ANIMAL SOLID MANURE: STORAGE, HANDLING AND DISPOSAL

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Contents

Summary

Concentration and intensification of both livestock and poultry production has enabled animal agriculture to produce more meat at less cost, but on the other hand, it has created water and air pollution problems. The expansion of indoor housing has largely led to increased amounts of liquid slurry rather than solid manure systems, but the latter still play an important role in the overall systems management. Solid manure, which is more than 20% solids, includes material from traditional covered straw yards, manure with a lot of straw in it, poultry litter, and solids from mechanical slurry separators. Solid manures can make a lot of liquid waste if they are heaped outside, and produce objectionable odors when they are not properly managed. Collection, storage, treatment and land application of solid manures are discussed in detail. In each of these four stages, the emphasis is on containment.

1. Introduction

Back in the mid-1960s about 55 million hogs were being raised on near 1 million farms in the United States. In 1997, the number of hogs increased slightly (almost 61 million) as compared to 30 or 40 years ago, but the number of farms had dropped significantly to less than 110 000. In 1996, there were less than 5000 hog operations that kept 2000 or more animals, but those farms account for more than half of all pigs produced in the nation. Similar trends can be found in other countries and in all types of animal agriculture. There has been a dramatic shift in the distribution of animals due to implementation of more efficient and intensive agricultural practices. What used to be a diverse industry, where farmers kept small numbers of several different types of livestock and poultry, has become very specialized. Most animals today are raised in confinement housing facilities designed as environmental growth chambers. This presents not only an environmental improvement over the years of animals being raised in mud lots with uncontrolled odors, runoff and pathogens, but also a challenge of dealing with concentrated accumulations of manure in a sustainable manner.

Livestock and poultry are largely concentrated in certain regions instead of being spread out through large areas. For example, in Europe almost 65% of the total number of pigs being produced are raised in only four countries: France, Germany, The Netherlands and Spain. In the US, of the 10.5 million cattle raised in feedlots, about 80% are concentrated in four states: Texas, Kansas, Nebraska and Colorado. To some extent, local authorities and governments with the aim of both accelerating regional development and creating jobs have encouraged the development of concentrated activities. However, in many cases the geographical advantages of certain areas (including fertile and low-grade arable land, and good communications network), also played an important role in the consolidation of concentrated activities within a certain region. While all of this consolidation has enabled animal agriculture to produce more meat at less cost, it has created both water and air pollution problems.

Both liquid and dry animal manure can be a valuable source of crop nutrients. Land application is the way manure has been handled for centuries. If carried out properly, land application of manure is an excellent use of the nutrients contained in manure, replacing nitrogen, phosphorus and potassium that would otherwise come from chemical fertilizers. But when manure is applied to land in amounts greater than can be used by crops and retained by the soil, nitrogen, phosphorus and other nutrients leach and run off into surface and groundwater.

The expansion of indoor housing has largely led to increased amounts of liquid slurry rather than solid manure systems. Spills of liquid animal waste directly into water have an immediate environmental impact, threatening fish and other aquatic life. In addition, the excessive growth and decay of algae and other aquatic organisms that feed on excessive nutrients in water deplete dissolved oxygen. The resulting hypoxia (low oxygen) from chronic nutrient enrichment can result in fish kills, odor and overall degradation of water quality. Serious spills of animal manure into waterways have occurred frequently in recent years. In the UK, the majority of reported pollution incidents are due to the escape of animal slurries or silage effluents. About 9% of all water pollution incidents reported to the British National River Association (NRA) in 1990 were caused by animal manure and one third of those was considered to be of major significance. An informal survey of leading livestock-producing states in the US indicates that state enforcement actions taken in response to spills or discharges nearly doubled between 1992 and 1995. In Iowa, Minnesota and Missouri (accounting for 36% of hog production in the US) recorded animal waste spills rose from 20 in 1992 to more than 40 in 1996. There is still much debate as to the cause and extent of animal agriculture contribution to these problems. Regulations to tighten the standards associated with manure management and educational programs in the form of required operator training are now standard in many countries in order to prevent some of the events of the past from reoccurring.

Solid manures are less likely than liquid slurries to cause pollution, but they can make a lot of liquid waste if they are heaped outside. This liquid has a high organic matter content and there is a potential risk of it causing pollution to both surface and ground water. Runoff from open feedlots handling manure as solid can cause water quality problems as well. Also, solid manures produce objectionable odors when they are not properly managed. This article will discuss how animal solid manures can be handled and managed in order to minimize potential pollution effects.

2. Solid Manure Characteristics

Animal manure contains complex organic compounds originated from the undigested and wasted feed as well as simple organic and inorganic compounds produced in the gastrointestinal tract of animals. Once excreted, manure will naturally undergo anaerobic decomposition, producing a number of odorous gases and compounds. Production and characteristics of manure on a farm are largely affected by feed rations, species and growth stages of animals, manure collection and handling methods, and the amount of water added into the manure collection systems.

2.1 Handling Properties

Animal manures are generally classified by the type of stock and also by their physical form. Manure can be solid, semi-solid or liquid. Solid manure, which is more than 20% solids, include material from traditional covered straw yards, manure with a lot of straw in it, poultry litter, and solids from mechanical slurry separators. It will generally contain enough bedding material, or have enough dry matter to be stacked. Most meat-type poultry are raised on dry litter bases in production facilities where the waste is handled in this solid form.

Semi-solid manure is between 12 and 20% solids. It has a tendency to slump (move due to gravity forces) and it is difficult to stack. Semi-solid manure needs to be handled with box scrapers, bucket loaders or tank spreaders equipped to contain any liquid during transport. Layer production facilities with alley scrapers or deep-pit storage, dairy and beef cattle farms, and swine open concrete slab buildings are the type of facilities that produce semi-solid manure.

Manure with less than 12% total solids are usually handled as liquid slurry and will not be covered in this article.

Mechanically separated solids from liquid slurry may be classified as either solid or semi-solid depending on the efficiency of the equipment and the dry matter content of the end material.

2.2 Manure Production

The characteristics of solid manure and litter must be known to plan, design and operate manure collection, storage, pre-treatment and utilization systems for livestock enterprises. Representative sampling is difficult with manures as concentrated and heterogeneous as solid manures. It is therefore better to consider the available information as guidelines or reasonable estimates rather than accurate and precise data. Characteristics indicated in this article and in other literature should be used with an understanding of the variations in the data and their relative value. Examples of unit manure production from different animal species are given in Table 1.

Farm	**Type of animals**	**Average weight (kg)**	**Manure production**			
			As excreted	**Unit**	**Farm size (no. of livestock)**	**Total (t day^{-1})***
Swine	Finishing pig	75 – 100	7	kg (animal-day)$^{-1}$	5000	35
	Gestating sow	180 – 200	8	kg (animal-day)$^{-1}$	4000	32
Dairy	Dairy cow	500 – 650	40	kg (animal-day)$^{-1}$	800	32
Beef	Beef cow	300 – 400	15	kg (animal-day)$^{-1}$	500	7.5
Poultry	Layer hen	1.8 – 2.0	120	kg (1000 bird-day)$^{-1}$	5000	0.6
	Broiler breeder	3.0 – 3.5	250	kg (1000 bird-day)$^{-1}$	5000	1.25
	Turkey breeder	8 – 10	400	kg (1000 bird-day)$^{-1}$	5000	2

* 1 t = 1000 kg

Table 1. Unit manure production from different animal species

Data in this table represent averages from a wide database of published and unpublished information on livestock manure.

2.3 Nutrient Content

Solid manure also contains significant amounts of nutrients. Summary data on the nutrient content of solid manure from different animal species is given in Table 2.

Farm	**Type of animals**	**% dry matter**	**N (g kg^{-1})**	**P_2O_5 (g kg^{-1})**	**K_2O (g kg^{-1})**
Swine	Finishing pigs and gestating sows	20 – 30	7 –11	7 –13	5 – 9
Dairy	Milking cows	20 – 30	5 – 6	3 – 7	4 –11
Beef	Beef cows	25 – 60	6 – 12	4 – 9	4 –11
Poultry	Layer	35 – 55	14 – 17	16 – 25	10 – 13

	Broiler	60 – 80	16 – 36	25 – 40	16 – 25
	Turkeys	50 – 75	15 – 30	30 – 35	15 – 20

Source: Veenhuizen, M.A., Eckert, D.J., Elder, K., Johnson, J., Lyon, W.F., Mancl, K.M. and Schnitkey, G. (1992). *Ohio livestock manure and wastewater management guide*, 120 pp. The Ohio State University Extension Bulletin 604, Columbus, Ohio.

Table 2. Characteristics of solid manure from different animal farms.

Bedding is used in most solid manure and some semisolid manure-handling systems. Table 3 provides characteristics of common bedding materials as related to water absorption and fertilizer nutrients. This information can be used for the calculation of the nutrient value of manure for land application when bedding is used. An estimate of the bedding used can be obtained by measuring the amount used for a small number of animals and extending it to the whole herd. The volume of bedding is reduced in the manure to about half of its dry volume.

Material	**kg of water absorbed per kg of bedding***	**Density (kg m^{-3})**	**Air dry composition (g kg^{-1})***		
			N	**P_2O_5**	**K_2O**
Wheat straw (baled)	2.2	80 – 110	6	2	10
Oat straw (baled)	2.5	110 – 130	6	2	13
Cornstalks (shredded)	2.5	65 – 80	8	4	9
Wood shavings or sawdust	1.5	145 – 200	2	1	2

* typically 10% moisture content

Table 3. Characteristics of common bedding materials.

Manure from hoop structures with deep straw bedding has generally highly variable characteristics depending on the dunging locations. A recent study on a hoop structure for grow-finish swine show bedding moisture to vary from 20 to 75%, nitrogen content ranging from 5 to 20 g N kg^{-1}, phosphorus from 6.5 to 20 g P kg^{-1}, and potassium from 6 to 25 g K kg^{-1}.

Solid-liquid separation has been historically studied and used as an alternative manure treatment method from the standpoint of improving manure handling properties and producing manure solids for animal feeding, energy generation and compost production. Effective solid-liquid separation that is capable of removing a substantial amount of organic solids from fresh liquid or slurries can potentially offer the benefits of production of nutrient-rich organic solids, odor reduction in subsequent liquid manure storages, and improvement in the economics of subsequent liquid manure treatment processes. The separated solids can be utilized on farms near animal operations or can be economically exported to other areas as fertilizer and soil conditioning products.

The nutrient content of separated solids, also called solid cakes, varies with the type of manure being separated (swine, dairy, beef), the type of separator and the total solid content of the raw slurry. Generally the nutrient separation efficiency increases with the total solid content of the slurry. Belt presses and centrifuges are found to have higher separation efficiencies and produce drier solids than screen separators. Various mechanical separators have been evaluated in recent years. Examples of some of the characteristics of separated solids obtained with various types of slurries and equipment are given in Table 4.

Type of animals	**Type of separator**	**Initial dry matter (%)**	**Separated solids dry matter (%)**	**N ($g\ kg^{-1}$)**	**P_2O_5 ($g\ kg^{-1}$)**	**K_2O ($g\ kg^{-1}$)**
Swine	Vibrating/ rotating screens	1 – 2	11 – 12	2.8	1.1	0.8
	Belt press	3 – 8	14 – 18	—	—	—
	Screw press	4 – 5	20 – 40	6 – 9	3 – 10	2 – 3
	Centrifuge	1 – 7	22	7.6	5.4	–
Dairy	Vibrating/ rotating screens	1 – 2	12 – 20	—	—	—
	Belt press	13	21	3.5	0.7	1.5
	Screw press	8 – 9	20 – 30	—	—	—
	Centrifuge	3 – 6	21	5.5	2.9	—

Table 4. Characteristics of mechanically separated solids from swine and dairy manure.

The performance data included in this table may be used only as reference data when evaluating different types of separators. The testing and reporting procedures used by different researchers varied greatly, not to mention the large differences in the characteristics of the manures used.

2.4 Nutrient Losses

The system and length of storage primarily affect the nitrogen content of manure. Long-term storages result in less organic nitrogen and more ammonium nitrogen. With increased length of storage, more ammonium nitrogen is released to the atmosphere through volatilization processes. Ammonia arising from livestock manures and slurries can cause long-term damage to sensitive ecosystems. Ammonia is the most prevalent alkaline gas in the atmosphere and plays a significant role in the environment. The least amount of nitrogen loss is associated with slurry storage pits, dry house whole litter and covered storages. Deep pit manure stacking and open stockpiled litter have moderate to high nitrogen losses. Phosphorus (P) and potassium (K) are not lost prior to land application unless there is runoff and leaching from uncovered stockpiles. Table 5 summarizes the range of nitrogen (N), P and K losses in solid manure systems as affected by storage.

Storage method	**% losses**		
	N	**P**	**K**
Daily scrap and haul	15 – 35	10 – 20	20 – 30
Manure pack	20 – 40	5 – 10	5 – 10

Open lot	40 – 60	20 – 40	30 – 50
Deep pit (poultry)	15 – 45	5 – 10	5 – 10

Source: Sutton, A.L. (1994). Proper animal manure utilization. *Journal of Soil and Water Conservation* **39**, pp. 65–70.

Table 5. Nutrient losses from animal solid manure as affected by method of storage. These values were based on composition of manure applied to land versus composition of freshly excreted manure, adjusted for dilution effects of the various systems.

On deep litter systems for fattening pigs, ammonia emission is reduced compared with housing on fully slatted floors, but emissions of air-polluting nitrogen gases tend to be higher due to the formation of nitrous oxide gas (N_2O), which contributes to the greenhouse effect and affects the ozone layer.

Due to the organic nature of animal manures, specific management practices must be used to maximize the value of manures as a nutrient resource. Besides losses through volatilization, nitrogen in manures can be lost by denitrification and leaching when applied to the soil. Broadcast application of solid manure may result in 15 to 30% nitrogen losses. If the manure is rapidly incorporated in the soil, nitrogen losses are reduced to 1 to 5%.

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Biographical Sketch

José R. Bicudo is an environmental engineer with more than 10 years experience addressing technical and policy issues related to management/treatment of livestock wastes. He currently works as an Assistant Professor in the Department of Biosystems and Agricultural Engineering, University of Kentucky. This is a position with statewide responsibilities as a livestock systems specialist working with beef and dairy facilities, grazing systems, manure management, and water quality. Before joining the University of Kentucky, Dr. Bicudo worked as an Extension Engineer at University of Minnesota from 1998 to 2000. The main objective of his extension program was to provide information to the state's pork industry on the implementation of technologies for the control of odor and gas emissions from their operations. Dr. Bicudo worked from 1997 to 1998 as a Post-Doctoral Research Associate in the Department of Biological and Agricultural Engineering, North Carolina State University. He provided support to six research/demonstration projects (at pilot and full scale) on innovative treatment technologies for swine manure, including evaluation of equipment and processes. This large scale R&D operation, which included another five projects, was probably the most comprehensive comparison of manure management techniques in the U.S. Dr. Bicudo worked in Portugal for 7 years as a research officer in a major research laboratory located in Lisbon, from 1990 to 1997. While in Portugal he coordinated and developed a national plan on manure management/treatment for pork producers. He conducted research on aerobic and anaerobic systems for the treatment of swine manure and developed a number of extension and scientific publications related to this topic. From 1995 to 1997, Dr. Bicudo was an active member of the European Union Concerted Action CT94 1897 – Processing strategies for farm livestock slurries to minimize pollution and to maximize nutrient utilization together with other 14 researchers from different European countries. The main outcome of this Concerted Action was the publication of a book on Manure Management – Treatment Strategies for Sustainable Agriculture, which has been widely used in Europe since its publication in 1997.