Canada animal waste management guide

Canada Animal Waste Management Guide Committee
under the authority of
Canada Committee on Agricultural Engineering

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Canada animal waste management guide

For use by

Agricultural community
Government officials
Agricultural and engineering consultants

Involved in

Production Design
Management Assessment Regulatory work

CANADA ANIMAL WASTE MANAGEMENT GUIDE COMMITTEE

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CAUTION TO BE OBSERVED IN USING GUIDE INFORMATION

Information presented in this Guide is based on maintaining an ecological balance between nutrients supplied by animal manure and fertilizer and nutrients used by crops, without undue nuisance from other properties of manure. Individuals not trained or experienced in animal waste management should not extract portions of the Guide, nor draw inferences, without considering all aspects of the problem from the source of the waste through to re-utilization of the waste by crops.

Information is also presented on the nitrogen content of farm animal manure. To avoid any misunderstanding, the amount of nitrogen excreted by an animal is not the same amount of nitrogen available when the manure is applied to the crop. The amount of nitrogen available depends on the method of handling and processing, and should be assessed for each different type of management system.

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A. INTRODUCTION AND PURPOSE OF GUIDE

Growing public concern is being registered about all forms of pollution of our environment. At the same time, intensive livestock operations, some of them on limited land areas, are increasing in number and size.

This trend toward animal confinement for the production of eggs, meat and milk,coupled with the separation of animal feeding operations from feed production areas, tends to intensify the problems of handling animal wastes and thus increases the probability of causing pollution.

The number of residential dwellings on or near farmland is increasing. This condition will result in increased disputes between urbanites and farmers, particularly in the more densely populated areas of Canada. Thus, the need for properly designed and managed livestock facilities, and consideration of land-use policies in livestock production areas, becomes evident. Unfortunately, though many facets of livestock production have been automated, the technology related to waste management has not kept pace. Serious consideration must be given to this latter phase of management by producers, extension personnel and research workers to minimize problems with existing or new production facilities.

It is anticipated that the eventual solution to animal waste management problems will involve a balanced ecological system. This means that the nutrients returned to the farmland must be in balance with those removed by the crops grown.

The purpose of this Guide is to bring together the current practices that provide reasonable approaches to handling animal wastes. Emphasis is placed on the use of land as a recycling system.

This publication is for the use of individuals involved in operating, designing, assessing or managing a farm animal waste system. It is anticipated that this publication will set the basis for uniform animal waste management guidelines in Canada.

B. EXISTING LEGISLATION COVERING THE MANAGEMENT OF ANIMAL WASTES

At the federal government level, the Fisheries Act has implications in all parts of Canada since this legislation covers the control of pollution in water frequented by fish.

Each province has legislation covering the general control of water pollution,as well as health legislation covering pollution or nuisance that may endanger public health. Some provinces have extended this control to include the pollution of air (Alberta), the pollution of soil and air (British Columbia, Manitoba, Nova Scotia, Prince Edward Island and Newfoundland), and Ontario legislation encompasses a broad range of contaminants present in the natural environment.

In three provinces (British Columbia, Manitoba and Ontario), reasonable land disposal of animal waste from traditional or normal farm operations is exempted from certain requirements of their Acts. Legislation directed specifically to livestock production and/or manure management exists in a pollution control act and regulations in Saskatchewan and in public health regulations in Alberta and New Brunswick. Although it is not legislation, the Ontario Suggested Code of Practice contains recommendations for the establishment of livestock buildings and animal waste disposal.

Table B-l lists the relevant legislation in effect in each province.

TABLE B-1. RELEVANT LEGISLATION ON ANIMAL WASTE MANAGEMENT IN EACH PROVINCE

Province	Legislation	Administered by
British Columbia	Pollution Control Act, 1967	Pollution Control Branch, Department of Lands, Forests, and Water Resources
	Health Act	Department of Health Services
Alberta	The Public Health Act	Department of Health
	The Clean Air Act and The Clean Water Act	Division of Pollution Control, Department of the Environment
Saskatchewan	The Pollution (By Livestock) Control Act, 1971	Department of Agriculture
	The Water Resources Commission Act	Saskatchewan Water Resources Commission
	The Public Health Act	Department of Public Health
Manitoba	The Clean Environment Act	Department of Mines, Resources and Environmental Protection
	Public Health Act	Department of Health and Public Welfare
Ontario	The Environmental Protection Act, 1971	Department of the Environment
	The Ontario Water Resources Commission Act	Ontario Water Resources Commission, Department of the Environment
	The Public Health Act	Department of Health

TABLE B-1. RELEVANT LEGISLATION ON ANIMAL WASTE MANAGEMENT IN EACH PROVINCE (CONT'D.)

Province	Legislation	Administered
Quebec	Water Board Act	Quebec Water Board, Department of Municipal Affairs
	Public Health Act	Department of Social Affairs
New Brunswick	Water Act	New Brunswick Water Authority, Department of Natural Resources
	Health Act	Department of Health and Welfare
Nova Scotia	Water Act	Nova Scotia Water Resources Commission
	Public Health Act	Department of Public Health
	Environmental Pollution Control Act	Nova Scotia Environmental Pollution Council
Prince Edward Island	The Environmental Control Commission Act	Prince Edward Island Environmental Control Commission, Department of Community Services
	Public Health Act	Department of Health
Newfoundland and Labrador	Clean Air, Water and Soil Authority Act 1970	Department of Mines, Agriculture, and Resources
	Department of Health Act, 1965	Department of Health

C. MANURE MANAGEMENT

I. Importance

It is important that manure be managed to maintain the health and safety of humans and animals. Experience has demonstrated that pollution hazards can come from the mismanagement of manure from animal production. However, with an understanding of the potential sources and consequences of pollution, the provision of adequate facilities and the use of care and common sense in their operation, pollution can be controlled. Some of the more-important hazards or problems that require attention are as follows.

1.1. Gases from anaerobically stored manure

The main gases are ammonia, carbon dioxide, hydrogen sulfide and methane. Their properties and physiological effects are shown in Appendix I. Other gases in complex mixtures, such as volatile organic acids, mercaptans and amines can be present and contribute to the objectionable odor.

In parts of Canada, the odor nuisance from manure at the barn or feed lot and during land application is considered to be a major problem of the livestock industry.

Some odors are unavoidable from the barn, from liquid manure during agitation in the storage and from field spreading operations. However, with adequate facilities, management, and separation from neighbors, odor problems can be minimized.

Appendix 1 shows that besides being a nuisance some gases in sufficient concentrations can be toxic, can cause asphyxiation by displacement of oxygen and can be explosive. These gases can accumulate in covered liquid-manure storages or be released from open storage inside the barn, particularly during agitation. For instance, hydrogen sulfide is readily released and most dangerous within the first few minutes after agitation. Hence, maximum ventilation must be provided and exposure by humans and animals to this gas must be avoided. In high concentrations, hydrogen sulfide rapidly dulls the sense of smell and odor detection. Several deaths attributed to this gas have occurred. Smoking or use of an open flame should also be avoided because methane in critical proportions with air can be explosive.

1.2. Water pollution

The main water pollution hazards are associated with (a) inadequate manure storage facilities, (b) winter application on frozen soil or (c) excessively high rates of manure on land.

Manure and/or its constituents can be carried overland into surface water supplies and be responsible for (a) nitrate poisoning of animals and humans that drink contaminated water, (b) the transmission of certain diseases if these disease-producing organisms are present in the manure, (c) nutrient enrichment (eutrophication) and the resultant unsightly growth of algae, and (d) septic and unsightly conditions due to depletion of the dissolved oxygen caused by the BOD (Biochemical Oxygen Demand) of the organic material in manure.

Similarly, heavy land applications of manure or manure stored directly on gravelly soils could be responsible for nitrate contamination of local groundwater supplies. If shallow bedrock that contains open fissures is also present, disease-producing organisms,as well,could be carried into the groundwater by downward percolating water.

1.3. <u>Other problems</u>

Noise, dust and pests may require consideration also. Noise from animals in confinement can be a problem when populated areas are close by. Some dust is associated with all classes of livestock and types of confinement but is generally most serious with housed poultry on litter. Dust can be a physical nuisance and carrier of odors and disease-producing organisms. Pests such as flies, birds and rodents are also sources of nuisance and possible carriers of disease.

2. Management Principles

Any practical animal production and manure management system is bound to cause some change in the natural environment. However, considering present farm economic conditions and the technical knowledge and developments now available, much of the pollution hazard from animal manure can be controlled by following these management principles:

(a) Access to sufficient land for crop utilization of manure and limiting the rate and time of application to avoid water pollution.
(b) Separation between confined animals and neighbors to avoid nuisance complaints, by allowing dilution of unavoidable barn and feedlot odors and flies and dissipation of noise.
(c) For housed animals, frequent manure removal from the barn into separate and undisturbed storage to minimize odor levels in the barn and avoid animal and human exposure to gas hazards,particularly from stored liquid manure.
(d) Sufficient manure-tight storage capacity to control surface water and groundwater pollution and avoid winter land application of manure.
(e) Rapid soil cover of manure to control odors during land spreading and control manure washing from fields when surface runoff occurs.

All of these principles should be considered and related simultaneously to the type of animal management system that exists or is being planned. The manure systems outlined in the following sections are based as close as possible on meeting the requirements of these principles.

D. UTILIZATION OF MANURE IN CROP PRODUCTION

1. General Information

1.1 Introduction

The traditional agricultural enterprise was self-sustaining in that the animals produced were supported by the feed grown. In such an enterprise, animal manure was treated as a scarce resource, to be used in the maintenance of soil fertility. Crop yields tended to be low, large acreages were required for animal maintenance, and manure was probably applied to soils at low rates. Intensification of livestock operations has resulted in relatively high concentrations of animals on small land areas - areas that are often much smaller than would be required to produce enough animal feed to be self sufficient. In these situations manure becomes a problem to be dealt with in the most economical way, rather than a resource to be utilized. IT IS IMPORTANT THAT CONTINUOUS BLOCKS OF PRODUCTIVE AGRICULTURAL LAND BE MAINTAINED IN CLOSE PROXIMITY TO THESE ANIMAL CONCENTRATIONS FOR THE DISPOSAL AND UTILIZATION OF WASTES. THIS POINT SHOULD BE CAREFULLY CONSIDERED IN ALL LAND USE PLANNING. With carefully integrated animal and crop production practices the application of manure to soils will present little danger of polluting surface or ground water.

1.2 Forms of nitrogen in the soil

Nitrogen is essential to crop production. The forms of nitrogen used by the plant are ammonium-nitrogen and nitrate-nitrogen. Manure contains some nitrogen which on soils can be released in the forms usable by plants. Ammonium nitrogen is converted to nitrates through the process of nitrification. Nitrogen can be lost from the soil under certain conditions as ammonia or gaseous compounds such as nitrous oxide and nitrogen. Nitrate-nitrogen is not adsorbed to soil and can be leached from the root zone. Ammonium-nitrogen is held on the surface of soil particles. The movement of the nitrate-nitrogen depends on the amount of water movement in the soil. Thus, in high rainfall areas the nitrate-nitrogen is leached more readily than in low rainfall areas. Where irrigation is practiced the application rate and amount also affect the movement of nitrate-nitrogen in the soil.

1.3 Nitrogen content of manure determines application

Utilization of manure in crop production is an example of cycling components of waste products back into the soil and the crop. The main components are nitrogen in the form of nitrate and phosphorus in the form of phosphate and also the element potassium. The crop is subsequently removed from the land.

Following addition of manure to the soil, the organic phosphorus in the manure may be converted to mineral phosphates. Phosphates are less mobile than nitrates, because insoluble compounds are formed when phosphates combine with calcium, iron or aluminum. Potassium does not move readily in the soil. Accordingly, because of the high mobility of nitrate, the relatively lower mobility of potassium, and the relative insolubility of phosphates in the soil, the amount of manure that can safely be applied per acre per year is largely determined by the nitrogen content of the manure and the amount of nitrogen that is removed by the crop. Hence, it is essential to know how much nitrogen is removed from the soil per acre by common crops, and how much is added by the manure originating from common livestock operations. Table D-1 gives the nutrient content of manure as excreted.

Table D-l. NITROGEN, PHOSPHORUS AND POTASSIUM EXCRETED BY LIVESTOCK OVER A 365-DAY PERIOD*

Note - Figures refer to freshly voided manure and includes feces and urine. The kind of manure management system has a very large influence on actual nutrient content at time of land application.

	Nitrogen (lb N)	Phosphorus (lb P_20_5)	Potash (lb K_20)
1 dairy cow (1200 lb)	140	65	175
2 beef cows (400 - 1100 lb)	140	65	175
6 hogs (30 - 200 lb)	140	79	49
120 hens (5 lb)	140	112	62
180 broilers (0 - 4 lb)	140	63	54

* Adapted from Land Requirements for Utilization of Liquid Manure in Crop Production by G. E. Jones, T. H. Lane, and L. R. Webber, Ont. Dept. of Agr. and Food Information Leaflet, June, 1968.

Nitrate should be kept from entering groundwater or surface water because of its potential toxicity to livestock and infants when consumed in the water supply. While the tolerance for nitrate is moderately high (regulatory agencies generally accept a limit of 10 ppm nitrate-nitrogen in drinking water), cases are on record of groundwater supplies far exceeding this value. High concentrations have frequently been traced to mismanagement of animal manure.

High concentrations of nitrate in growing forages can also occur when nitrate levels in soils far exceed the crop requirements. High nitrate forages have been implicated on occasions in illness or death of cattle.

1.4 Soil type and topography

In order to maximize economic returns and prevent pollution to surface or groundwaters, operators should utilize manure within a carefully planned and operated soil and crop management scheme. Farmers are encouraged to make use of soil testing services to determine plant nutrient requirements and, where possible, the nutrient content of the manure to be applied. Under conditions of sound management, the productivity of the soil will increase as the fertility and physical conditions improve. The application of manure to impermeable soils can lead to surface water pollution particularly on sloping land. It is therefore not good practice to apply manure when conditions will allow drainage of the effluent to enter the natural watercourse directly.

Texture of the soil will have a bearing on the movement of nitrate to groundwater. It is generally correct to go by the rule that the finer the texture of soil, the slower the rate of downward movement of percolation water through the root zone. Leaching losses of nitrates tend to be greater in coarser-textured soils.

2. Manure Application Rate

2.1 Nitrogen balance on the farm

On any farm, additions of nitrogen are made in several ways:

(a) Purchased feeds and concentrates brought on to the farm.
(b) The addition of nitrogen in the form of fertilizers.
(c) Fixation of nitrogen by plants and by free-living soil microorganisms.

Nitrogen is lost from the farm in several ways:

(a) Volatilization of nitrogen in the form of ammonia or denitrification products (molecular nitrogen, nitrous oxide, etc.) from the soil.
(b) Similar volatilization losses from manure.
(c) Nitrogen contained in farm products removed from the farm.
(d) Leaching losses of nitrate-nitrogen.
(e) Losses by soil erosion.

For any particular farm it would be impossible to calculate a precise balance because losses of nitrogen resulting from volatilization and leaching are difficult to evaluate. However, it is likely that a carefully integrated system of feed and animal production would require very little fertilizer nitrogen other than that available in manure; the deficit represented in the animals sold off the farm would be nearly balanced by natural fixation processes. This ideal is not usually achieved and most farmers will probably have to consider additional inputs in the form of fertilizer nitrogen.

2.2 Local advice should be sought

In some provinces guidelines are available to indicate the maximum quantities of manure that should be applied to cropped soils. For example, in Ontario these guidelines are published by the Ministry of the Environment in a Suqqested Code of Practice, and in Alberta they are published by the Department of Agriculture in A Guide to Animal Manure Disposal in Alberta.

It is recommended that farmers consult the appropriate provincial agency and, with as much information as can be gained from soil tests and manure analyses, plan their manure utilization system according to provincial practice.

E. SITE SELECTION, ZONING AND BUILDING CONSTRUCTION

1. Site Selection

Planning of barn or feedlot location on a livestock farm is especially important. Things to consider are odor, prevailing wind direction, neighbor location, drainage, subsoil conditions, manure storage location, manure pile or feedlot runoff detention, natural bodies of surface and subsurface water, farm water supply, snow, space for expansion, and traffic routes for farm operations.

Each farm will require individual attention and some points discussed may be covered by specific requirements in provincial or other local legislation. Local authorities should be consulted before construction.

Take advantage of prevailing winds to carry unavoidable odors away from neighbors and the farm house. Also, separate the site as far away as possible from neighboring dwellings to allow dilution of these odors and minimize nuisance from flies. Consult proper local authorities concerning required separation distances, but do not overlook the importance of manure system design and operation as nuisance control measures.

Avoid low areas subject to flooding. Look for a site where there is a natural slope to provide drainage away from the barn or feedlot. A natural slope allows gravity flow of liquid manure to a storage or feedlot runoff to a detention basin. Either select a feedlot site at the top of a ridge, or construct a ditch or terrace above the lot to intercept and divert unpolluted runoff water.

A uniform slope of 1 to 5% and a relatively impervious soil (loam to clay loam) is desirable for unpaved feedlots. However, sand or gravelly soil is preferred beneath paved areas, for good natural or artificial drainage to prevent heaving and cracking of the pavement.

Chose an impervious clay site for below-ground storages. If any sand or gravel is found in the excavation, protect against groundwater pollution by providing an impervious lining. As a further precaution against water pollution, locate all manure as far as possible from natural bodies of water.

The accumulation of some snow, which gets mixed with manure on open confinement areas, is practically unavoidable in most parts of Canada. To minimize snowdrifts in these areas, choose a site about 100 to 200 feet downwind from a porous windbreak (shelter belt of trees or shrubs). Alternatively, a porous windbreak can be constructed or planted upwind from the feedlot site. A board fence windbreak 10 to 12 feet high with boards spaced to provide about 20% porosity, will allow a large part of drifting snow to settle into drifts before it reaches the feedlot.

2. Zoning

Aspects such as zoning, proximity to proposed or existing residences and prevailing wind direction must be evaluated before constructing or modifying a livestock enterprise. Good relationships between farmers, neighbors and regulatory bodies are absolutely necessary to attain a satisfactory balance at the agricultural-urban boundary. It is recognized that it is impossible to control all odors emanating from a livestock operation, particularly at manure-spreading time. Existing technology cannot fully cope with a little 'country atmosphere' that will predominate from time to time. Residents and regulatory officials must be made aware of waste management from an agricultural point of view. If an individual cannot tolerate animal odors occasionally, he must reassess his desire to live in a country setting.

It is hoped that zoning officials will avoid direct zoning of residential areas into predominately agricultural areas and thus minimize future conflicts between residents and farmers. An earlier statement in this publication is repeated for emphasis: "IT IS IMPORTANT THAT CONTINUOUS BLOCKS OF PRODUCTIVE AGRICULTURAL LAND BE MAINTAINED IN CLOSE PROXIMITY TO ANIMAL CONCENTRATIONS FOR THE DISPOSAL AND UTILIZATION OF WASTES. THIS POINT SHOULD BE CAREFULLY CONSIDERED IN ALL LAND-USE PLANNING". It should be expected that an agricultural operation in an area zoned for agriculture represents reasonable land use.

3. Farm Building Construction

Farm buildings should be designed and constructed in accordance with the Canadian Code for Farm Buildings, 1970*, and should meet local health and sanitary requirements.

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* Issued by the Associate Committee on the National Building Code, National Research Council of Canada, Ottawa.

The Canada Farm Building Plan Service design center prepares detailed, large-scale plans for Canadian agriculture. These plans, prepared in cooperation with the provinces, are available at provincial Department of Agriculture distribution centers or from local extension advisors.

In humid, mild climatic areas, it is good practice to install eave troughs on buildings to divert roof drainage away from the site. In colder climates with deep snow, eave troughing requires too much maintenance. Here it is better to provide a gravel splash pad at the base of the wall for erosion control where roof runoff occurs. In either case, it is important to divert unpolluted roof runoff away from adjoining open lot areas to minimize the transport of manure and the volume of waste to be handled. Where eave troughs are unsatisfactory, slope roofs away from the open lot.

Although some odors and dust are unavoidable from barn ventilation systems, it helps to exhaust the air down toward the ground and in a direction downwind and away from residences.

F. MANURE HANDLING SYSTEMS

1. Introduction

From a functional viewpoint, most manure handling systems for confined animal operations have common parts that are operated in the following sequence: collection (temporary storage); transfer to storage; storage; removal from storage; transportation to land; land application and incorporation. Some of the basic requirements for these functional parts are discussed in Part 2 of this section.

Although manure handling systems are functionally similar and some pieces of equipment are common, there is in practice no singular system. Because the methods of animal management and the properties of manure are not the same for all animals, suitable handling systems have been developed separately for each kind of animal. Recommended systems for beef cattle, dairy cattle, swine and poultry are outlined in specific detail in parts 3 to 6 of this section and where necessary, the effect of climatic differences across Canada have been taken into account. Some of the several alternate systems shown for each kind of animal differ simply in the provision of more or less automation. Other alternatives are specifically tied to given methods of animal management and particularly to the way fresh manure is modified in its consistency (its resistance to movement or separation). The consistency of fresh manure is always changed, more or less, somewhere within the handling system.

Although other factors are involved, the moisture content of manure has an important effect on its consistency and hence on the selection of handling equipment and facilities. Based on consistency, manure is handled generally as either a <u>liquid,</u> <u>solid</u> or <u>semisolid.</u> For example, where animal management practices exclude or restrict the use of bedding, <u>liquid</u> <u>manure</u> with a thin consistency is produced by adding water (intentionally, or from leaky waterers). Some liquefaction also takes place when liquid manure is stored anaerobically. At 85% moisture content or greater, liquid manure will flow by gravity from deep horizontal gutters, and, at 90% or greater, it can be readily pumped. Appendix II gives a useful graph to determine the amount of dilution water required to change the moisture content of manure. On the other hand, where ample bedding is used or manure is subjected to natural or induced air drying, <u>solid</u> <u>manure</u> is usually produced with a stiff, non-flowing consistency that is handled by an established line of solid manure equipment. Manure with 8% bedding or greater will have this consistency. There are however, existing management practices where the amount of bedding or drying is limited, and <u>semisolid</u> manure is produced with a thick consistency that may flow slowly or hardly at all. For instance, when about 2% long straw bedding is added to fresh dairy cattle manure, this mixture will likely flow slowly, whereas very little flow will likely occur with additions of about 4%. Some modifications to conventional solid manure facilities and equipment are required to handle semisolid manure.

In each of the alternate systems outlined later, manure consistency is taken into account by specifying the type of handling facilities and equipment required.

2. Parts of the System

2.1 Collection and transfer

Odor production in confinement barns can be minimized when collection facilities are small and manure is transferred at frequent intervals to separate storage. The in-barn environment is therefore subjected only to the unavoidable odors from animals and fresh manure. Large collection facilities for liquid manure actually become anaerobic manure storages. Where collection and storage are combined, special precautions such as extra ventilation are necessary to minimize risks from hazardous gases released during agitation.

Transfer equipment must be suited to the consistency of the manure. For solid manure, an established supply of mechanical equipment is available to scrape (or load), convey and stockpile the manure. Tractor scoops used for semisolid manure require a substantial buckwall against which manure is pushed to load the scoop. Also, where box-type manure spreaders are used to transfer semisolid manure, end-gate attachments will be required to contain the manure in the spreader.

Liquid manure can be transferred horizontally from the collection area either by gravity flow in deep gutters or by mechanical scrapers. Where site conditions allow a storage location below the level of the collection area, collected manure usually flows by gravity either directly, or through an intermediate small storage, into a separate large storage. The installation of a gas trap can protect the barn from dangerous gases released from the storage. Alternatively, if the air openings between the barn and the storage are small in area and the tank is completely covered, a continuous-running fan exhausting from the storage will provide similar protection plus some barn ventilation. However, where site conditions require a storage location above the level of the collection area, transfer pumps must be used. Conventional open impeller sewage pumps are being used successfully, although they can clog occasionally. Helical rotor pumps are also used, but the synthetic rubber stator in these pumps can be damaged if they are operated dry. More costly non-clog pumps, used successfully for years in municipal sewage treatment plants, are available; these pumps have smooth-vaned recessed impellers that will pass any solids that can enter the pump inlet.

2.2 Storage

Storage structures are required to hold manure and feedlot runoff between periods of land application. Although different farms have different storage needs, there are several general points related to storage location, size, construction and operation that should be observed. Specific requirements differ for solid, semisolid and liquid manure. Detailed plans for several types of storages, prepared by the Canada Farm Building Plan Service (CFBPS), are available through the extension engineers at provincial departments of agriculture.

2.2.1 Location. Locate the storage convenient to the barn or feedlot but at a site that will allow future expansion of the animal facilities and the storage. It should be accessible by solid farm roads to allow easy transport of manure and equipment to and from the storage. For belowground storages, avoid areas with a high water table, and choose a site where surface water runoff can be diverted. The soil should be well compacted to prevent differential settlement of the storage structure and, where an earthen storage is considered, the soil should be sufficiently impervious to contain manure liquids.

2.2.2 Size. The size of manure storage depends on the type and number of animals, the length of time that manure is stored and, with liquid manure, the volume of dilution water added. The daily volumes of fresh manure produced by different animals are shown in Table F-l. The number of animals is the average number confined during the storage period, not the number of animals produced. The storage time period should be sufficient to avoid having to spread manure on snow, frozen ground or sensitive crops. Fall and spring applications are best, requiring up to 6 months storage capacity for most farm situations. In regions with a long winter period, storage capacity for 200 days or greater may be required. To minimize the space required in a liquid manure storage, avoid excessive amounts of dilution water. Unless land application through an irrigation system is planned, add sufficient water only to bring the moisture content to about 90% for easy agitation and pumping.

To determine the size of manure storage, the following formula can be used:

$$V_s = (N_a \times V_m \times T) + V_w$$

where V_s = volume of storage, in cubic feet

N_a = number of animals confined during the storage period

V_m = volume of manure produced, in cubic feet per animal per day (see Table F-1)

T = storage time in days

V_w = volume of dilution water required for liquid manure storages, in cubic feet (see Table F-1 for moisture contents of fresh manure and Appendix II for dilution water requirements to change their moisture contents)

TABLE F-1. ANIMAL MANURE CHARACTERISTICS (URINE AND FECES AS VOIDED)

Class of livestock	Volume of manure per animal* ft^3/day	Volume of manure and bedding per animal* ft^3/day	Undiluted manure moisture %	Urine in manure %	BOD per animal lb/day	Nutrients per animal		
						N lb/day	P_2O_5 lb/day	K_2O lb/day
Cattle								
-Beef or dairy calf (0 to 3 mo)	0.19							
-Beef or dairy calf (3 to 6 mo)	0.25							
-Beef feeder or dairy heifer (6 to 15 mo)	0.5	0.6		25		0.07-0.18	0.06-0.17	0.04-0.1
-Beef feeder or dairy heifer (15 to 24 mo)	0.75	0.8						
-Beef cow (1200 lb)	1.0	1.2						
-Dairy cow (1200 lb)	1.6		85-87	30	2.5	0.13-0.42	0.14-0.21	0.16-0.36
-Open pen loose housing		2.0						
-Free stall loose housing		1.7						
-Tie stall		1.8						
Swine								
-40-200 lb (8 to 22 wk)	0.18		80-85	40	0.4	0.03-0.1	0.05-0.15	0.26-0.54
-10-25 lb (3 to 6 wk)	0.04							
-26-50 lb (6 to 9 wk)	0.08							
-51-75 lb (9 to 12 wk)	0.12							
-76-125 lb (12 to 16 wk)	0.18							
-126-175 lb (16 to 20 wk)	0.26							
-176-200 lb (20 to 22 wk)	0.32							
-Sow	0.40	0.48						
Chicken				0				
-Broiler (0 to 4 lb)	0.0028	0.005	litter-25		0.015	0.0012-0.005	0.002-0.01	0.0005-0.0045
-Laying hen (5 lb)	0.005		75-80					
Turkey	0.0045		75	0				
-Broiler (0 to 14 wk)	0.0065							
-Growing hen (0 to 22 wk)	0.01							
-Growing tom (0 to 24 wk)	0.012							
-Breeder								
Rabbit (doe and litter)	0.025							
Ewe sheep	0.1	0.15	75	20				
Horses	0.92	2	75	25				

* **From <u>Canadian</u>** Code for Farm Building, 1970, Associated Committee on the National Building Code, National Research Council of Canada, Ottawa.

Storage capacity requirements for the runoff from open feedlots and manure storages have received attention only recently. Therefore, it is not possible to make specific recommendations for the broad range of Canadian conditions. However, it is generally accepted that the required storage capacity is dependent on hydrologic factors which affect the runoff from the feedlot or manure storage area. Assistance from a hydrologist familiar with local conditions should be obtained to determine the size of storage. Some information is available from the United States and although it is not directly applicable to Canadian conditions, the storage design procedures used can serve as a guide. For example, studies in Nebraska (the study location with conditions closest to those in Western Canada) show that open dirt feedlot runoff control facilities can be designed and operated successfully. These facilities consist of an earthen settling basin to remove about half the runoff solids, and an earthen detention basin for short-term storage of the settling basin overflow. Over a period of 2 to 3 weeks the detention basin liquid is applied to the land before strong odors develop, and the solids from the settling basin are removed as required with a tractor scoop after sufficient natural drying takes place. Nebraska recommendations call for two basins with total volume to store 70 to 75% of the maximum 24-hour rainfall expected once every 10 years. The settling basin depth recommended is 2 feet to facilitate solids removal, and the storage volume is designed for 1 inch of runoff from the feedlot watershed area. In Western Canada, the spring runoff is likely to include greater snow-melt, and hence, greater solids content; therefore, the settling basin capacity should be somewhat greater than that required in Nebraska, and the basin probably should be paved to facilitate solids removal.

2.2.3 Construction. Storage facilities for manure or runoff should be manure-tight to avoid water pollution. Although most storages are constructed as single units, multiple units may be more economical to construct.

The main construction requirements for open solid manure storages are a slab to provide solid footing for the operation of loading equipment, a curb to contain the liquid runoff, and a drain leading to a runoff detention tank or earthen basin.

Semisolid manure storages require a slab surrounded by either a high concrete wall (Figure F-l) or, alternatively, a low curb surrounded by an earthen embankment to contain both the liquid runoff and the sloppy manure. A ramp entrance provides access for manure removal equipment, and a drain opening at the entrance leads runoff to a detention tank. The runoff detention tank can be quite small provided the main storage is designed to contain runoff after the detention tank has filled.

Liquid manure storages are either below or above the manure collection facilities. Storages below gutters or alleys can be either rectangular (Figure F-2) or circular (Figure F-3) reinforced concrete structures to accommodate gravity transfer from the barn. Agitation is necessary and is commonly done hydraulically with a tractor pto-powered liquid manure pump. The effective agitation radius using this method is limited to about 25 to 30 feet; therefore, large circular storages should be limited to 50 feet in diameter with tractor accesses at two opposite sides. Rectangular storages work best if divided into compartments no larger than 25 by 50 feet with the pump access opening centrally located along one long side. Where odors from storages will create a nuisance, rectangular storages can be covered at less cost than circular storages.

Inexpensive earthen manure storages can be used but they require a suitable dock to place a tractor and a pump agitator near the deepest part of the storage for manure removal. A slab of pavement is recommended under the pump location to prevent erosion while pumping. Unless manure is pumped under pressure to earthen storages, the inlet pipe should be above the liquid level in the storage; submerged inlets under gravity flow can plug. Earthen storages are also limited to manure-tight soil conditions (otherwise a waterproof lining will be required), and to locations where odors will not create a nuisance.

Liquid manure storages located above the collection facilities can be circular, concrete structures constructed mostly above ground. These storages are usually silo-type, 30 feet in diameter by up to 30 feet high (Figure F-4). Most experience with silo-type storages has been gained using swine manure; experience with dairy cattle and poultry manure is limited. Above-ground storages must be manure-tight. For poured reinforced concrete structures, this can be achieved by using good quality concrete; for concrete stave-walled structures, a waterproof plaster coating is required. The sump, pump and plumbing system for the aboveground storage is a most important part of these storages. It must be able to (a) transfer manure into the storage at convenient intervals, (b) agitate the manure before removal from storage and (c) remove manure from the storage and fill a tanker. A suitable sump, pump and plumbing arrangement is shown in Figure F-4, but other arrangements can be used.

Above-ground storages overcome construction problems in high watertable areas and provide a degree of safety due to the height of access. Although the concrete construction costs are generally less than below-ground structures with roof or cover in areas where there are a number of experienced silo contractors, the overall cost due to the required pump and plumbing is similar. Liquid manure forms a crust more readily in the silo-type storage; hence, odors are negligible except when pumping out.

2.2.4 <u>Operation of Liquid Manure Storages.</u> Some of the measures that can be taken to minimize operating problems are:

(a) Disturb liquid manure in storage as little as possible, to minimize the emission of odors. Further reduction of odor can be achieved by covering the storage.

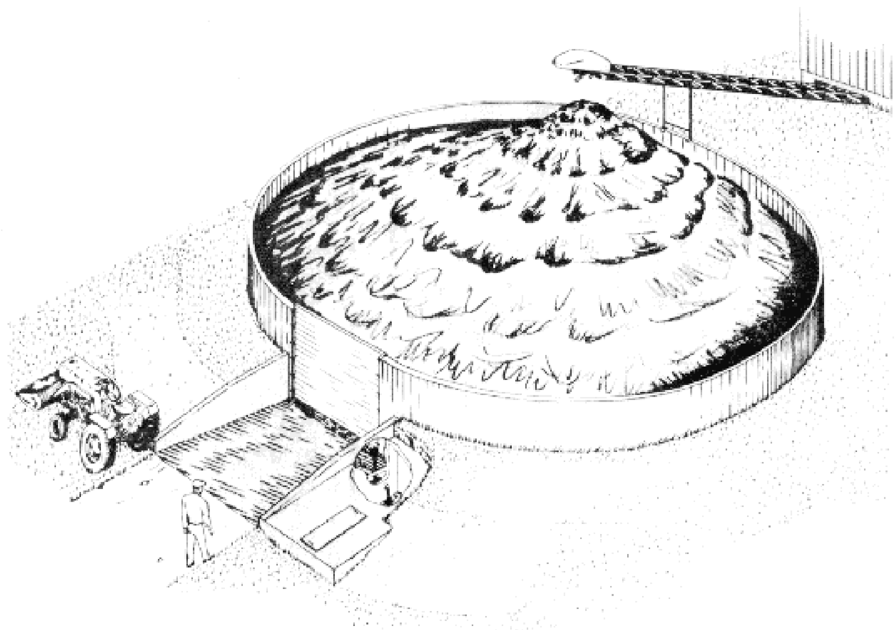

FIGURE F-l. Semisolid Manure Storage (CFBPS plan 2275)

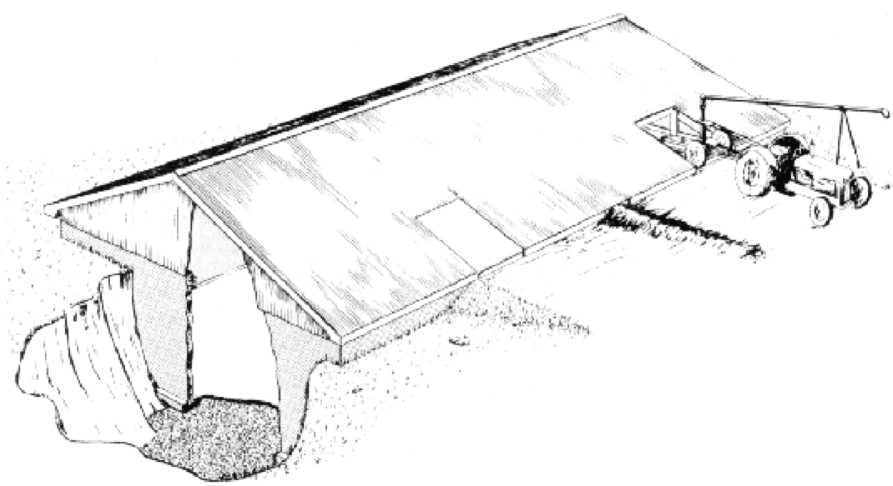

FIGURE F-2. Covered Belowground Rectangular Concrete Liquid Manure Storage (CFBPS plan 3053)

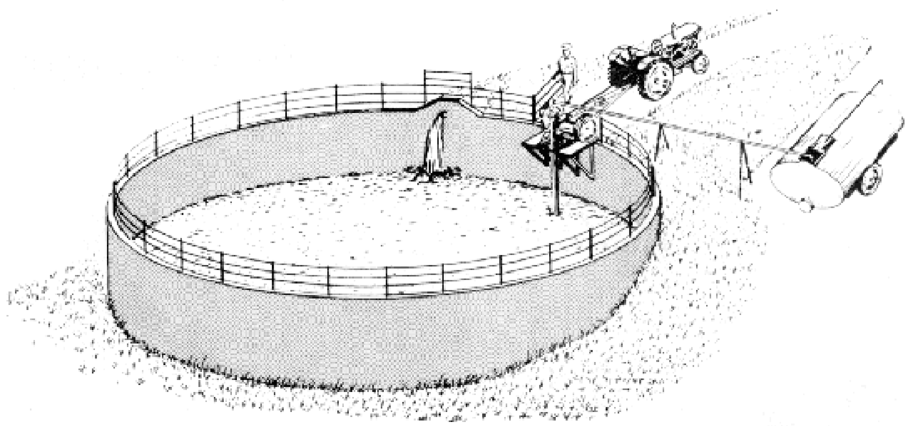

FIGURE F-3. Uncovered Circular Concrete Liquid Manure Storage (CFBPS plan 3052)

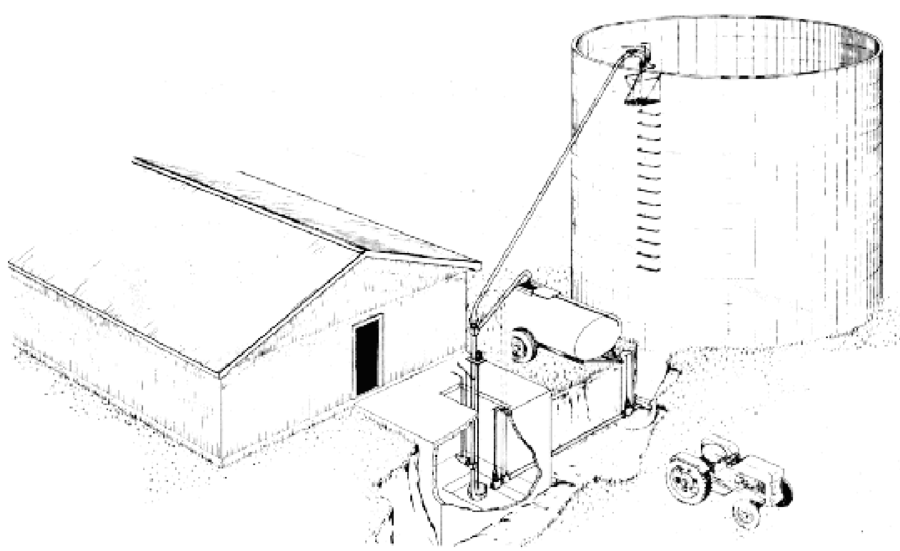

FIGURE F-4. Aboveground Silo-type Concrete Liquid Manure Storage (CFBPS plan 3250)

(b) Add only the minimum amount of dilution water necessary to allow agitation and pumping. Excess water increases storage requirements (or reduces the length of storage period for existing structures) and increases the quantities to be handled.

(c) Avoid coarsely ground feeds, particularly with swine. These feeds have created flow and settlement problems in conduits, gutters and storages.

(d) Avoid additions of hay and bedding; where hay is fed, chopped hay creates fewer pumping problems than long hay.

(e) Provide adequate agitation before manure removal from storage. Avoid agitation when the wind direction is toward the neighbors.

(f) When manure enters a separate covered storage through barn openings, exhaust ventilate from the storage or, provide a gas trap to prevent backflow of odorous and dangerous gases into the barn.

(g) Remove livestock and open all doors for maximum ventilation when agitating open storages within the barn to avoid gas hazards.

(h) Fence open-top outdoor storages to exclude children and domestic animals.

(I) Keep equipment access covers for openings into covered storages securely in place when not in use. Covers should weigh 40 pounds, should not float, and should be larger than their openings or secured with a safety chain so they can't fall into the storage.

(j) Avoid entering an indoor or covered storage, but if this action is necessary, do not enter alone. Make sure it is well ventilated and wear a rope safety harness with at least two men standing by on the rope end outside the storage in case of emergency. Additional precautions should be taken by wearing a self-contained breathing apparatus.

(k) Do not smoke or use matches or an open flame while inspecting an unventilated storage tank as some gases produced, particularly methane, can be explosive when mixed in certain critical proportions with air (see Appendix I).

2.3 <u>Removal, transport and land incorporation</u>

Suitable conventional handling equipment is available to remove, transport, and spread solid and liquid manure on the land. Special, but available equipment and facilities are required to handle semisolid manure and include a buck-wall for a scoop loader to work against and either a box spreader with end-gate or an open-top, flail-type tank spreader.

To minimize the odor nuisance when spreading manure on the land, spread it downwind from neighbors and during periods of the day when air movement favors odor dispersal. Covering manure by plowing or disking as soon as possible after spreading greatly reduces odor and also reduces the possibility of manure washing from fields during surface runoff.

Although not widely practiced, two methods for incorporating liquid manure into the land have been developed. In the plow-down method, inexpensive hoods are fitted to tanker outlets to divert manure downward into a 4-foot swath; a second tractor with wheels set wide apart and pulling a plow slightly wider than the manure swath, follows the tankers and covers the manure swath within seconds. This method is not efficient for most farm operations with only one tanker, but it can be improved by pooling equipment with other neighbors. Also, concentrating manure in a relatively narrow swath results in application rates higher than those with conventional spreading equipment. However, by reducing the tanker outlet size to 3 inches in diameter, reducing the discharge pressure at the outlet, and traveling at a forward speed of 3 to 4 miles per hour, the application rate can be kept below 45 tons of liquid manure per acre.

The second method for land incorporation of liquid manure is the soil injection method. This method holds the greatest potential for odor control, for prolonging the time period of application in the spring (such as interrow application in corn), for incorporating manure into hay and pasture without completely destroying the crop, and for achieving an acceptable rate of application. Soil injectors that are presently available (Appendix III) lead liquid manure under pressure from the tanker through tubes located behind deep cultivator teeth. From observations to date, some refinements are still required to avoid trash buildup ahead of the injector unit, to ensure adequate coverage behind the unit, and to make them suitable for row-crop application under a wide range of soil conditions. For the corn producer, injection could extend the time of manure application by a few weeks during the critical work period in the spring; for the hay and pasture producer, manure could be incorporated without plowing and unnecessary loss of crop. Application rates below 40 tons of liquid manure can readily be achieved.

Existing rapid cover plow-down and soil injection equipment is designed for liquid manure and is not suitable for producers that have an odor problem with solid and semisolid manure.

3. Beef Cattle

Five alternate manure handling systems are shown in Table F-2. The first two require minimum capital investment in housing but a relatively large feedlot area is needed, for example 200 to 300 square feet per feeder. Careful manure management is required to control environmental pollution; odor is difficult to control because of the large, open nature of confinement. The third system, which combines open feedlot and covered shelter, is more suitable for humid regions. Less area is required, for example 55 to 70 square feet per feeder. The last two systems are totally covered feedlots which allow the lowest animal area, for example 20 to 30 square feet per feeder. However, these totally covered systems require the greatest housing investment per animal.

4. Dairy Cattle

Table F-3 shows manure handling systems for the two common types of animal management, tie stall and free stall. For tie stall management, manure can be handled as either a solid or liquid. The three alternate systems for free stall management take advantage of the lesser bedding requirements and provide for handling manure as either a liquid or semisolid.

4.1 <u>Milking Center Wastes</u>

Where manure is handled as a liquid, all milking center wastes are best handled by using them for dilution of the liquid manure in storage. Depending on the location of the storage, these wastes can either flow to the storage by gravity through a pipe and gas trap, or collect in a sump from which they are pumped by a float-operated, sewage-type sump pump (CFBPS Plan 2102 shows such a system).

Where liquid manure storage is not available, the floor wash water containing milk and other wastes can be piped to a sediment tank (see Table F-4), and the overflow liquid piped to an underground disposal field (see Table F-5). Other methods of liquid disposal, such as an anaerobic lagoon and sprinkler irrigation, may be suitable in some areas, but prior approval from local authorities should be obtained. Individual practice determines the rate at which sediment accumulates in the tank and depends on the amount of manure and waste feed washed to the tank from the milking parlor floor and the amount of sanitizer used. Scraping of solid wastes from the parlor floor to the manure storage will reduce the rate of sediment buildup in the tank. Removal and land application of sediment is required at regular intervals to avoid carry-over of sediment, which will prematurely plug the disposal field. To determine the cleaning frequency, check the depth of sediment every few months after commencing operation.

TABLE F-2. MANURE HANDLING SYSTEMS FOR BEEF CATTLE

Type of animal management	Type of manure	Collection, transfer and storage	Removal and transport to land	Comments
Open field and woodlot	- Field droppings -------------------------------- - Manure near feeding-watering sites	 ----------------------------------- On slab or ground	Spread by livestock --------------------------------------- Tractor loader to spreader to land	If slab not used at feed and water site, change site locations periodically to minimize large concentrations of manure. Avoid sites where pollution of natural bodies of water will occur.
Open dirt feedlot (dry climate)	- Lot manure with bedding added -------------------------------- - Wet manure near feed bunks and water -------------------------------- - Lot and storage slab runoff	Tractor scraper to mounds on lot --------------------------------- Tractor scoop to curbed storage slab --------------------------------- Surface drains to settling basin. Overflow stored in detention basin	Tractor loader to spreader to land --------------------------------------- Liquids drain to settling basin, solids loaded to spreader to land -------------------------------------- <u>Settling Basin Sludge</u>: Tractor loader to spreader to land <u>Detention Basin Liquid</u>: Vacuum tanker to land <u>OR</u> Pump to irrigation system to land	Mound seldom needs to be removed if it can be maintained firm and dry. -- Storage slab may be upper part of settling basin -- Obtain local advice regarding size of settling and detention basins.
Open paved feedlot and covered bedded area (humid climate)	- Solid manure in covered bedded area ------------------------------- - Semisolid manure on paved lot ------------------------------- - Lot and stock pile runoff	On paved or dirt floor ----------------------------------- Tractor scraper to stock pile on curbed slab ----------------------------------- Surface drains and/or sewers to earth detention basin or concrete tank	Tractor loader to spreader to land --- Tractor loader to spreader to land -- Vacuum tanker to land <u>OR</u> Pump to irrigation system to land	Provide sufficient headroom in bedded area for bedding pack plus cattle space (10-12 ft typical) --- Let snow and ice mixed with manure melt and drain before handling
Covered feedlot with solid floor	- Solid manure in bedded area ------------------------------- - Semisolid manure at feeding-watering area -------------------------------- - Stockpile runoff	On paved or dirt floor ------------------------------------ Tractor scraper to stockpile on outdoor curbed or walled slab ----------------------------------- Surface drains and/or sewer to earth detention basin or concrete tank	Tractor loader to spreader to land --------------------------------------- Tractor loader to spreader to land --------------------------------------- Vacuum tanker to land <u>OR</u> Pump to irrigation system to land	Provide sufficient headroom in bedded area for bedding pack plus cattle space (10-12 foot typical) --- Use box spreader with endgate or open-top flail-type tanker ---
Covered feedlot with totally slotted floor	Liquid manure	Manure through slotted floor to tank storage below	Pump-agitator to tanker to land	When agitating liquid manure, remove livestock and open all doors to avoid gas hazard

TABLE F-3. MANURE HANDLING SYSTEMS FOR DAIRY CATTLE

Type of animal management	Type of manure	Collection and transfer	Storage	Removal and transport to land	Comments
Tie stall with bedding (see CFBPS plans) 2220 2618	- Solid manure ---------------- - Manure stack runoff	Shallow gutter, gutter cleaner to elevator --------------------------------------- Surface drain and/or sewer	Stack on curbed slab ----------------------------------- Detention tank or earthen basin	Tractor loader to spreader to land ------------------------- Vacuum tanker to land	In cold winter climates, manure dropped from slacker will freeze into a very steep cone and will interfere with stacker operation
Tie stall with restricted chopped bedding (see CFBPS plan) 2220	Liquid manure	Grate-covered shallow gutter, gutter cleaner to opening into storage OR Grate-covered deep gutter, continuous gravity flow from gutter into storage	If storage site below level of collection facilities, gravity flow to large tank (see CFBPS Plans 3052 and 3053) or earthen basin	Pump-agitator to tanker to land	Continuous fan exhausting from storage for low-rate barn ventilation, and to prevent gas entry and cold drafts from the gutter cleaner and continuous flow gutter openings
Free stall with slotted floor passages, restricted chopped bedding (see CFBPS plan) 2102	Liquid manure	Manure through slotted floor to trench below, flush trench with pump recirculation system, pump-agitator to storage	If storage site above level of collection facilities, gravity flow to short-term holding tank, pump to large above-ground circular tank (see CFBPS plan 3250)	Pump-agitator to tanker to land	When flushing trenches, remove cattle and open all doors to avoid gas hazard
Free stall with paved passages, restricted chopped bedding	Liquid manure	Tractor scraper to intermediate holding tank below floor level (see CFBPS Plans 2101, 2103 and 2104), pump- agitator to large storage tank (see CFBPS Plans 3250, 3252 and 3253) or earthen basin OR Tractor or shuttle scraper to sump and plunger pump (see CFBPS Plan 2112), through pipe to large storage tank (see CFBPS Plans 3252 and 3253) or earthen basin		Pump-agitator to tanker to land	Close floor openings from barn into storage when agitating holding tank
Free stall with paved passages, limited bedding	- Semisolid manure ------------------ - Stockpile runoff	Tractor scraper to elevator or buck wall (see CFBPS Plans 2101 , 2103, 2104, 2106) to storage OR Tractor scraper to buckwall or ramp to box spreader with end-gate to distant storage OR Tractor or shuttle scraper to sump and plunger pump (see CFBPS Plan 2112) through pipe to storage --------------------------------------- Surface drain and/or sewer	Stockpile on walled slab (see CFBPS Plan 2275) ------------------------------------- Detention tank or earthen basin	Tractor loader to spreader to land ---------------------------- Vacuum tanker to land	Semi-solid handling recommended with uncut hay and bedding

TABLE F-4. SEDIMENT TANK CAPACITIES FOR MILK WASTES*

No. of cows	Volume, gallons (imp.)	Settling Compartment		
		Length	Width	Water Depth
Up to 25	500	6 ft 9 in.	3 ft 0 in.	4 ft 0 in.
26 to 45	600	8 ft 0 in.	3 ft 0 in.	4 ft 0 in.
46 to 65	720	9 ft 0 in.	3 ft 3 in.	4 ft 0 in.
66 to 100	900	9 ft 0 in.	3 ft 6 in.	4 ft 6 in.

* From Canadian Code for Farm Buildings, 1970, Associate Committee on the National Building Code, National Research Council of Canada, Ottawa.

TABLE F-5. SIZE OF UNDERGROUND DISPOSAL FIELD FOR MILK WASTES*

No. of cows	Length of tile trench, ft.		
	Subsoil drainage		
	Good (Sand and gravel)	Medium (Sandy loam soil)	Poor (Silt and clay loam soil)
Up to 25	100	100	150
26 to 45	100	180	270
46 to 65	130	260	390
66 to 100	200	400	600

* From Canadian Code for Farm Buildings, 1970, Associate Committee on the National Building Code, National Research Council of Canada, Ottawa.

5. Swine

As shown in Table F-6, swine manure can be handled as either a solid or liquid. However, the general scarcity of bedding for solid manure systems had lead to the wide use of liquid manure systems. Several alternate facilities to collect and transfer liquid manure are shown. For breeding herds an optional system is shown using open paved runs and a covered bedded area.

6. Poultry

Two alternate manure handling systems for chicken broilers and heavy breeders and three systems for layers are shown in Table F-7. Important management considerations are covered under Comments.

6.1 Dead Bird Disposal

Dead birds can be disposed of by burial in disposal pits or by incineration. In either case, check with local authorities before construction; certain requirements for burial may have to be met, and licencing of incinerators is required in some provinces.

The main requirements for disposal pits are that they be located and constructed to avoid polluting water supplies and that they be safe. Although local water table and soil conditions must be taken into consideration, in general, disposal pits should be located at least 150 feet from any well or spring used as a water supply. They can be made of metal, concrete or other locally approved material that is waterproof, and should be constructed to exclude insects and rodents. The addition of lime helps control odors. For safety, cover pits with tight-fitting lids equipped with a locking device.

Incinerators for dead bird disposal should be designed to consume all material and should meet Incinerator Institute of America Standards for Type 4 wastes as well as additional local requirements. Incinerators should be fire-safe and located so that prevailing winds carry exhaust fumes away from neighbors.

7. Equipment

The alternative handling systems outlined above have different equipment and construction requirements. To assess alternate systems, it is helpful to know equipment performance, availability and price. Since performance data are not always available, the use of equipment and its field performance under local conditions should be investigated.

To assist in contacting suppliers of various equipment regarding availability and price, a list of manufacturers is shown in Appendix III. This information was derived from the Directory Issue of the Canadian Farm Equipment Dealer magazine and from provincial representatives. Further information on equipment distributors is contained in the directory.

Listing of manufacturers does not imply endorsement of particular equipment, and if some manufacturers have been inadvertently omitted, apologies are here recorded.

TABLE F-6. MANURE HANDLING SYSTEMS FOR SWINE

Type of animal management	Type of manure	Collection and transfer	Storage	Removal and transport to land	Comments
Bedded pens (see CFBPS plans) 3017 3024 3025 3028 3032 3036	- Solid manure -------------------- - Manure stack runoff	Shallow gutter, gutter cleaner to elevator -- Surface drains and/or sewer	Stack on curbed slab --------------------------- Detention tank or earthen basin	Tractor loader to spreader to land ---------------------------------- Vacuum tanker to land	Only practical where bedding is abundant and in expensive
Little or no bedding (see CFBPS plans) 3017 3021 3022 3023 3024 3025 3028 3032 3035 3036	Liquid manure	Hand scrape to shallow gutter, shovel or gutter cleaner to opening into storage <u>OR</u> Hand scrape to deep narrow gutter, gravity flow from gutter through valve and gas trap into storage <u>OR</u> Partially slotted floor, through slots to either: (i) trench below, gravity flow from trench through flap- gate and gas trap into storage , or (ii) trench below, removal from trench and transfer by vacuum tanker to distant storage , or (iii) continuous loop trench below for oxidation ditch. Effluent overflow into storage (see part G, sect. 2.1)	If storage site below level of collection facilities, gravity flow to large tank (see CFBPS Plans 3252 and 3253) or earthen basin If storage site above level of collection facilities, gravity flow to short-term holding tank, pump to large above-ground circular tank (see CFBPS Plan 3250)	Pump-agitator to tanker to land OR Vacuum tanker to land	To exclude long term storage gases from barn, provide a gas trap where manure enters storage, OR provide a continuous -running fan exhausting from storage. This fan should be selected to give the first stage ventilation rate required by the livestock.
Open paved runs and covered bedded area (optional for breeding herds)	Solid manure ---------------------- - Runoff from paved runs and manure stack	Hand scrape to open paved run, tractor scrape to storage --- Surface drains and/or sewer	Stack on curbed slab ----------------------------- Detention tank or earthen basin	Tractor loader to spreader to land ------------------------------------ Vacuum tanker to land	--------------------------------

TABLE F-7. MANURE HANDLING SYSTEMS FOR POULTRY

Type of animal management	Type of manure	Collection and transfer	Storage	Removal and transport to land	Comments
Floor housing with bedding (broilers, replacement pullets, heavy breeders)	Dry litter	On paved floor, tractor loader to truck or spreader to storage	Part on floor, part in stockpile on curbed slab	Tractor loader to spreader to land	Stockpile storage required only if housing must be cleaned and re populated during winter period
Heated floor housing no bedding (broilers)	Dry droppings	On concrete floor	On floor	Tractor loader to spreader to land	Experimental; floor slab heated by circulating hot water in steel or plastic piping
Ceiling suspended or floor supported cages (layers and light breeders) OR wire floor OR wall to wall cages	Liquid manure	Shallow trench, tractor shuttle scraper (for ceiling suspended cages) or cable shuttle scraper (for floor supported cages) to: (I) opening into storage, or (ii)cross conveyor to storage	Large tank	Pump-agitator to tanker to land OR Vacuum tanker to land	Add dilution water during agitation, as required for pumping
	- Semisolid manure	Shallow trench, tractor shuttle scraper (for ceiling suspended cages) or cable shuttle scraper (for floor supported cages) to cross conveyor to storage	Stockpile on walled or curbed slab	Tractor loader to spreader to land	Use of dropping boards assists in drying manure
	Stockpile runoff	Surface drain and/or sewer	Detention tank or earthen basin	Vacuum tanker to land	Avoid dilution water
	- Semisolid manure	Droppings directly into deep pit below (see CFBPS Quick Release Plans Q-5000 and Q-5001)		Tractor loader to spreader to land	Avoid adding dilution water to minimize odor. Maximum ventilation in pit area to assist drying of manure

G. PROCESSING OF ANIMAL WASTES

Processing of manure to reduce some of its objectionable characteristics is not yet widely done. However, the following processing systems, which are either being used, researched or considered for manure, are discussed to indicate their present status.

1 . Anaerobic Process

Anaerobic decomposition takes place in water-saturated organic wastes when dissolved or free oxygen is not present. Depending on the nature of the waste and other environmental conditions, many complex reactions can take place. Different types of anaerobic bacteria break down organic and other material by using chemically bound oxygen in substances such as sulfates ($S0_4$), carbon dioxide ($C0_2$) and various organic compounds containing combined oxygen. The end products are new bacterial cells, inert solids, water and gases such as carbon dioxide, methane, hydrogen sulfide, organic acids, and mercaptans. The latter three gases are odorous, and methane when mixed with air can be explosive. Because of the hazardous and odorous gases produced, the anaerobic process for animal wastes will likely have limited use in Canada.

The anaerobic lagoon and digester are two systems of current interest for the anaerobic processing of animal wastes.

1.1. Anaerobic lagoon

During the summer months, anaerobic lagoons provide a suitable environment for the biological decomposition of manure; little activity takes place in the winter. However, because the accompanying odors are a nuisance, these structures have not been accepted generally except in isolated locations away from neighbors. Most anaerobic lagoons are essentially out-of-door storages where manure is diluted by rain and melted snow and some breakdown of material occurs.

If construction of an anaerobic lagoon is being considered, there are several basic site requirements that should be met. A lagoon should be located:
(a) far enough from any living area to avoid being a nuisance
(b) on the leeward side of the farm house
(c) in an area with suitable space for expansion
(d) to exclude or, in low rainfall areas, to control surface drainage to the lagoon from adjacent areas
(e) to avoid contamination of surface water and
(f) in an area where impervious clay exists; if sand or gravel is encountered in the excavation, an impervious lining will be required to protect against groundwater pollution.

The effluent from overflowing anaerobic lagoons is not acceptable in quality by most water authorities for discharge into a natural body of water. Storing the effluent and applying it to cropland is a suitable method of handling this problem.

Additional recommendations for loading rates and lagoon construction are contained in Part 2 of the Canadian Code for Farm Buildings*. However, consult local authorities and secure approval of design before commencing construction.

1.2. Anaerobic digester

Anaerobic digesters are widely used for the processing of dilute organic sludge removed from municipal and industrial sewage. Most digesters are circular, air-tight structures 20 to 35 feet deep and are equipped with external mixing devices and heat exchangers to maintain a sludge temperature between 90 and 95ºF. Sludge is added once a day or oftener. Once the digestion process is established, sufficient methane gas is usually produced to heat the digesting sludge and provide excess fuel for other uses. After World War II, a limited number of digesters were built in Europe, Asia and Africa to use manure and crop wastes for the production of methane gas as a source of power on farms.

These experiences have raised some recent interest in the possible use of digesters to process manure, but no known digesters are used commercially for this purpose in Canada. Although there are advantages to be gained from manure digesters, such as the production of a stable end product and a valuable gaseous fuel, several limitations require careful consideration. These limitations include a high capital cost for proper structures, equipment and gas control devices, continual care to avoid explosions, and at least daily feeding of diluted manure to the digester. Continual supervision is necessary and various remedial measures must be taken when the process becomes 'upset' since it is extremely sensitive to environmental conditions such as pH and temperature. Also, although some volume reduction is achieved, considerable digested material will require storage and application to cropland. Because of these limitations, digesters for manure are not likely to be used widely in the near future.

2 . Aerobic Process

Aerobic decomposition occurs when a dilute mixture of organic wastes and water is supplied with dissolved oxygen. Under these conditions, aerobic bacteria use the organic matter as a food source in biochemical and oxidation reactions to produce new bacterial cells, carbon dioxide and water as the primary end products. In practical systems, all of the organic matter will not be decomposed aerobically and accumulation of these stable solids along with fixed solids will result.

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* Issued by the Associate Committee on the National Building Code, National Research Council of Canada, Ottawa.

The main benefits of aerobic decomposition are that the entire process is essentially odorless, the pollutional characteristics and volume of the waste are reduced, and the minerals are concentrated. The processed waste still requires storage space and application to cropland, but several of the objectionable features of unprocessed wastes are reduced considerably. There are several different systems used to process organic wastes aerobically, but the three systems that have received the most attention for animal manure are the indoor oxidation ditch, the mechanical aerated lagoon and the naturally aerated lagoon. Naturally aerated lagoons, however, will have limited use due to their large surface area and water requirements. For example, an aerobic lagoon to process the manure from 1,000 head of swine would require a surface area of 19 acres and over 15 million gallons of water to fill it initially for operation.

It is also doubtful whether the relatively small volume of manure added would maintain a satisfactory liquid depth in the lagoon.

2.1. <u>Oxidation ditch for swine</u>

Although some manure from animals other than swine is being processed by the oxidation ditch, most field experience has been with swine manure. In Canada, there are a few oxidation ditches operating in commercial-sized swine barns, but in the United States about 400 ditches are operating mainly for control of odors in the barn and storage and during land application.

The oxidation ditch in northern climates is an indoor continuous concrete channel, shaped like a racetrack and located beneath t:he slotted floor sections of the pens. Most ditches are operated on a continuous flow basis where the ditch is kept full to the level of an overflow sluice gate. An aeration rotor (or rotors), located within the central one third of the straight section of the ditch, adds oxygen from the air and mixes the liquid, called mixed liquor, by circulating it around the ditch. The effluent (mixed liquor) passes over the sluice gate into a storage structure. Although the effluent usually has little odor, it has a BOD_5 of about 2000 to 3000 mg/litre and is not suitable for direct discharge to a natural body of water.

Very little information is available on the volume of effluent produced. In a British Columbia operation, an effluent volume of up to 10 times the calculated manure volume added to the ditch was caused by waterers that allowed swine to waste water excessively. On the other hand, the effluent volume observed at several Michigan and Ohio operations was only about a third of the manure volume added to the ditch. Increased evaporation by the rotor action undoubtedly accounts for liquid losses, but ditch leakage is also possible.

2.1.1. <u>Design.</u> The essential design requirements to be met concern the liquid volume and depth in the ditch, and the rotor capacity to supply oxygen and circulate the liquid.

For oxidation ditch design in swine finishing barns (150 lb average hog weight), the following guidelines are used:

(a) Liquid volume in the ditch of 10 cubic feet per hog.
(b) Liquid depth in the ditch between 18 inches (preferred) and 24 inches (maximum).
(c) Total ditch depth to provide 1-foot clearance between the liquid surface and the lowest members of the slotted floor structure.
(d) Maximum spacing of 300 to 350 feet between rotors along the ditch length.
(e) Rotor aeration capacity to add 0.6 to 0.8 pounds of oxygen daily per hog.
(f) Rotor pumping capacity to circulate liquid around the ditch at a velocity of 1.25 feet per second.

Consult rotor manufacturers specifications to determine the rotor length, blade immersion depth and speed to meet the oxygen requirements as well as the necessary horsepower. Rotors are commonly designed to operate at 100 rpm and a blade immersion of 5 to 6 inches.

2.1.2. Operation. Before adding swine to the barn, adjust the height of the overflow sluice gate and fill the ditch with water to the design depth. Start the rotor with the blades set at the design immersion depth. Increase the swine population in the barn gradually during the first few weeks of operation to allow the establishment of suitable biological material in the ditch and to minimize foaming.

Foaming often occurs during the starting period and this type of foam can be controlled by various antifoam agents or a water spray. After the process is established and when sufficient oxygen is maintained in the mixed liquor, foaming is generally not a problem. However, periods of foaming and/or production of obnoxious odors can be caused by changes in conditions which upset the microbial activity in the mixed liquor. These changes can be due to a clogged overflow which increases the liquid depth and rotor submergence, rapid increases in swine population, variations in feed or antibiotics used, additions of detergents or disinfectants when sanitizing pens and, to some extent, seasonal variations in temperature. As a safeguard against unexpected foaming, a foam switch is available commercially. When activated by rising foam, the switch will stop the rotor until foaming subsides. Swine have been suffocated by foam that filled the pens.

Exercise extreme caution when restarting an oxidation ditch that has been inoperative for a few days or more. The manure added during this period will turn the mixed liquor anaerobic and if it is agitated by the rotor, foaming and the release of dangerous and odorous gases will occur. It is recommended that at least half the liquid be removed. and replaced with water, maximum barn ventilation by fans and open doors be provided and, if possible, the animals should be removed.

Field experience indicates that the daily power costs for rotor operation are about 1/2 to 1 cent per hog based on an electricity cost of 2 cents per kilowatt-hour.

2.2. Mechanically aerated lagoon

In principle, the biological reactions in a mechanically aerated lagoon are essentially the same as those in an oxidation ditch, except during the winter. Mechanically aerated lagoons for manure are still in the field trial stage of development and several different methods of operations are receiving attention.

An aerated lagoon is supplied with oxygen from the air, usually by a floating mechanical aerator, although field trials with different types of air diffusers located in the lagoon are being conducted. Since these lagoons are located outdoors, very little biological activity takes place in the winter and freezing problems in many parts of Canada can be anticipated. The manure handling system must also be designed to add manure to the lagoon at least daily to avoid upsetting the biological activity.

At present, there is insufficient information on mechanically aerated lagoon design to make definite recommendations.

3. Dehydration

In the dehydration process, manure is dried to a moisture content of 10% of less by the addition of heat. At this moisture level, the manure is relatively free from odor and can be further processed into a granular soil conditioner with a low fertility analysis suitable for marketing.

Limited amounts of dried manure are presently being produced in a few dehydrating operations in Canada and the United States. However, several aspects should receive careful consideration before construction. Past experience has shown that manure-drying plants have gone out of business for two basic reasons; they were found to be uneconomical and a public nuisance. The economics of dehydration depend on the volume and moisture content of the raw manure, which affect the operating costs of drying, and on the nonfarm market demand for dried manure. To minimize nuisance, additional expenses will be required for air pollution control devices, such as cyclone separators to control the discharge of manure particles and afterburners to control the discharge of odorous gases.

Commercial driers specifically for manure have recently become available but sufficient field experience has not been gained to determine the range of conditions under which they are suitable.

4. Incineration

Incinerators are used to dispose of sewage sludge by drying, burning and reducing the sludge to ash. Sludges with a high proportion of volatile solids will burn without additional fuel once combustion is started, but other sludges usually require the continuous addition of fuel. Supplemental fuel is always necessary to establish combustion temperatures.

Except at some animal research laboratories, there are no known incinerators used to dispose of manure. Incineration greatly reduces the volume of manure to an inert ash, but odor and other air pollutants produced require control. Check with local authorities before construction; the licencing of incinerators is required in some provinces. Present equipment and processing costs do not appear to make this process economical for manure unless some new modification to existing types of incinerators is developed.

5. Composting

Composting of manure is a process that is receiving increased interest and some recent field experience and experimentation. Composting under aerobic conditions is a relatively fast and low-odor biological process where organic matter is broken down by bacteria and fungi to produce a dark-colored humus, carbon dioxide, water and heat as the main end products. The material heats naturally during the process and reaches temperatures ranging between 120 and 160 F.

The basic requirements for composting are the mixing and aeration of raw material that has a carbon to nitrogen ratio between 20:1 and 30:1 and a moisture content between 40 and 70%. To obtain a suitable raw material, most manures require the addition of dry material with a high carbon content. Chopped straw, ground corncobs or other crop residues have been used, and the possibility of using municipal garbage as a source of carbon is being investigated. The process requires continual attention. It has operated successfully under Canadian winter temperatures, but should be sheltered to allow suitable control of the moisture content.

The two processing systems used are the open windrow and the high-rate mechanical composter methods. The process takes up to a few weeks to complete using the windrow method, where the material is placed in rows about 4 feet high by 8 feet wide and turned several times to mix and aerate. Stable compost can be produced in 5 to 10 days using the high-rate composter method, where the material is mixed at least daily and an aeration system adds oxygen. The compost can then be stockpiled to mature further; it is not overly attractive to flies and usually has only an earthy or slightly musty odor.

APPENDIX I. PROPERTIES OF NOXIOUS GASES AND THEIR PHYSIOLOGICAL EFFECTS

Gas	Sp. Gr. [2]	Odor	Color	Explosive Range [3] Min. (%)	Max. (%)	M10 [4] (ppm)	MAC [5] (ppm)	Concentration [6] (ppm)	Exposure Period [7]	Physiological Effects [8]
Ammonia (NH_3)	0.6	sharp, pungent	none	16	--	53	100		–	IRRITANT
								400	--	Irritation of throat
								700	--	Irritation of eyes
								1,700	--	Coughing and frothing
								3,000	30 min	Asphyxiating
								5,000	40 min	Could be fatal
Carbon Dioxide ($C0_2$)	1.5	none	none	--	--	--	5,500			ASPHYXIANT
								20,000	--	Safe
								30,000	--	Increased breathing
								40,000	--	Drowsiness, headaches
								60,000	30 min	Heavy, asphyxiating breathing
								300,000	30 min	Could be fatal
Hydrogen Sulfide (H_2S)	1.2	rotten egg smell, nauseating	none	4	46	0.7	20			POISON
								100	hours	Irritation of eyes & nose
								200	60 min	Headaches, dizziness
								500	30 min	Nausea, excitement, insomnia
								1,000	--	Unconsciousness, death
Methane (CH_4)	0.5	none	none	5	15	--	--			ASPHYXIANT
								500,000	--	Headache, non-toxic

1 From: Origin, Identification, Concentration and Control of Noxious Gases in Animal Confinement Production Units by E.P. Taiganides and R.K. White, Dept. of Agr. Eng., Ohio State Univ., Columbus, Ohio. Research Paper of The Ohio State University Research Foundation.

2 Sp. Gr. = specific gravity: the ratio of the weight of pure gas to standard atmospheric air. If number is less than 1 the gas is lighter than air; if greater than 1 it is heavier than air.

3 Explosive Range: the range within which a mixture of the gas with atmospheric air can explode with a spark. (% is by volume).

4 MID = Minimum Identifiable Odor: the threshold odor; i.e., the lowest concentration (highest dilution) from which an odor is detected

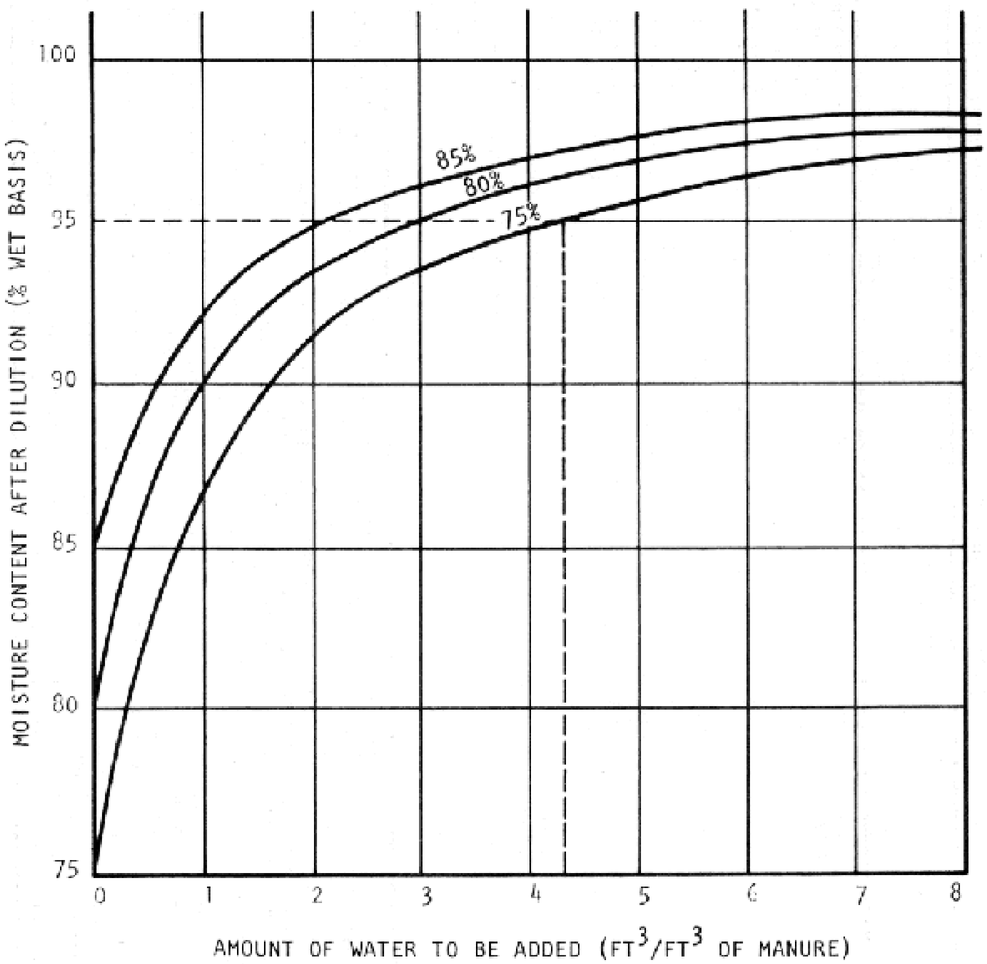
5 MAC = Maximum Allowable Concentration: the concentration set by health agencies as the maximum in an atmosphere where men work over an 8-10 hour period. These levels must be lower in confinement units because animals stay in such environment continuously for 24 hours.

6 Concentration, in parts of the pure gas in million parts of atmospheric air; to change concentration to % by volume, divide the listed numbers by 10,000

7 Exposure Period: the time during which the effects of the noxious gas are felt by an adult human being and an animal (especially pig) of about 150 lbs in weight

8 Physiological Effects: those found to occur in adult humans; similar effects would be felt by animals weighing 150 lb; lighter animals will be affected sooner and at lower levels; heavier animals at later times and higher concentrations

APPENDIX II. **VOLUME OF DILUTION WATER REQUIRED TO CHANGE THE MOISTURE CONTENT OF MANURE**



EXAMPLE: To bring manure that has 75% moisture content up to 95% moisture, 4 1/3 cubic feet of water must be added to each cubic foot of manure.

APPENDIX III. EQUIPMENT MANUFACTURERS

Each manufacturers address is listed at end of appendix

BARN GUTTER CLEANERS

Acorn Equipment
Agromatic
Avco New Idea Farm Equipment Div.
Badger Northland Inc.
Beatty Farm Equipment
Berg Equipment (Canada)
Butler Mfg. (Canada)
Clay Equipment
Clayton Mfg.
Dion Freres
Farmway
Houle J & Fils
Ideal Machinery
Jamesway
Jenkins Equipment
Jutras
Klinzing A.F.
La Joie R.A.
Massey-Ferguson Ind.
Mayrath
Melroe Div.
Patz
Ralco Farm Equipment
Starline
Wood A.R. Mfg.

POULTRY HOUSE PIT CLEANERS

Anderson Box
Beatty Farm Equipment
Big Dutchman
Bolens Div.
Clayton Mfg.
Henn-Rich Mfg.
Jamesway
Jenkins Equipment
LeJohn Machine
Melroe Div.
Patz
Starline
Ventilateur Victoria
Wood A.R. Mfg.

LITTER AND MANURE CONVEYORS AND STACKERS

Beatty Farm Equipment
Big Dutchman
Brower Mfg.
Jutras
Kasten Mfg.
Kosch
Massey-Ferguson Ind.
Pedlar People
Thomas Equipment

MANURE SPREADERS (BOX TYPE)

Allis-Chalmers
Avco New Idea Farm Equipment Div.
Case J.I.
Cobey
Decker Mfg.
Deere John
Du-Al Mfg.
Farmhand of Canada
Gehl
International Harvester Co. of Canada
J.F. Farm Machinery
Krone Bernard Mfg.
Maple Leaf Mfg.
Massey-Ferguson Ind.
New Holland
Schuler Mfg. & Equipment
Schwartz Mfg.
Starline
White, George $ Sons Ltd.

MANURE SPREADERS (FLAIL TANKER)

Allis-Chalmers
Avco New Idea Farm Equipment Div.
Brady Div. of Koehring Co.
Deere John
Desjardins
Hawk Bilt Mfg.
Howard Rotovator
International Harvester Co. of Canada
Massey-Ferguson Ind.
New Holland Div.
Starline

LIQUID MANURE TANKERS (PUMP FILLED)

A.O. Smith Harvestore
Badger Northland Inc.
Calumet Co.
Grose Welding
Hawk Bilt Mfg.
Holz A Mfg.
Howard Rotovator
International Harvester Co. of Canada
J.F. Farm Machinery
La Joie Co.
New Holland
Metal Ind.
Pearson Bros.
Ralco Farm Equipment
Sahlstrom Mfg.
Universal Machine $ Engineering Products (1964)
Vaughan
West Coast Spreaders
Westside

LIQUID MANURE TANKERS (VACUUM FILLED)

Avco New Idea Farm Equipment Div.
Beatty Farm Equipment
Calumet Co.
Clay Equipment Corp.
Cox $ Co.
Hawkeye Steel Products Inc.
Houle $ Fils Inc.
Kejohn Machine
Lely Ltd.
Lejohn Ltd.
Martin Elam M. Machinery Mfg.
Pearson Bros.
Westside

LIQUID MANURE PUMPS (SUBMERGED CENTRIFUGAL)

A.O. Smith Harvestore
Badger Northland
Beatty Farm Equipment
Clay Equipment Corp.
Grose Welding
Holz A Mfg.
International Harvester of Canada
J.F. Farm Machinery
Lely
Mitchel-Lewis-Staver
Parma Water Lifter
Sahlstrom Mfg.
Starline
Vaughan
Wade R.M.

OTHER LIQUID MANURE PUMPS (MEDIUM TO HIGH PRESSURE CENTRIFUGAL)

Barnes Pumps
Construction Machinery of Canada
Enpo-Cornell
Gorman-Rupp of Canada
Hale Fire Pump
I.T.T. Industries
Marlow Pumps
Mitchell-Lewis-Staver
Monarch Machinery
Myers F.E. $ Bros.

HIGH PRESSURE PUMPS (POSITIVE DISPLACEMENT)

Challenge Mfg. Co. (helifern)
Holz
Pearson Bros.
Robbins $ Myers, Inc.

SUMP PUMPS (FOR MILKING CENTER WASTES)

Ackley Mfg.
Albany Pump
Armstrong S.A.
Barnes Pump
Beatty Farm Equipment
Clubine J.O.
Gorman-Rupp of Canada
ITT Fluid Handling Div.
Jacuzzi (Canada)
Monarch Machinery
Myers F.E. F, Bros. (Canada)
Otaco
Renn Cupit Ind.
Sta-rite Ind. of Canada
Western Land Roller

SOIL INJECTORS FOR LIQUID MANURE

Avco New Idea Farm Equipment Div.
Badger Northland Inc.
Clay Equipment Corp.
Grose Welding Ltd.
Lely
Pearson Bros.
Sahlstrom Mfg.

ADDRESS OF MANUFACTURERS

A.O. Smith Harvestore Products Inc., 550 W. Algonquin Rd., Arlington Heights, Illinois.

Ackley Mfg. Co., 13770 S.E. Ambler Rd., Clackamas, Ore. 97015.

Acorn Equipment Co. Inc., P.O. Box 207, Stevens Pt., Wisc. 54481.

Agromatic, a division of A.F. Klinzing Co. Inc., P.O. Box 891, Prairie Rd., Fond du Lac, Wisc. 54935.

Albany Pump Co. Ltd., 320 Oakdale Rd., Downsview 479, Ontario.

Allis-Chalmers, Milwaukee, Wisc. 53201.

Anderson Box Co., Box 31157, Indianapolis, Ind.

Armstrong, S.A., Ltd., 1400 O'Connor Dr., Toronto 16.

Avco New Idea Farm Equipment Div., Coldwater, Ohio. 45828.

Badger Northland Inc., Kaukauna, Wisc.

Barnes Pumps of Canada Ltd., 1711 Mattawa Ave., Mississauga, Ont.

Beatty Farm Equipment Co., Fergus, Ont.

Berg Equipment Co. (Canada) Ltd., R.R. 6, London, Ont.

Big Dutchman, Div. of U.S. Industries Inc., 200 Franklin St., Zeeland, Mich. 40464.

Bolens Div., FMC Corp., 215 S. Park St., Port Washington, Wisc.53074.

Brady Div. of Koehring Co., P.O. Box 1456, Des Moines, Iowa 50305.

Brower Manufacturing Co., 640 S. 5th Quincy, Ill.

Butler Mfg. Co. (Canada) Ltd,, Burlington, Ont.

Calumet Co., 340 North Water St., Algoma, Wis. 54201.

Case, J.I. Co., 17 Vicker., Islington, Ont.

Challenge Mfg. Co. Inc., 1308 67th St., Oakland, California, 94608.

Clay Equipment Corp., Cedar Falls, Iowa. 50613.

Clayton Mfg. Co., 4213 N. Temple City Blvd., El Monte, Calif. 91731.

Clubine, J.O., Ltd., 234 Princess St., Winnipeg, Man.

Cobey Co., South East St., Galion, Ohio 44833.

Construction Machinery Co. of Canada, Box 231, Waterloo, Ontario.

Cox, R.J. $ Co., R.R. # 2, Arcanum, Ohio.

Decker Mfg. Co., Janesville, Wisc. 53545.

Deere, John Ltd., 610 King St. W., P.O. Box 610, Hamilton, Ont.

Desjardines Ltee., St. Andre Cte, Kamouraska, Que.

Dion Freres Inc., P. 0. Box 360, Ste-Therese de Blainville, Que.

Du-Al Mfg. Co., 1000 B. Ave., Sious Falls, S.D. 57104

Enpo-Cornell Pump Co., a division of Piqua Machine & Mfg. Co., Piqua, Ohio 45356.

Farmhand of Canada Ltd., 1270 Sargent Ave., Winnipeg.

Farmway Co. Inc., 1034 Depot St., Manawa, Wisc. 54949.

Gehl Co., 143 Water St., West Bend, Wisc. 53095.

Gorman-Rupp of Canada Ltd., 70 Burwell Rd., St. Thomas, Ont.

Grose Welding Ltd., Alma, Ont.

Hale Fire Pump Co., 708 Spring Mill Ave., Coshohocken, Pa. 19428.

Hawk Bilt Co., 402 E. 6th St., Vinton, Iowa 52349.

Hawkeye Steel Products Inc., P.O. Box 149, Waterloo, Iowa 50704.

Henn-Rich Mfg. Ltd., 75 Archibald St., St. Boniface, Man.

Holz, A.V., Mfg. Co., P.O. Box 1359, Newburgh, N.Y.

Houle, J., & Fils Inc., Route No.13, Wickham, Quebec.

Howard Rotavator Co. Ltd., West Horndon, Essex, England.

ITT Fluid Handling, Div. of ITT Canada Ltd., 171 Dawson Rd., Guelph, Ont

Ideal Machinery Co. Ltd., 1100 Leclaire, St. Cesaire, Cty. Rouville, Que.

International Harvester Co. of Canada Ltd., 208 Hillyard St., Hamilton, Ont.

J.F. Farm Machinery Ltd., P.O. Box 760, Exeter, Ont.

Jacuzzi Canada Ltd., 270 Rexdale Blvd., Rexdale, Ont.

Jamesway Co. Ltd., 756 Bishop St., P.O. Box 67, Preston, Ont.

Jenkins Equipment Co., Inc., 2810 Baker Rd., Dexter, Mich. 48130.

Jutras Co. Ltd., The, C.P. 398, Victoriaville, Cte Arthabaska, Que.

Kasten Mfg. Corp., Allenton, Wisc. 53002.

Kejohn Machinery Ltd., Box 426, Lambeth, Ont.

Klinzing, A.F., Co. Inc., Hwy. 23 E. at Prairie Rd., P.O. Box 891, Fond du Lac, Wisconsin 54935.

Kosch Co., P.O. Box 707, Columbus, Neb. 68601

Krone, Bernard GmbH Maschinenfabrik c/o I.Q. Farm & Industrial Equipment, P.O. Box 5000, 1144 Speers Rd., Oakville, Ont.

Lajoie, R.A., Cie, Ltee., C.P. 69, St. Pie Co. Bagot, Que.

Lely Ltd., P.O. Box 5023, Burlington, Ont.

LeJohn Machine Ltd., 77 Panet Rd., St. Boniface, Man.

Maple Leaf Mfg. Co., The, Box 40, Rockwood, Ont.

Marlow Pumps Mid-mar Ltd., 1 Research Rd., Brampton, Ont.

Martin, Elam M., Machinery Mfg., R.R. 3, Wallenstein, Ont.

Massey-Ferguson Industries Ltd., 915 King St. W., Toronto.

Mayrath Co., Compton, 111. 61318.

Melroe Div., Clark Equipment Co., Gwinner, ND 58040.

Metals Industries Ltd., P.O. Box 790, Brandon, Man.

Mitchel-Lewis-Staver, Portland, Oregon.

Monarch Machinery Ltd., 889 Erin St., Winnipeg 10.

Myers, F.E., F, Bros. Co., (Canada) Ltd., The, 808 Courtland Ave. E., Kitchener, Ont.

New Holland Div. of Sperry Rand Corp., New Holland, Pa 17557.

Otaco Ltd., West St. S., Orillia, Ont.

Parma Water Lifter Co., Box 248, Parma, Ida. 83660.

Patz Co., Pound, Wisc. 54161.

Pearson Bros. Co. Inc., P.O. Box 192, U.S. Rt.#34 East, Galva, 111. 61434.

Pedlar People Ltd., The, 519 Simcoe St. S., Oshawa, Ont.

Ralco Farm Equipment Co., P.O. Box 69, St. Pie Bagot, Que.

Renn-Cupit Industries Ltd., 419-34th Ave., S.E. Calgary, Alta.

Robbins & Myers Co., Brantford, Ont.

Sahlstrom Mfg. Co., 422 Main St., Box 589, Bennington, Vermont 05201.

Schuler Mfg. & Equipment Co. Inc., R.R. #1, Griswoll, Iowa 51535.

Schwartz Mfg. Co., P.O. Box 248, Lester Prairie, Minn. 55354.

Sta-Rite Industries of Canada Ltd., 265 Fairall St., Ajax, Ont.

Starline Inc., 300 West Front St., Harvard, Iii. 60033.

Thomas Equipment Ltd., Centreville, N.B.

Universal Machine & Engineered Products (1964) Ltd., 1354 Waverley St., Winnipeg 19.

Vaughan Co. Inc., Rt. 1, Box 1033, Montesano, Wash. 98563.

Ventilateur Victoria Ltee., C.P. 173, 109 Boul. Gamache, Victoriaville, Que.

Wade, R.M. & Co., 1919 N.W. Thurman, Portland, Ore. 97209.

West Coast Truck Bodies, 17510-57th Ave., Surrey, B.C.

Western Land Roller Co., 1341 West 2nd St., Hastings, Nebr. 68901.

Westside Iron Works, Mount Vernon, Washington.

White, George, & Sons Co. Ltd., Cabell St., P.O. Box 129, Terminal B, London, Ont.

Wood, A.R., Mfg. Co., Box 218, Luverne, Minn. 56156.