon is constructed is sufficient, keep the size as large as possible.

The solids in the storage should be spread as soon after removing the hogs as the weather and soil conditions permit. This will insure a maximum return from the wastes and will prepare the system for a new herd.

Criteria for Going to an Aeration System - At the present time, the main factor in favor of going to an aeration system is the control of odors. If odors are not a problem, then stay with liquid or solid spreading or lagoons or perhaps a combination of the two.

Aeration of wastes will not control all odors of a swine production unit. Fresh manure on floors, slats and around the farm still produce an objectionable odor.

Dehydration

Swine manure when sufficiently dry may be stored, sacked, or spread without problem. The process of drying appears to be difficult as well as expensive. Also, the market for dried swine manure is questionable. Generally, swine manure as it is produced contains about 85 per cent water and 15 per cent dry matter. If one wishes to produce dried manure containing 90 pounds of dry matter and 10 pounds of water from this, he must start with 600 pounds of wet, raw manure. This means that 500 pounds of water must be removed in the drying process. One may use the energy of the sun and other schemes, but it is still a difficult process to produce a product with little demand. Not only must drying equipment do a good job drying the manure, but it must be equipped with an "after burner" to prevent odorous gases from escaping into the atmosphere. The Michigan State Agricultural Experiment Station is conducting some experiments in the drying of poultry manure. However, these results are not directly applicable to swine wastes as they contain more moisture than poultry manure.

Incineration

Incineration appears to have little to offer for the disposal of swine manure. It will reduce the solids, but heat must be provided. Odors and gases from the system pollute the air and are often objectionable to nearby inhabitants.

Composting

Composting requires time and equipment that is usually beyond the scope of most swine producers. However, if manure can be collected in large quantities along with other wastes, composting does offer some possibility.

Odor Control

Odors have been pointed to by many as the most severe problem at the present. This may be true for the small or moderate size operator who is disposing of the swine manure by lagooning or spreading. In either case, the odors can be greatly reduced by some relatively inexpensive methods.

Addition of Chemicals - Some of the more common chemicals that will reduce odors while spreading are ammonium nitrate, anhydrous ammonia, powdered lime, nitrate and anhydrous ammonia. These are the most highly recommended for farm use. The addition of one to two pounds of ammonium nitrate per hundred (100) gallons of liquid swine wastes, just prior to mixing and spreading, will greatly reduce the usual accompanying odors.

What the chemicals generally do is to take the manure from an acid condition to an alkaline one. Thus, many of the acid forming bacteria are inhibited and the odorous gases are stopped. There may still be ammonia odor with the manure, but it is usually not so objectionable as hydrogen sulfide, sulfur dioxide, and the mercaptan gases.

Lime usually acts more slowly than the other ingredients, but it will perform similarly.

The chlorine chemicals are strong oxidation-reduction agents which releases oxygen for the oxidation process. Thus, the system is temporarily changed to one that inhibits anaerobic bacteria and promotes aerobic ones. Therefore, the odors are greatly reduced. Also, chlorine in sufficient quantities is toxic to bacteria which greatly inhibits their activity and gas production.

Aeration - As indicated previously, aerobic bacteria essentially produce only carbon dioxide and water which are odorless. Therefore, if the waste storage is aerated, the growth of aerobic bacteria will be promoted and odors will be greatly reduced. One of the main accomplishments of the oxidation ditch and aerated lagoon is odor control. For only odor control, aeration does not have to be as great as when aerobic decomposition is also desired. However, it is difficult to draw a clear line between the two. Any quantity of air is helpful in producing aerobic conditions and odor control. Some laboratory experiments indicate that a quantity of oxygen equal to the 5-day biochemical oxygen demand of the wastes may be sufficient. This is equal to about one-half pound of oxygen each day per 150 pound hog.

Summary

At one time the fertilizer value of manure made it an asset to the producer, but at the present time there is no practical use for manure, and it is a liability rather than an asset. Proceeding from this viewpoint the disposal of manure is an expense that must be considered as a cost of production, and it is logical for the livestock producer to think of developing a least cost system of disposal that is satisfactory from the standpoint of pollution.

There are three mediums for the disposal of waste: air, land and water. The public is demanding that water and air cease to be used for disposal, and the land is the only medium available for wastes and many ingredients of wastes. However, some elements of properly controlled biological degradation may be released into the air without constituting pollution, but since most systems of biological degradation are not complete, there must ultimately be some land available for disposal.

The disposal of manure on agricultural land still appears to be one of the more economical and reliable systems, although odors may be a serious problem at times. Biological systems have not been completely reliable and some of the more sophisticated systems are relatively expensive, and every swine production system should have sufficient land available for the disposal of manure.

Odors can still be a serious problem in some circumstances, and the location of intensive swine production systems near urban areas is a mistake that should be avoided.

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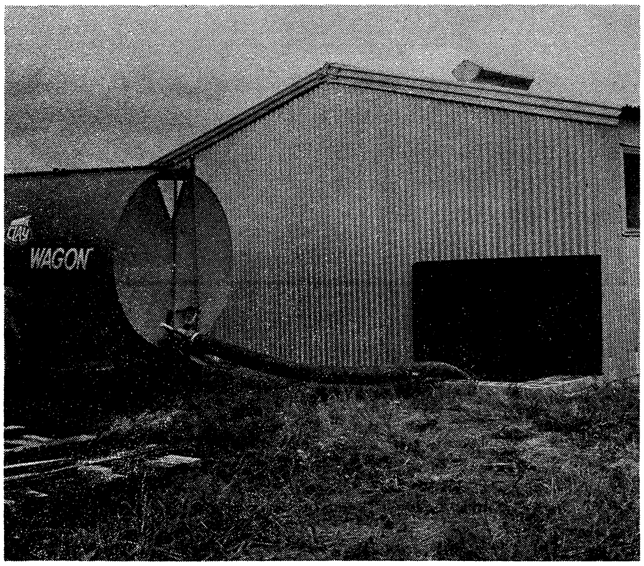

Figure 1. Vacuum wagon removing swine wastes from pit at rear of finishing house

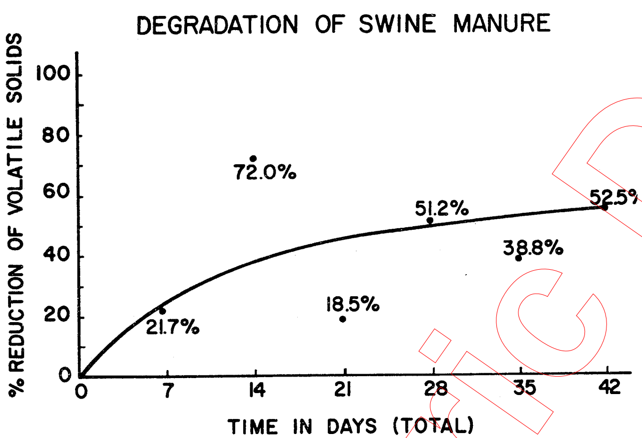

Figure 2. Decomposition of swine manure at 73°F under aerobic conditions

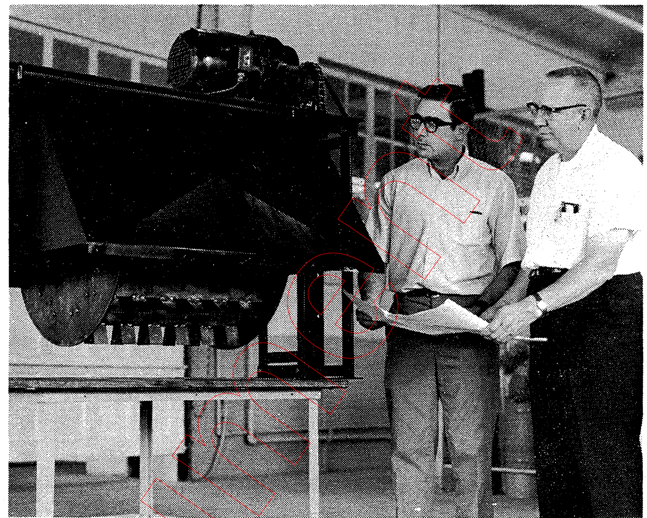

Figure 3. Laboratory fabricated rotor aerator being checked prior to placement in experimental oxidation ditch

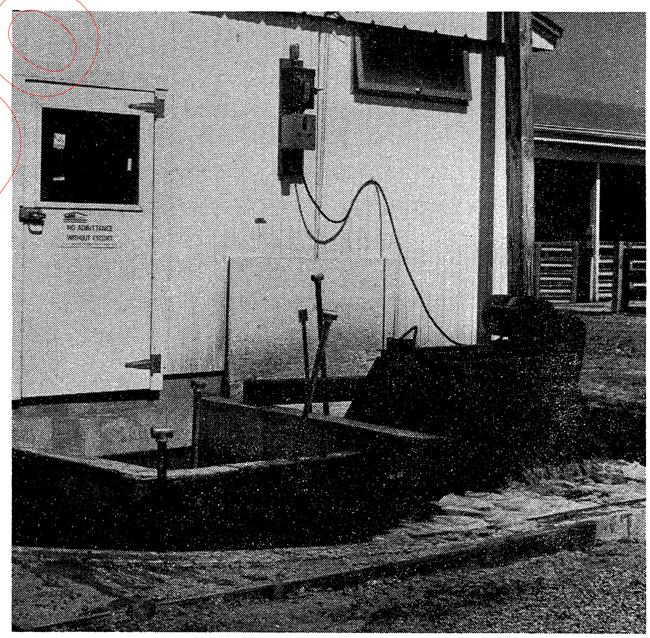

Figure 4. Rotor aerator installed in oxidation ditch which extends under floor of gestation house.

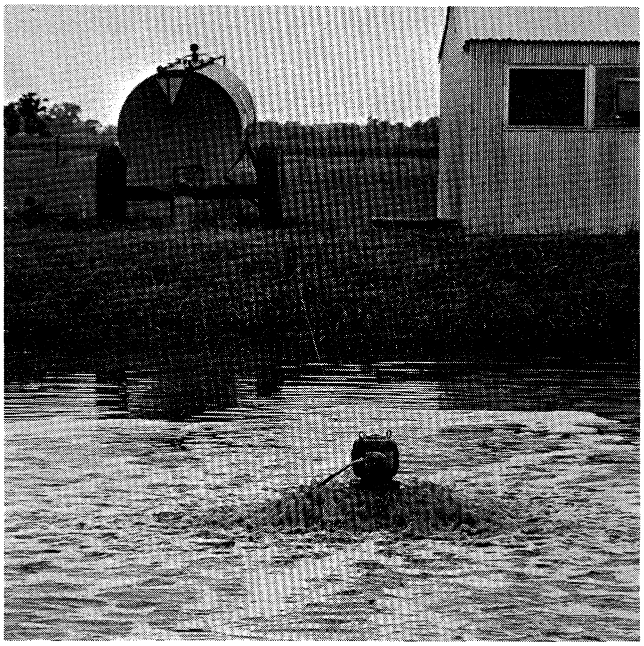

Figure 5. Floating aerator in an oxidation lagoon on the Purdue Swine Farm

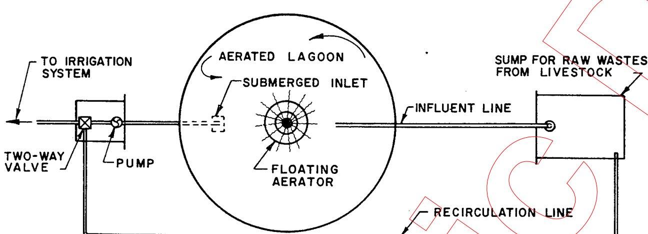

Figure 6. Plan of combination lagoon and irrigation system for the disposal of livestock wastes

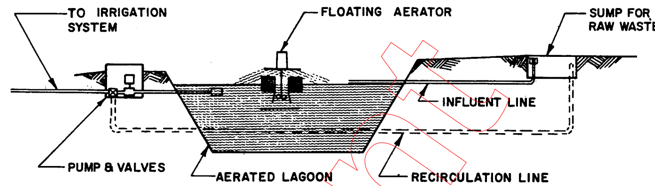

Figure 7. Cross section through combination lagoon and irrigation system for the disposal of livestock wastes

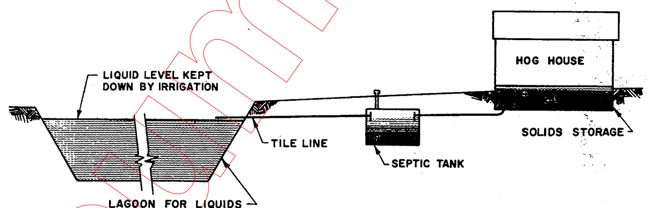

Figure 8. Combination of storage of solids for eventual spreading and a lagoon for liquids