CHAPTER 5

INDUSTRY SUBCATEGORIZATION FOR EFFLUENT LIMITATIONS GUIDELINES AND STANDARDS

5.0 INTRODUCTION

The Clean Water Act requires EPA to consider a number of different factors when developing Effluent Limitations Guidelines and Standards (ELG) that represent the best available technology economically achievable for a particular industry category. These factors include the age of the equipment and facilities, the manufacturing processes employed, the types of treatment technology to reduce effluent discharges, and the cost of effluent reductions. One way the Agency takes these factors into account is by breaking down categories of industries into separate classes of similar characteristics. The division of a point source category into groups called "subcategories" provides a mechanism for addressing variations among products, raw materials, processes, and other parameters that can result in distinct effluent characteristics. This provides each subcategory with a uniform set of effluent limitations guidelines that take into account technology achievability and economic impacts unique to that subcategory.

In developing the CAFO ELG, EPA assessed the factors described above and developed additional factors that specifically address the characteristics unique to CAFOs. Furthermore, EPA reviewed the existing ELG supporting documents for the basis for subcategorization. Finally, it is EPA's goal to simplify this regulation by revising both the ELG and the NPDES permit regulations together, and to develop a subcategorization scheme consistent with both regulations. For this proposal, EPA considered the following factors:

- 5.1.1 Basis for the existing ELG (40 CFR Part 412)
- 5.1.2 Production processes
- 5.1.3 Animal type
- 5.1.4 Water use practices
- 5.1.5 Wastes and wastewater characteristics
- 5.1.6 Facility age
- 5.1.7 Facility size
- 5.1.8 Geographical location
- 5.1.9 Pollution control technologies
- 5.1.10 Non-water quality environmental impacts

5.1 Factors Considered as the Basis for Subcategorization

EPA considered a number of potential subcategorization approaches for CAFOs. EPA used information collected during site visits as well as outreach communications with the industry to develop these approaches. A brief discussion of each approach is presented below.

5.1.1 Basis for Subcategorization in the Existing ELG

EPA developed the subcategorization in the existing ELG (40 CFR Part 412) on the basis of animal type, housing, and numbers of animals (USEPA, 1974). As one option for revision, EPA considered maintaining the existing basis of subcategorization, and refining the performance standards for these facilities (described in Chapter 9 as Regulatory Scenario 4 where the ELG applicability is established at 1,000 AU). EPA also considered expanding the scope of the ELG, and considered the existing subcategorization as the basis (described in Chapter 9 as Regulatory Scenarios 2 and 3). The subcategories analyzed under the existing ELG are listed below:

- beef cattle, open lot
- beef cattle, housed lot
- dairy cattle, stall barn
- dairy cattle, free stall barn
- dairy cattle, cowyard with milking center
- swine, open dirt or pasture
- swine, slotted floor house
- swine, solid concrete floor
- chickens, broilers
- chickens, layers
- chickens, layer breed and replacement
- turkeys, open lot
- turkey, housed lot

EPA developed model farms to distinguish animal type, current housing types, and numbers of animals that could be used to evaluate costs for each existing potential subcategory. EPA notes that the industries have changed operational practices considerably in the past few decades. EPA and industry stakeholders both agreed that the basis for subcategorization needed to reflect current industry trends. Stakeholders suggested EPA should consider elimination of any reference to outdated technologies such as continuous flow watering systems for poultry. EPA also notes that changes in production processes have essentially excluded swine nurseries and dairy heifer operations. Finally, EPA notes that the analysis for the animal types listed above reflect assumptions regarding animal sizes, ages, and/or weights that were common to the industry in 1974. In many cases, these parameters are substantially different today than they were in 1974 (See Chapter 4). Nevertheless, EPA determined animal types were still an important factor that needed to be further evaluated. Animal type is further described in section 5.1.3.

5.1.2 Production Processes

EPA interpreted "production processes" to be the production of meat, eggs, or milk by CAFOs. The production process also includes the housing systems commonly used. Manure handling and treatment are discussed in section 5.1.9. One basis for subcategorization is the type of production system in place; for example, the swine production pyramid of breeding, nursery, and finishing could be used as a basis of subcategorizing swine CAFOs. In consultation with the industry, EPA determined there were too many life-cycle variables to allow reasonable subcategorization, and that segmentation based on these variables was unlikely to result in substantially different effluent guidelines and standards. In the case of chickens, such an approach would result in over a dozen subcategorizations that overlap. The applicable subcategory could also vary for each group of animals produced at a given operation. EPA determined segmentation in this fashion would complicate rather than simplify the regulation.

Another approach could be based on building type or confinement practice; for example, open lots, stall barns, and total confinement housing could be used as a basis for subcategorization. EPA collected sufficient data to warrant development of a new subcategory for veal, which was previously included in the beef cattle subcategory. Veal operations confine fewer animals than do many beef feedlots, and veal are usually maintained in housing where wastes are stored in lagoons or tanks. As discussed in Chapter 10, EPA also found the bases for BAT and NSPS for veal operations are different than that for beef cattle.

EPA also determined that the previous basis for separating wet and dry poultry operations was inappropriate. EPA developed model farms by size (number of birds), location (region), and function (broiler or layer) to further evaluate production processes. EPA did not find that these factors influenced the ability for the regulated industries to achieve the performance standards. Furthermore, since broilers and layers both are mostly dry manure systems, and since it would complicate the regulation by segmenting each subsector, EPA decided not to segment the industry for the proposed rule.

For the other animal sectors, EPA looked at and determined that there was no reason to segment the industry. EPA's data and site visits indicated that facilities often managed animals in more than one fashion at a single location, and furthermore, that such a subcategorization could actually provide disincentives for facilities to employ new technologies. Nevertheless, EPA acknowledges production processes are an important factor in distinguishing various facilities, and developed its cost models to reflect the differences in production processes. Cost estimates developed for the various technology options described in Chapter 10 indicate that differences in production processes do not consistently influence the ability of the facility to achieve the performance standards.

5.1.3 Animal Type

EPA considered both animal type and animal maturity as a possible means of subcategorization. Animal type is clearly a significant factor and was successfully used as the first level of categorization in the existing ELG. However, the animal breed, animal weight, number of turns produced, feed and water consumption, manure production, manure contents, and production system vary not only by animal type, but also by animal function and maturity. These differences suggest further evaluation of animal function and animal maturity for the purposes of subcategorization. For example, sows for breeding are often confined, fed, housed, and maintained differently from nursery pigs or finishing pigs. Chickens raised for meat production are a different breed of chicken, have a different weight, eat a different diet, and are raised differently than those used for egg production. Such an approach could also mean a beef feedlot would have to track the average weights of each animal breed and age on the facility. Many other production related factors are necessarily complicated, such as fluctuating market demands, number of turns the facility produces annually, efficiency of a given animal or breed of animal to assimilate feed, costs and makeup of feed, and many other highly variable factors. These factors do not lend themselves to industry segmentation.

EPA notes two cases where the existing regulation needed clarification regarding scope of certain animal types: immature swine and immature dairy. The existing regulation only counted those swine that weigh more than 55 pounds, and accounts for only the confined mature dairy (whether milked or dry) when determining the applicability for the dairy operation. Some stakeholders perceive an inconsistency between sectors and how CAFOs are defined, and consider the inconsistency a major loophole. Therefore, EPA collected data on the numbers and sizes of operations that confine immature animals.

In the 1970s, farms that confined only nursery pigs were relatively scarce. The vast majority of these operations maintained all phases of swine production (farrow to finish) at one location. The size of a swine operation was readily identified by the number of sows or the number of finishing pigs kept on site. Swine nurseries may have been located in separate buildings, but the animals were still maintained at the same site. Since the regulations applied to the entire facility and all animals kept in confinement, once a facility was defined as CAFO for one group of animals, all animals and manure generated in confinement were considered part of the CAFO. Though half of the swine industry today still practices farrow-to-finish production, and the vast majority of the remaining operations are grow-finish operations, the increased use of contracts to handle certain phases of production and the increased specialization found in the swine production pyramids has resulted in the emergence of operations that solely confine nursery pigs (i.e. swine weighing less than 55 pounds). Even in the 1990s, there were an estimated 100 operations that only confine immature swine (i.e. nurseries). However, EPA data indicates such operations are increasing in both number and size, and looked at ways to subcategorize these operations and include them under the revised regulatory scope.

EPA considered a number of mechanisms for covering immature swine. The simplest approach is to count all swine, regardless of size or age. EPA determined counting all animals would double the effective size of operations that have breeding functions. While this would include nursery facilities, this approach also changes the existing basis without improving the regulation. Alternatively, all swine would be counted but a weighting factor could be used to distinguish animal sizes. This approach is inconsistent with EPA's attempt to simplify the regulations by removing mixed animal multipliers and animal unit calculations. Furthermore EPA believes the current subcategorization is still effective for regulating all but those facilities that house immature swine only. To target the perceived immature animal loophole, EPA selected the approach of counting both numbers of mature swine and numbers of immature swine, either one of which could define the facility as a CAFO. Once a facility is defined as a CAFO for either age group of animals, all animals in confinement would be considered as part of the CAFO. This approach minimizes changes to the applicability to most facilities with mature swine, though it is possible some breeding facilities with high numbers of pigs per litter could now be defined as a CAFO.

The existing regulation also applies to operations confining mature dairy, whether milked or dry. In the 1970s, most dairies maintained calves and heifers for replacement on site, though such animals were frequently kept on pasture. The number of heifers and calves kept varied from year to year and by season, but the milking herd was relatively constant. Bulls, when kept on site at all, were few in number. The threshold for dairy already takes into account housing and management of animals at dairies, including the frequent use of pasture to keep some animals. EPA still believes the threshold based on mature dairy inherently accounts for some calves and heifers being kept in confinement. For reasons described above, EPA elected to continue to count only mature animals at a dairy.

Since the 1970s, some dairy operations have focused time and resources on the actual milking herd, and have elected not to keep heifers and calves on site. An estimated 18% dairies use contract heifer operations to keep the heifers until needed. Though EPA estimates there are fewer than100 large heifer operations, the trend continues for offsite management of heifers. Such heifer operations may use pasture, but more commonly use a feedlot type system for maintaining the animals. Therefore, EPA proposes to count heifers maintained separately from the milking herd using the same basis as beef cattle. Note that both beef cattle and heifers are counted together under this approach.

In addition to animal type and age, EPA performed additional analysis on animal function: pullets for replacement, turkeys for breeding, swine breeding facilities, swine finishing facilities, swine nurseries (swine under 55 pounds), and beef backgrounding yards. However, EPA believes segmentation of the industry to reflect these other animal functions would not improve practicability of the regulation. Many facilities could fall under more than one applicability, causing additional confusion in implementing applicable regulatory requirements. EPA concluded size and age of animal was only appropriate for the purpose of including those animals previously unspecified in the applicability of the ELG.

5.1.4 Water Use Practices

EPA considered water use practices at dairy, swine, and layer facilities employing liquid or semi-solid based technologies such as flush waste handling systems, deep pits, and scrapers. In considering these practices as a basis for subcategorization, first EPA costed the dairy industry for scrape or flush, and conservatively costed all swine facilities as utilizing flush type manure handling systems. EPA costed these sectors for the various technology options, and concluded water use practices did not prevent a facility from achieving performance standards. EPA determined a subcategorization based on water use practices could in some cases provide a disincentive for a facility to reduce fresh water consumption. Therefore, EPA did not select water use practices as a basis for subcategorization.

5.1.5 Wastes and Wastewater Characteristics

EPA analyzed data available from USDA, universities, industry, and the literature. For a given animal type, there is reasonably consistent manure generation, and similar pollutant generation. However, site specific factors such as animal management, feeding regiments, and manure handling will affect the form and quantity of the final waste products.   EPA determined nutrients were the primary pollutant of concern, and evaluated some methods of subcategorization based on nutrient generation.

EPA considered a method for comparing sows and nursery pigs to finishing pigs where the method looks at manure, nitrogen, phosphorus, BOD_5, and volatile solids (VS) on a per pound (lb) animal basis. Depending on the metric used, from 9,000 to 12,000 immature pigs equate to 2,500 finishing pigs (or equivalent to 1,000 AU of swine). Therefore EPA selected 10,000 swine under 55 pounds as the equivalent of 2,500 mature swine. See Section 5.1.3 for additional discussion of immature animals.

Manure/litter can be treated and reused as bedding materials, and wastewaters can be recycled for washing or flushing, but ultimately all manure nutrients will be land applied. Even manure processed into value added products (such as pelletizing or composting) or used for alternative uses (such as incineration or digestion) will eventually be land applied. Therefore, EPA considered an approach that evaluated the nutrient content of the manure, namely phosphorus. One method of nutrient based subcategorization would use published USDA NRCS manure nutrient values to determine a threshold at which a facility would be defined as a CAFO. One limitation to such an approach is that it would not encourage management strategies to reduce nutrient content of the manure, and the approach does not consider the form of the nutrient, only the presence of the nutrient. Form of the nutrient (i.e. organic or inorganic) is especially important where land application of manure should be done with the intention of nutrient assimilation by the crop and soil.

EPA considered another approach by which the mass of a particular nutrient (i.e. phosphorus) could be used as a basis for categorization. This approach encourages nutrient management and conservation, however this approach was not selected due to its costs, complexity, and potential additional requirements for rigorous sampling. Furthermore, the approach would not allow for site specific determination of the land application rate for any other nutrient. EPA also did not select a particular pollutant such as nutrients as a basis for subcategorization because nutrients (such as phosphorus) may be an important consideration today, but in the future the focus may shift to some other parameter such as metals or pathogens.

5.1.6 Facility Age

EPA evaluated the age of facilities as a possible means of subcategorization because older facilities may have different processes and equipment which could result in different wastewater characteristics. These differences may require significantly greater or more costly control technologies to comply with regulations.

During site visits EPA looked at facilities of all ages. EPA believes these older facilities are subject to full compliance with state and federal regulations just like the newer facilities. In addition, many older facilities are similar to newer facilities because they have improved, replaced, or modified equipment and practices over time. For example, many wet layer facilities are retrofitting to dry manure systems, few if any large swine facilities use open lots, and ventilation systems are replaced with newer technologies. Even though confinement housing may be considered to have a 20 to 30 year useful life, modifications are continuously made to the internal structures such as replacement of floor materials, new feeding systems, and updated drinking water equipment. These and other examples are documented in the record (See W-00-27, Section 5.3).

As described in Chapter 6, wastes and wastewater characteristics are predominantly dependent on animal type and animal age. The age of the facility is also taken into consideration through the production process factor. Treatment, storage, method of manure handling, and other forms of manure management will affect the form of the manure and wastewaters generated. However, the age of the facility does not have an appreciable impact on the wastewater characteristics and was not considered as a basis for subcategorization.

5.1.7 Facility Size

EPA considered subcategorization on the basis of facility size. EPA analyzed several size groups for each major livestock sector, including the existing ELG applicability threshold of 1,000 AU (see Chapter 11 for the size groups analyzed). Within each size group EPA considered the predominant practices, and developed cost models to reflect these baseline practices. EPA found facilities may use different treatment, storage, and handling practices based on size, but for the size of facilities under consideration for revisions to the ELG (i.e. >300 AU), facilities of all sizes generally use similar practices. The animal breeds (i.e. preferred animal strains and genetics) maintained also do not vary measurably by facility size, and therefore there is very little variation in manure and waste characteristics.

EPA adjusted costs for each size group modeled to reflect these baseline characteristics. Essential requirements governing waste management are closely related for all sized facilities. For some technology options the costs to meet the performance standards may affect more smaller operations, such as fixed costs for groundwater assessments. For other technology options, such as land application standards, smaller facilities are better able to meet the performance standards. EPA did not find that farm size consistently influenced the ability of the facilities to achieve the performance standards for each technology option (see the EA for more information on impacts). Furthermore, pollution potential from AFOs (i.e. >300 AU) is approximately the same per unit of animal production for all sizes of facilities. Finally, to minimize confusion, inconsistencies, and administrative burden, EPA intends to set the ELG to apply to anyone defined as a CAFO. EPA thus determined that the industry should not be subcategorized on the basis of facility size.

5.1.8 Geographical Location

EPA considered subcategorization on the basis of geographical location. EPA analyzed key production regions for each major livestock sector (see Chapter 11 for definitions of the regions analyzed). Animal breeds maintained and therefore manure and waste characteristics do not vary measurably by region. Within each region EPA considered the predominant practices (see Chapter 4), and developed cost models to reflect these baseline practices. EPA identified different treatment, storage, and handling practices based on location for the size of facilities under consideration for revisions to the ELG (i.e. >300 AU). Treatment technologies vary by location, as does performance of technologies such as anaerobic lagoons, evaporation ponds, and methane recovery lagoons. Costs to install and operate certain technologies such as storage and manure handling equipment will vary by location. This distribution of costs and practices by location suggests subcategorization based on geographic distribution. EPA also recognizes geographic location may have an affect on the market for raw materials and products, the predominance of contractual relationships, and the value of the products. These issues are addressed in the Economic Assessment Document (EA).

Two factors are especially subject to geographical location, specifically the availability of cropland for application of manure and the selection of manure handling and storage practices appropriate to the local climate. However, these factors encourage conservation by efficient use of water, including recycle and reuse, and encourages the installation of practices for the entire category to reduce treatment costs, reduce hauling costs, improve distribution of manure nutrients, and improve pollutant removals. These new practices may also positively affect non-water quality environmental impacts. Ultimately, the impact of location and climate is so highly variable as to prove unreliable in defining subcategories.

5.1.9 Pollution Control Technologies

EPA evaluated water pollution control technologies currently being used by the industry as a basis for establishing regulations. Treatability of wastes was not a factor for categorization since wastes from CAFOs are concentrated and present in such quantities that no direct discharge from the production area is allowed. Furthermore, pollution control technologies are often complementary to or directly part of the production process, and the rationale for not using production processes as a basis for subcategorization also apply. See 5.1.2 for a further discussion of production processes. Finally, use of pollution control technologies to segment the industry may result in disincentives for new and innovative treatment technologies.

5.1.10 Non-Water Quality Environmental Impacts

Non-water quality impacts from the CAFO result from transportation of manure and wastes to off-site locations, and emissions of volatile organic compounds to the air. While non-water quality characteristics are of concern to EPA, the impacts are the result of individual facility practices and do not apply uniformly to different industry segments. To the extent there are similarities, these similarities do not lend themselves towards subcategorization of the industry in a way that provides better controls than the proposed approach. Therefore non-water quality impacts are not an appropriate basis for subcategorization. Chapter 13 provides further information concerning non-water quality impacts of CAFOs.

5.2 Proposed Revised Subcategories

Animal type is a significant factor and was used as the first level of subcategorization. Animal age was used as the second level of subcategorization for swine and mature dairy cattle. EPA is not proposing changes to the ELG for the sheep or lambs, horses, or ducks subcategories. The proposed revisions to the ELG subcategories are presented in the following table. The table indicates the minimum number of animals that defines the facility as a CAFO in the NPDES regulations. Once defined as a CAFO, the ELG applies to that facility.

Table 5-1. Revised ELG Applicability

Subcategory	Minimum Number of Animals to be Defined as a CAFO	
	Two-Tiered NPDES Scenario	Three-Tiered NPDES Scenario
Veal	500	300
Mature dairy cattle (whether milked or dry)	350	200
Cattle other than mature dairy or veal	500	300
Swine each weighing over 25 kilograms	1,250	750
Swine each weighing less than 25 kilograms	5,000	3,000
Turkeys	27,500	16,500
Chickens	50,000	30,000

5.3 References

USEPA. 1974. Development Document for Effluent Limitations Guidelines and New Source Performance Standards - Feedlots Point Source Category. U.S. Environmental Protection Agency, Washington, DC.

CHAPTER 6

WASTEWATER CHARACTERIZATION AND MANURE CHARACTERISTICS

6.0 INTRODUCTION

This chapter describes waste streams generated by the animal feeding industry. Differences in waste composition and generation between animal types within each sector are highlighted.

The types of animal production and housing techniques determine whether the waste will be managed as a liquid, semisolid, or solid (Figure 6-1). The type of manure and how it is collected have a direct impact on the nutrient value of the waste and its value as a soil amendment or for other uses.

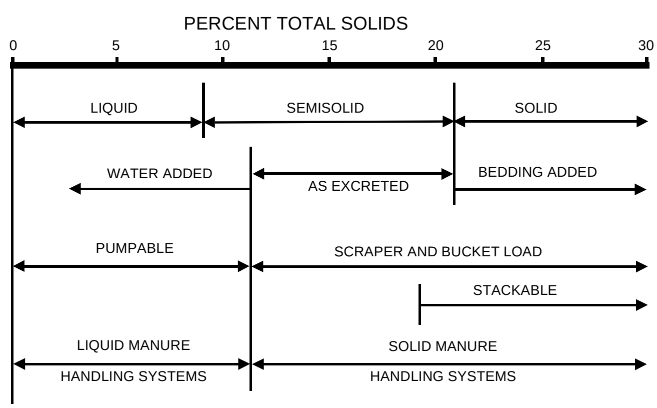

Figure 6-1. Manure characteristics that influence management options (after Ohio State University Extension, 1998).

6.1 Swine Waste

Swine waste contains numerous chemical and biological constituents such as nutrients, heavy metals, and pathogens that can potentially contaminate the environment. The composition of swine waste and rate of its excretion by the pig vary with the stage of physical development, the pig's gender, and if a female whether she is farrowing. As noted in Chapter 4, during the course of their life cycle, pigs receive up to six different diets to maximize growth at each stage of physical development. Each diet is composed of a unique mix of nutrients and minerals and those differences are reflected in the different composition of manure generated over the pig's life.

Swine waste also undergoes physical and chemical changes after it has been excreted by the pig. For example, swine waste volume and composition change after the waste becomes mixed with water, feed, and bedding materials. Furthermore, microbial activity alters the chemical makeup of the waste by metabolizing organic matter and generating chemical by-products. Additional chemical changes can occur depending on how the waste is stored and whether it is treated.

For swine operations, typical manure handling practices are designed to produce either a liquid or a semi-solid. Thus, the nutrient component of manure usually becomes more dilute because of the addition of water used to aid in collection of the manure. In addition, ammonia volatilization reduces nitrogen concentrations in both liquid and dry manure handling systems. Phosphorus concentrations increase in manure that is handled dry as the water content decreases.

As discussed in Chapter 4, swine manure typically is collected and stored by means of pit storage, lagoons, or a combination of the two. Most lagoons operate anaerobically. Aerated lagoons have received less attention because of their higher costs; however, the potential for decreased odor might increase their use. Svoboda (1995) achieved nitrogen removal ranging from 47 to 70 percent (depending on aeration) through nitrification and denitrification in an aerobic treatment reactor using whole pig slurry. The proportion of phosphorus and potassium typically remaining after storage is higher than nitrogen. However, up to 80 percent of the phosphorus in lagoons is found in the bottom sludge versus the water fraction (MWPS, 1993).

Jones and Sutton (1994) analyzed manure nutrient content just before land application in liquid manure pit and anaerobic lagoon samples. On a mass basis for pit storage, nitrogen decreases ranged from 11 to 47 percent; phosphorus, 9 to 67 percent; and potassium, 5 to 42 percent. In the water fraction of lagoons, nitrogen decreases ranged from 76 to 84 percent; phosphorus, 78 to 92 percent; and potassium, 71 to 85 percent. Nitrogen decreases in these two storage systems were primarily due to volatilization; phosphorus and potassium decreases were due to accumulation in sludge. Boland et al. (1997) found that for deep pit systems almost four times as much land was needed when applying manure based on phosphorus rather than nitrogen, 2.5 times for tank storage, and 1.7 times for lagoon systems. These differences can be attributed to less ammonia volatilization in deep pit systems and solids settling in lagoons.

A field study of Missouri swine lagoon surface-to-volume ratios found that large swine lagoons have significantly higher total nitrogen concentrations than small lagoons. This finding suggests that nutrient concentrations and thus land application of treated swine manure should be based on the design and performance characteristics of the lagoon rather than on manure production alone (Fulhage, 1998).

The use of evaporative lagoon systems has increased in arid regions. These systems rely on evaporation to reduce wastewater with pollutants accumulating in the lagoon sludge. This approach results in reduced or no land application of wastes. For example, due to a lack of adequate land disposal area in Arizona, Blume and McCleve (1997) increased the evaporation of wastewater from a 6,000-hog flush/lagoon treatment system by spraying the wastewater into the air. Although information on volatilization was not available, the evaporative increase from spraying and pond evaporation versus pond evaporation alone was 51 percent.

The following sections characterize swine waste in terms of generation rates and chemical and biological contaminants. Differences between swine types and operations and changes to the waste after it leaves the pig are also characterized.

6.1.1 Quantity of Manure Generated

Table 6-1 shows the quantity of manure generated by different types of swine. Variation in these quantities can be attributed to different ages and sizes of animals within a group (USDA, 1992). Manure production can also vary depending on the digestibility of feed rations. For example, corn, which is 90 percent digestible, results in less total solids in manure than a less digestible feed such as barley, which is 70 percent digestible (USDA, 1992).

Table 6-1. Quantity of Manure Excreted by Different Types of Swine

	Manure Mass (lb/yr/1,000 lb of animal mass)			
Type of Swine	**Maximum Reported**	**Minimum Reported**	**USDA 1998 Value**	
Grower-Finisher	44,327[a]	14,600[a]	Grower-Finisher 29,380[d]	Farrow to Finish 38,940[e]
Replacement Gilt	29,872[a]	11,972[a,b]		
Boar	31,527[a]	7,483[b]	Farrow 12,220[d]	
Gestating Sow	18,250[a]	9,928[b]		
Lactating Sow	32,120[a]	21,900[a,b]		
Sow and Litter	21,900[c]	21,900[c]		
Nursery Pig	54,142[a]	23,981[c]	---	

[a]NCSU, 1994.
[b]USDA, 1992.
[c]MWPS, 1993.
[d]USDA, 1998.
[e]Adapted from USDA, 1998.
--- Not available.

As described in Chapter 3, there are three stages of swine production—farrow, nursery, and grower-finisher. Some swine operations encompass all three stages, whereas others specialize in just one. This section discusses the type of animal included in each operation and summarizes data on the quantity of manure produced by different operations.

Farrowing Operations

Farrowing operations include boars, gestating sows, lactating sows, and the sows' litters. Newborn pigs remain at the farrowing facility until they are weaned, which typically takes 3 to 4 weeks. Lactating sows and their litters produce the most manure, whereas boars produce the least. Manure production values for 1,000 lb of animal in a farrowing operation range from 7,483 (USDA, 1992) to 32,120 lb/yr (NCSU, 1994), as shown in Table 6-2.

Nursery Operations
After farrowing and weaning, young pigs are moved to a nursery, which is the second phase of swine production, at approximately 15 pounds. They remain in the nursery for 7 to 8 weeks until they weigh approximately 60 pounds and are then transferred to a grower-finisher operation. Nursery pigs produce manure at rates of 23,981 (MWPS, 1993) to 54,142 lb/yr/1,000 lb of animal (NCSU, 1994) (Table 6-2).

Grower-Finisher Operations
In a finishing operation pigs are raised to market weight, which is approximately 240 to 280 pounds. This third stage of swine production is typically 15 to 18 weeks long, after which finished hogs are sent to market at approximately 26 weeks of age. A grower-finisher operation raises pigs over a relatively long period of time, during which their weight changes substantially. This weight change affects the quantity of manure produced (USDA, 1992). Values for manure production from growing-finishing pigs range from 11,972 (USDA, 1992) to 44,327 lb/yr/1,000 lb of animal (NCSU, 1994) (Table 6-2).

Farrow to Finish Operations
A farrow to finish operation includes all three stages of swine production. Because of the large variability in animal types present in this type of operation, manure production values vary widely, from 7,483 lb/yr/1,000 lb of animal for boars (USDA, 1992) to 54,142 lb/yr/1,000 lb of animal for nursery pigs (NCSU, 1994) (Table 6-1).

6.1.2 Description of Waste Constituents and Concentrations

Swine waste contains substantial amounts of nitrogen, phosphorus, potassium, and pathogens and smaller amounts of other elements and pharmaceuticals. This section provides a summary of the constituents of swine waste as reported in the literature. There is significant variability in the generation rates presented below; this variability can be attributed to different nutritional needs for swine in the same operation type (sows and boars, for example) and for swine of different ages and sizes grouped in the same operation. Also, as shown earlier in Table 6-1, different types of swine produce different quantities of manure.

Nitrogen
Nitrogen is usually measured as total nitrogen or as total Kjeldhal nitrogen (TKN). Although TKN does not include nitrate-nitrogen (NO_3-N), it may be considered equal to total nitrogen because NO_3-N is present only in very small quantities in swine manure (0.051 to 1.241 lb/yr/1,000 lb of animal) (NCSU, 1994; USDA, 1998). Published values for nitrogen production range from 54.8 (USDA, 1992) to 228.8 lb/yr/1,000 lb of animal (NCSU, 1994) in swine manure, as shown in Table 6-2. In general, boars produce the least amount of nitrogen per thousand pounds of animal and grower-finisher pigs produce the most.

Table 6-2. Quantity of Nitrogen Present in Swine Manure as Excreted

Operation Type	Nitrogen (lb/yr/1,000 lb of animal mass)		
	Maximum Reported	**Minimum Reported**	**USDA 1998 Value**
Farrow to Finish	NA	NA	220.0[c]
Grower-Finisher	228.8[a]	87.6[b]	166.0[d]
Farrow	214.0[a]	54.8[b]	81.0[d]
Nursery	224.1[a]	134.0[a]	---

[a]NCSU, 1994.
[b]USDA, 1992.
[c]Adapted from USDA, 1998.
[d]USDA, 1998.

Phosphorus

The quantity of phosphorus as excreted in swine manure is shown in Table 6-3 for different types of swine operations. Phosphorus content ranges from 18.3 (USDA, 1992) to 168.2 lb/yr/1,000 lb of animal (NCSU, 1994)—boars excrete the least amount of phosphorus in manure per thousand pounds of animal, whereas grower-finisher pigs excrete the most.

Table 6-3. Quantity of Phosphorus Present in Swine Manure as Excreted

Operation Type	Phosphorus (lb/yr/1,000 lb of animal mass)		
	Maximum Reported	**Minimum Reported**	**USDA 1998 Value**
Farrow to Finish	NA	NA	64.1[d]
Grower-Finisher	168.2[a]	29.2[b]	48.3[e]
Farrow	68.3[a]	18.3[b]	26.2[e]
Nursery	93.4[a,b]	54.6[c]	---

[a]NCSU, 1994.
[b]USDA, 1992.
[c]MWPS, 1993.
[d]Adapted from USDA, 1998.
[e]USDA, 1998.

Potassium

Table 6-4 shows the range of measured potassium quantities in manure for each type of swine operation. Boars produce the least amount of potassium at 36.50 lb/yr/1,000 lb of animal (USDA, 1992), whereas grower-finisher pigs produce the most at 177.4 lb/yr/1,000 lb of animal (NCSU, 1994).

Table 6-4. Quantity of Potassium Present in Swine Manure as Excreted

Operation Type	Potassium (lb/yr/1,000 lb of animal mass)		
	Maximum Reported	Minimum Reported	USDA 1998 Value
Farrow to Finish	NA	NA	154.79[d]
Grower-Finisher	177.4[a]	47.45[b]	116.79[e]
Breeder	136.6[a]	36.50[b]	47.96[e]
Nursery	130.6[a]	103.88[c]	---

[a]NCSU, 1994.
[b]USDA, 1992.
[c]MWPS, 1993.
[d]Adapted from USDA, 1998.
[e]USDA, 1998.

Table 6-5 shows differences in the quantity of nutrients in manure at different stages of storage and handling. The data shows a decrease in nutrient quantities from a manure slurry, which is untreated, to lagoon liquid and finally to secondary lagoon liquid. Lagoon sludge contains less nitrogen and potassium but more phosphorus than lagoon liquid, because phosphorus tends to be associated with the particulate fraction of manure, and nitrogen and potassium are usually in dissolved form. Table 6-6 shows the percent of manure nutrient content as excreted that is retained using different manure management systems. Table 6-7 shows manure nutrient concentrations in pit storage and anaerobic lagoons.

Table 6-5. Comparison of Nutrient Quantity in Manure for Different Storage and Treatment Methods

Nutrient	Mean Quantity in Manure (lb/yr/1000 lb of animal mass)					Land-Applied Quantity After Losses[b]	
	Paved Surface Scraped Manure[a]	Liquid Manure Slurry[a]	Anaerobic Lagoon Liquid[a]	Anaerobic Secondary Lagoon Liquid[a]	Anaerobic Lagoon Sludge[a]	Farrow	Grower
Nitrogen	137.65	164.44	34.71	28.79	6.57	20.29	17.23
Phosphorus	61.05	51.28	6.06	4.47	6.18	22.12	17.11
Potassium	79.81	78.20	29.84	23.13	1.46	43.01	43.75

[a]NCSU, 1994.
[b]USDA, 1998.

Table 6-6. Percent of Original Nutrient Content of Manure Retained by Various Management Systems

Management System	Nitrogen	Phosphoru s	Potassium
Manure stored in open lot, cool humid region	55-70	65-80	55-70
Manure liquids and solids stored in an uncovered, essentially watertight structure	75-85	85-95	85-95
Manure liquids and solids (diluted less than 50%) held in waste storage pond	70-75	80-90	80-90
Manure stored in pits beneath slatted floor	70-85	90-95	90-95
Manure treated in anaerobic lagoon or stored in waste storage pond after being diluted more than 50%	20-30	35-50	50-60

Source: Adapted from Jones and Sutton, 1994.

Table 6-7. Nutrient Concentrations for Manure in Pit Storage and Anaerobic Lagoons for Different Types of Swine

Animal Type	Manure Produced 1000 gal/yr	Nitrogen lb N/1000 gal/yr	Phosphorus lb P/1000 gal/yr	Potassium lb K/1000 gal/yr
Pit Storage				
Grower-Finisher	0.53	32.75	11.55	22.41
Lactating Sow	1.4	15.00	5.25	9.13
Gestating Sow	0.5	25.00	13.55	22.41
Nursery	0.13	25.00	8.44	18.26
Anaerobic Lagoon				
Grower-Finisher	0.95	5.60	1.639	3.486
Lactating Sow	2.10	4.10	0.874	1.660
Gestating Sow	0.90	4.40	1.857	3.320
Nursery	0.22	5.00	1.398	2.656

Source: Adapted from Jones and Sutton, 1994.

Metals and Other Elements

Other elements present in manure include the micronutrients calcium, chlorine, magnesium, sodium, and sulfur, and heavy metals such as arsenic, cadmium, iron, lead, manganese, and nickel. Many of these elements are found in swine feed; others, such as heavy metals, are found in pharmaceutical feed additives. Table 6-8 shows the range of quantities of these elements in manure as excreted, after storage, at different stages of treatment, and when it is land applied.

Table 6-8. Comparison of the Mean Quantity of Metals and Other Elements in Manure for Different Storage and Treatment Methods

	Quantity produced in manure (lb/yr/1000 lb animal mass)					
Element	**As Excreted**	**Paved Surface Scraped Manure**[a]	**Liquid Manure Slurry**[a]	**Anaerobic Lagoon Liquid**[a]	**Anaerobic Secondary Lagoon Liquid**[a]	**Anaerobic Lagoon Sludge**[a]
Aluminum	1.340[a]	0.797	3.289	0.176	---	---
Arsenic	0.252[a]	---	0.003	0.004	---	---
Boron	1.132[b]-1.232[a]	0.239	0.086	0.042	0.037	0.004
Cadmium	0.010[a.b]	0.001	0.002	0.002	---	0.001
Calcium	120.45[b]-121.468[a]	117.932	48.433	7.547	6.459	6.373
Chlorine	93.335[a]-94.9[b]	90.615	27.073	18.571	---	0.378
Cobalt	0.014[a]	0.013	---	0.002	---	---
Copper	0.437[a]-0.438[b]	0.960	0.665	0.073	0.036	0.082
Chromium	---	---	---	---	---	0.007
Iron	5.84[b]-6.606[a]	16.858	4.643	0.486	0.292	0.713
Lead	0.030[a]-0.031[b]	0.019	---	0.033	---	0.007
Magnesium	25.55[b]-27.064[a]	33.766	16.884	2.461	1.587	1.837
Manganese	0.640[a]-0.694[b]	4.573	0.790	0.055	0.022	0.082
Molybdenum	0.010[a,b]	0.001	---	0.001	---	0.003
Nickel	0.029[a]	0.048	0.016	0.130	---	0.003
Selenium	---	---	---	0.000	---	---
Sodium	23.980[a]-24.455[b]	24.536	18.148	10.396	---	0.536
Sulfur	27.192[a]-27.74[b]	24.791	14.702	2.089	1.542	1.333
Zinc	1.825[b]-1.855[a]	2.414	2.210	0.191	0.036	0.212

[a]NCSU, 1994.
[b]ASAE, 1998.

Swine manure contains many kinds of bacteria, several of which are naturally present in the digestive systems of the animals. Others are in the pigs' general environment and can be ingested but are not a necessary component of digestion. Table 6-9 presents a summary of measured values of these bacteria in swine manure as excreted and at various stages of treatment.

Table 6-9. Comparison of the Mean Concentration of Pathogens in Manure for Different Storage and Treatment Methods

Type of Bacteria	Quantity Present in Manure (bacterial colonies per pound of manure)				
	Manure As Excreted	Paved Surface Scraped Manure	Liquid Manure Slurry	Anaerobic Lagoon Liquid	Anaerobic Lagoon Sludge
Enterococcus bacteria	3.128E+09	1.395E+09	3.839E+09	1.232E+06	---
Escherichia coliform bacteria	4.500E+07	5.400E+07	1.302E+08	---	---
Facultative bacteria	---	5.400E+11	5.164E+11	---	---
Fecal coliform bacteria	1.106E+09	4.800E+08	1.777E+07	2.502E+06	---
Fecal streptococcus bacteria	2.873E+10	---	2.276E+07	2.285E+06	---
Streptococcus bacteria	1.980E+08	2.205E+10	1.995E+10	---	---
Total aerobic bacteria	---	2.745E+11	1.269E+11	---	---
Total anaerobic bacteria	---	5.400E+11	1.092E+11	---	---
Total bacteria	---	---	---	3.885E+08	7.769E+09
Total coliform bacteria	2.445E+09	1.598E+09	9.551E+07	1.083E+07	---

Source: NCSU, 1994.

Pharmaceuticals

To promote growth and to control the spread of disease, antibiotics and other pharmaceutical agents are often added to feed rations. Many of these chemicals are transformed or broken down through digestion and their components are excreted in manure. Table 6-10 lists several common pharmaceuticals added to swine feed and their frequency of use as reported in *Swine '95 Part I: Reference of 1995 Swine Management Practices* (USDA APHIS, 1995).

Table 6-10. Type of Pharmaceutical Agents Administered in Feed, Percent of Operations that Administer them, and Average Total Days Used

Antibiotic/Agent in Feed	Percent Operations	Standard Error	Average Total Number Days	Standard Error
Chlortetracycline/Sulfathiazole/Penicillin	6.7	2.1	33.8	5.3
Chlorotetracycline/Sulfamethazine/Penicillin	6.4	2.0	23.6	3.6
Tylosin/Sulfamethazine	4.8	2.1	45.6	4.1
Carbadox	12.4	2.5	31.2	2.1
Lincomycin	4.3	1.4	60.3	17.6
Apramycin	2.8	1.2	50.9	22.7
Chlortetracycline	41.1	4.0	58.1	4.6
Oxytetracycline	9.6	2.2	39.2	6.6
Neomycin/Oxytetracycline	10.4	3.0	55.3	14.6
Tylosin	30.4	3.7	57.4	5.1
Bacitracin (BMD)	52.1	4.1	72.2	4.0
Virginiamycin	3.8	1.3	65.1	11.6
Zinc oxide	5.0	2.1	81.2	22.9
Copper sulfate	6.1	1.9	62.8	11.3
Other	4.6	2.2	97.6	11.8

Source: USDA APHIS, 1995.

Physical Characteristics

Tables 6-11 and 6-12 lists several characteristics of swine manure as excreted by pigs classified by different operation types and with different types of storage and treatment methods.

Table 6-11. Physical Characteristics of Swine Manure by Operation Type and Lagoon System

Characteristic	Physical Characteristics in Swine Manure (lb/yr/1000 lb unless otherwise noted)						
	Grower-Finisher as Excreted	Farrow as Excreted	Farrow to Finish as Excreted	Liquid Manure Slurry[b]	Anaerobic Lagoon Sludge[b]	Anaerobic Lagoon Liquid[b]	Anaerobic Secondary Lagoon Liquid[b]
Manure	11,972[a]-33,830[b]	7,483[a]-27,313[b]	7,483[a]-39,586[b]	6,205	270	7,381	7,381
Urine	42.1[b]-49.0[b]	---	39.0[b]-74.0[b]	---	---	---	---
Density (lb/ft^3)	61.8[b]-62.8[b]	---	61.3-62.8	8.4	8.9	8.4	8.35
Moisture (%)	90[a]-91[a]	90[a]-97[a]	90[a]-97[a]	---	92[a]	100[a]	---
Total solids	3.28[a]-6.34[a]	1.9[a]-6.0[a]	1.9[a]-11.0[a]	---	7.60%[c]	0.25%[c]	---
Total dissolved solids	1.29[a]	---	1.29[a]	---	---	---	---
Volatile solids	2.92[a]-5.40[a]	1.00-5.40	1.00-8.80	---	379.89 [c] lb/1000 gal	10.00 [c] lb/1000 gal	---
Fixed solids	0.36[a]-0.94[a]	0.30[a]-0.60[a]	0.30[a]-1.80[a]	---	253.27 [c] lb/1000 gal	10.83 [c] lb/1000 gal	---
C:N ratio	6[a]-7[a]	3[a]-6[a]	3[a]-8[a]	---	8[a]	---	2[a]

[a]USDA, 1992.
[b]NCSU, 1994.
[c]USDA, 1996.

Table 6-12. Physical Characteristics of Different Types of Swine Wastes

Physical Characteristic	lb/yr/1000 lb	lb/ 1000 gallons	
	Paved Surface Scraped Manure[a]	Feedlot Runoff Water[b]	Settling Basin Sludge[b]
Manure	21,089	---	---
Density (lb/ft^3)	62.4	---	---
Moisture (%)	---	98.50	88.8
Total solids	---	1.50	11.2

[A]NCSU, 1994
[b]USDA, 1996

6.2 Poultry Waste

Poultry wastes differ in composition between the three bird types addressed in this document - layers, broilers, and turkeys. Each bird type is raised for a specific role and is provided with a diet tailored to its nutritional needs. Hence, layers are fed diets to maximize egg production whereas broilers are fed diets to promote growth and development. Within each subsector, however, variation in manure composition as excreted is quite small due to the high degree of integration, use of standardized feed, and total confinement (USEPA, 1999). However, there are differences in composition and quantity generated between operations due to variations in length and type of manure storage employed by the operation.

Broilers and turkeys have similar production regimes in terms of manure production, manure handling, and nutrient recovery. The floor of the house is covered with a bedding material that absorbs liquid. During the growth of the flock, continuous air flow removes ammonia and other gasses resulting in lower nitrogen content of the litter (manure and bedding). Another result of continuous air flow is a reduction in the moisture content of the litter over that of freshly excreted manure.

Manure produced by the laying industry typically includes no bedding. Two main types of manure handling are handling as excreted manure (with no bedding) and water-flushed collection. In high-rise cages or scrape-out/belt systems, manure is excreted onto the floor below with no bedding to absorb moisture. The ventilation system dries the manure as it is stored. Nutrients are more concentrated without bedding than with bedding, as in the broiler and turkey manure handling procedures. Flushing layer manure with water results in diluted nutrient concentrations, but increases the amount of waste that must be disposed.

As shown in Table 6-13, manure generation rates differ considerably between layers and broilers. The maximum reported generation rate for broilers is over 30 percent greater than for layers. Pullets have the lowest generation rate- almost half the rate of manure production for broilers and only 70 percent of the production rate for layers.

6.2.1 Broiler Waste Characteristics

6.2.1.1 *Quantity of Manure Generated*

Manure production is frequently presented as volume or weight of manure produced per 1,000 pounds of animal mass. There is significant variation between the minimum and maximum reported values for manure generation in broilers. Table 6-13 contains the minimum, maximum, and 1998 USDA reported values for manure generation rates for broilers. The 1998 USDA reported value for manure generation was utilized in EPA's analyses.

Table 6-13. Quantity of Manure Excreted for Broilers

Manure Mass (lb/yr/1,000 lb of animal mass)		
Minimum Reported	**Maximum Reported**	**USDA 1998 Value**
25,550[a]	31,025[b]	29,940[c]

[a]MWPS, 1993.
[b]ASAE, 1998.
[c]USDA, 1998.

6.2.1.2 *Description of Waste Constituents and Concentrations*

Broiler waste contains nitrogen, phosphorus, potassium, and smaller amounts of other elements and pathogens. This section provides a summary of the constituents of broiler manure and litter as reported in the literature.

Table 6-14 shows selected physical and chemical characteristics for broiler manure as excreted and after application of different storage practices. Manure quantity decreases under dry storage practices, especially when stored as a manure cake.

Table 6-14. Consistency of Broiler Manure as Excreted and for Different Storage Methods

	Physical Characteristics of Manure (lb/yr/1,000 lb of animal mass unless otherwise noted)					
Physical Characteristic	**As Excreted**	**Broiler Litter[d]**	**Broiler House Litter[c]**	**Broiler House Manure Cake[c]**	**Broiler Litter Stockpile[c]**	**Broiler-Roaster House Litter[c]**
Manure/Litter	25,550[a]–31,025[b]	12,775	7,449	2,364	6,733	5,710
Density	63.0[a]–63.7[c]	---	31.7	34.3	33.1	29.0
Moisture	75[d]	24	---	---	---	---
Total solids	7,300[d]–8,030[b]	9,673	5,857	1,429	4,083	4,349
Volatile solids	5,475[d]–8,030[a]	7,811	4,666	1,110	2,903	3,349
Fixed solids	1,825[d]	1862	---	---	---	---
C:N ratio	8[d]	9	---	---	---	---

[a]ASAE, 1998.
[b]MWPS, 1993.
[c]NCSU, 1994.
[d]USDA, 1992.

Broilers excrete numerous nutrients including nitrogen, phosphorous, and potassium. As shown in Table 6-15, nitrogen is excreted at the highest rate of the three nutrients. In general, broilers produce more nitrogen and potassium per pound of bird than do layers, although potassium production rates are near equivalent on a time-averaged basis (USDA, 1998). These levels are altered when manure is stored and or treated. Liquid manure volumes and nutrient concentrations are presented in Table 6-16 for raw and stored manure. Table 6-17 shows nutrient production after application of storage practices. Storage as a manure cake significantly reduces nutrient content, especially nitrogen. Table 6-18 shows metals in broiler manure as excreted and for different storage and treatment methods. The concentration of bacteria in broiler house litter is shown in Table 6-19.

Table 6-15. Nutrient Quantity in Broiler Manure as Excreted

Nutrient	Quantity Present in Manure (lb/yr/1,000 lb of animal mass)		
	Minimum Reported	Maximum Reported	Time-Averaged Value
Nitrogen	310.25[a]	401.50[b,c]	401.65[e]
Phosphorus	71.68[a]	124.10[b]	116.77[e]
Potassium	139.27[d]	167.90[b]	157.04[e]

[a]MWPS, 1993.
[b]USDA, 1992.
[c]ASAE, 1998.
[d]NCSU, 1994.
[e]USDA, 1998.

Table 6-16. Broiler Liquid Manure Produced and Nutrient Concentrations for Different Storage Methods

Storage Method	Manure Produced (1000 gal/yr)	Nutrient Concentration (lb nutrient/1000 gal)		
		Nitrogen	Phosphorus	Potassium
Raw Manure	0.006	130.4	36.3	44.3
Pit Storage [a]	0.010	63.00	17.48	24.07
Anaerobic Lagoon Storage [b]	0.016	8.50	1.88	2.91

Source: MWPS, 1993 as presented by Jones and Sutton, 1994.
[a] Includes dilution water.
[b] Includes rainfall and dilution water.

Table 6-17. Nutrient Quantity in Broiler Litter for Different Storage Methods

Nutrient	Quantity Present in Manure and Litter (lb/yr/1,000 lb of animal mass)				
	Broiler Litter[a]	Broiler House Litter[b]	Broiler House Manure Cake[b]	Broiler Litter Stockpile[b]	Broiler-Roaster House Litter[b]
Nitrogen	248.20	26.59	53.80	109.87	196.71
Phosphorus	124.10	112.70	27.18	112.70	87.09
Potassium	146.00	144.06	35.37	89.52	110.67

[a]USDA, 1992.
[b]NRCS, 1994.

Table 6-18. Quantity of Metals and Other Elements Present in Broiler Manure as Excreted and for Different Storage Methods

Element	Quantity Present in Manure and Litter (lb/yr/1,000 lb of animal mass)				
	As Excreted	Broiler House Litter[a]	Broiler House Manure Cake[a]	Broiler Litter Stockpile[a]	Broiler-Roaster House Litter[a]
Aluminum	---	4.901	---	---	---
Arsenic	---	0.176	---	---	---
Barium	---	0.148	---	---	---
Boron	0.795[a]	0.211	0.052	0.131	0.133
Cadmium	0.017[a]	0.012	0.002	0.001	0.014
Calcium	136.626[a]–149.650[b]	158.424	40.197	212.888	117.184
Chlorine	296.537[a]	47.694	---	51.803	---
Cobalt	---	0.007	---	---	---
Copper	0.331[a]–0.358[b]	1.984	0.481	0.968	1.389
Chromium	---	0.566	0.185	0.006	0.942
Iron	29.509[a]	4.381	1.420	5.991	4.553
Lead	0.033[a]	0.151	0.054	---	0.204
Magnesium	50.336[a]–54.750[b]	32.871	8.225	27.596	24.046
Manganese	2.378[a]	2.957	0.815	2.344	2.170
Mercury	---	0.001	---	---	---
Molybdenum	0.134[a]	0.003	0.001	0.002	0.002
Nickel	0.111[a]	0.427	0.217	0.008	0.352
Selenium	---	0.002	---	---	---
Silicon	---	5.323	---	---	---
Sodium	50.336[a]–54.750[b]	48.668	12.390	22.290	37.143
Strontium	---	0.339	---	---	---
Sulfur	28.763[a]–31.025[b]	45.749	10.876	33.892	39.229
Zinc	1.208[a]–1.314[b]	2.652	0.713	2.112	1.932

[a]NCSU, 1994.
[b]ASAE, 1998.

Microbial populations are very active in broiler litter and include enterococcus, fecal coliform, salmonella, and streptococcus. Table 6-19 shows bacteria levels per pound of manure.

Table 6-19. Concentration of Bacteria in Broiler House Litter

Parameter	Concentration of Bacteria (bacteria colonies/lb manure)
Total bacteria	4.775E+11
Total coliform bacteria	2.285E+06
Fecal coliform bacteria	7.758E+06
Streptococcus bacteria	6.728E+09
Salmonella	2.048E+06
Total aerobic bacteria	7.107E+09

Source: NCSU, 1994.

6.2.2 Layer Waste Characteristics

6.2.2.1 *Quantity of Manure Generated*

Manure production is frequently presented as volume or weight of manure produced per 1,000 pounds of animal mass. There is less variation between the minimum and maximum reported values for manure generation in layers than for broilers. Table 6-20 contains the minimum, maximum, and 1998 USDA reported values for manure generation rates for layers. The 1998 USDA reported value for manure generation was utilized in EPA's analyses.

Table 6-20. Quantity of Manure Excreted for Layers

Manure Mass (lb/yr/1,000 lb of animal mass)		
Minimum Reported	**Maximum Reported**	**USDA 1998 Value**
19,163[a]	23,722[b]	22,900[c]

[a]MWPS, 1993.
[b]NCSU, 1994.
[c]USDA, 1998.

6.2.2.2 *Description of Waste Constituents and Concentrations*

Layer waste contains nitrogen, phosphorus, potassium, and smaller amounts of other elements and pathogens. This section provides a summary of the constituents of layer manure as reported in the literature. Table 6-21 shows selected physical and chemical characteristics for layer manure as excreted and after application of different storage and treatment practices. Manure quantity decreases under dry storage practices but increases significantly when converted to a slurry or stored and treated in an anaerobic lagoon.

Table 6-21. Physical Characteristics of Layer Manure as Excreted and for Different Storage Methods

Physical Characteristic	Physical Characteristics of Manure (lb/yr/1,000 lb of animal mass unless otherwise noted)						
	As Excreted	High-rise Litter[d]	Paved Surface Scraped Manure[b]	Unpaved Deep Pit Stored Manure[b]	Liquid Manure Slurry[b]	Anaerobic Lagoon Liquid[b]	Anaerobic Lagoon Sludge[b]
Manure	19,163[a]–23,722[b]	14126	9877	32534	53598	9881	98805
Density (lb/ft^3)	60.0[a,c]–65.1[d]	62.4	51.3	7.8	8.4	8.4	8.4
Moisture (%)	74.8[a]–75.0[d]	---	---	---	---	---	---
Total solids	5,512[d]–6,019[b]	4979	5216	3646	265	1633	1633
Total suspended solids	2,477[b]	---	---	748	101	---	---
Volatile solids	3,942[d]–4,440[b]	3483	3137	2401	119	722	722
Volatile suspended solids	481[b]–4,380[c]	---	---	637	52	---	---
Fixed solids	1,570[d]	---	---	---	---	---	---
C:N ratio	7[d]	---	---	---	---	---	---

[a]MWPS, 1993.
[b]NCSU, 1994.
[c]ASAE, 1998.
[d]USDA, 1992.

Layers excrete numerous nutrients including nitrogen, phosphorous, and potassium. As shown in Table 6-22, nitrogen is excreted at the highest rate of these three nutrients. Nutrient concentrations of liquid manure are shown in Table 6-23. Table 6-24 shows nutrient production after application of storage and/or treatment practices. Table 6-25 shows metals in layer manure as excreted and for different storage and treatment methods.

Table 6-22. Quantity of Nutrients in Layer Manure as Excreted

Nutrient	Quantity Present in Manure (lb/yr/1,000 lb of animal mass)		
	Minimum Reported	Maximum Reported	Time-Averaged Value
Nitrogen	264.63[a]	315.43[b]	308.35[d]
Phosphorus	99.55[a]	113.15[c]	114.27[d]
Potassium	106.05[a]	124.10[c]	119.54[d]

[a]MWPS, 1993.
[b]NCSU, 1994.
[c]USDA, 1992.
[d]USDA, 1998.

Table 6-23. Annual Volumes of Liquid Layer Manure Produced and Nutrient Concentrations

Storage Method	Manure Produced (1000gal/yr)	Nutrient (lb nutrient/1000 gal)		
		Nitrogen	Phosphorus	Potassium
Raw Manure	0.011	110.2	35.4	37.7
Pit Storage [a]	0.017	60.00	19.67	23.24
Anaerobic Lagoon Storage [b]	0.027	7.00	1.75	2.91

Source: MWPS, 1993 as presented by Jones and Sutton, 1994.
[a] Includes dilution water.
[b] Includes rainfall and dilution water.

Table 6-24. Nutrient Quantity in Layer Litter for Different Storage Methods

Nutrient	Quantity Present in Manure and Litter (lb/yr/1,000 lb of animal mass)					
	High-rise Litter[a]	Paved Surface Scraped Manure[b]	Unpaved Deep Pit Stored Manure[b]	Liquid Manure Slurry[b]	Anaerobic Lagoon Liquid[b]	Anaerobic Lagoon Sludge[b]
Nitrogen	199.44	165.79	238.42	42.35	24.63	24.63
Phosphorus	97.60	110.21	94.55	4.77	39.87	39.87
Potassium	114.40	107.96	114.40	54.75	9.60	9.60

[a]USDA, 1992.
[b]NCSU, 1994.

Table 6-25. Quantity of Metals and Other Elements Present in Layer Manure as Excreted and for Different Storage Methods

Element	Quantity Present in Manure and Litter (lb/yr/1,000 lb of animal mass)						
	As Excreted	High-rise Litter[c]	Paved Surface Scraped Manure[a]	Unpaved Deep Pit Stored Manure[a]	Liquid Manure Slurry[a]	Anaerobic Lagoon Liquid[a]	Anaerobic Lagoon Sludge[a]
Aluminum	9.987[a]	2.161	---	4.039	---	---	---
Arsenic	0.050[a]	---	---	---	0.002	---	---
Boron	0.651[a]–0.657[b]	0.157	0.178	0.125	0.059	0.041	0.041
Cadmium	0.014[a,b]	0.001	---	---	0.000	0.007	0.007
Calcium	474.500[b]–491.891[a]	288.598	375.753	138.050	6.945	55.653	55.653
Chlorine	204.400[b]–242.608[a]	28.394	---	27.554	21.777	---	---
Cobalt	0.029[a]	---	---	---	---	---	---
Copper	0.303[b]–0.308[a]	0.244	0.285	0.302	0.030	0.167	0.167
Chromium	---	0.114	0.188	---	0.002	---	---
Iron	21.900[b]–24.143[a]	2.936	14.008	7.089	0.387	5.727	5.727
Lead	0.270[b]–0.274[a]	0.135	0.656	---	0.005	0.023	0.023
Magnesium	51.100[b]–51.129[a]	58.577	28.306	16.495	2.188	13.629	13.629
Manganese	1.945[a]–2.227[b]	2.032	2.165	1.579	0.044	1.896	1.896
Mercury	---	---	---	---	0.000	---	---
Molybdenum	0.109[a]–0.110[b]	0.002	0.002	---	---	---	---
Nickel	0.091[a,b]	0.351	0.418	---	0.075	0.029	0.029
Selenium	0.010[a]	---	---	---	---	---	---
Sodium	36.500[b]–43.292[a]	19.646	16.268	20.082	11.755	3.958	3.958
Sulfur	51.053[a]–51.100[b]	49.971	23.554	16.762	3.918	8.414	8.414
Zinc	1.640[a]–6.935[b]	2.162	1.721	1.609	0.100	1.346	1.346

[a]NCSU, 1994.
[b]ASAE, 1998.
[c]USDA, 1992.

Microbial populations are quite active in layer litter and include enterococcus, fecal coliform, salmonella, and streptococcus. Table 6-26 shows bacteria levels per pound of manure. As shown in this table, converting the litter to a slurry substantially reduces the concentration of bacteria.

Table 6-26. Concentration of Bacteria in Layer Litter

Type of Bacteria	Concentration in Manure (bacterial colonies/lb manure)	
	As Excreted	**Layer Liquid Manure Slurry**
Enterococcus bacteria	2.786E+13	---
Fecal coliform bacteria	1.552E+13	1.058E+06
Fecal streptococcus bacteria	3.375E+13	---
Salmonella	1.327E+10	---
Streptococcus bacteria	6.237E+13	---
Total aerobic bacteria	8.568E+15	---
Total bacteria	9.716E+16	---
Total coliform bacteria	1.835E+14	7.547E+06
Yeast	1.327E+15	---

Source: NCSU, 1994.

6.2.3 Turkey Waste Characteristics

Turkey operations usually separate and handle the birds in groups according to age, gender, size, or special management needs such as hatcheries or breeder farms. The types of animals are

- Poults (young turkeys)
- Turkey hens for slaughter
- Turkey toms for slaughter
- Hens kept for breeding

Although three major strains of turkeys are grown, the high degree of industry integration, standardized feed, and complete confinement has resulted in very little variation in manure characteristics. The exact quantity and composition of manure depends mostly on the specifics of farm management, such as precision feeding, control of wasted feed, and ammonia volatilization losses. Litter characteristics also vary according to material used for bedding.

6.2.3.1 *Quantity of Manure Generated*

Manure production is frequently presented as volume or weight of manure produced per 1,000 pounds of animal mass. Table 6-27 shows manure production as excreted for turkey hens and turkeys for slaughter.

Table 6-27. Annual Fresh Excreted Manure Production (lb/yr/1,000 lb of animal mass)

<table>
<tr><th>Animal Type</th><th>Range of Annual Manure Production Values</th><th>USDA 1998 Value</th></tr>
<tr><td>Turkeys for slaughter</td><td rowspan="2">15,914[a]-17,155[b]</td><td>16,360[c]</td></tr>
<tr><td>Hens for breeding</td><td>18,240[c]</td></tr>
</table>

[a]USDA, 1992.
[b]ASAE, 1998.
[c]USDA, 1998.

6.2.3.2 *Description of Waste Constituents and Concentrations*

Turkey waste contains nitrogen, phosphorus, potassium, and smaller amounts of other elements and pathogens. This section provides a summary of the constituents of turkey manure and litter as reported in the literature.

Composition of Manure

Exact manure composition depends on length and type of storage, as well as other management practices specific to each farm. Table 6-28 shows nutrients in turkey manure as excreted. Turkeys for slaughter produce more nitrogen and potassium in fresh excreted manure and breeding hens produce more phosphorus.

Table 6-28. Quantity of Nutrients Present in Fresh Excreted Turkey Manure (lb/yr/1,000 lb of animal mass)

<table>
<tr><th rowspan="2">Animal Type</th><th colspan="2">Nitrogen</th><th colspan="2">Phosphorus</th><th colspan="2">Potassium</th></tr>
<tr><th>Range Includes Minimum</th><th>Maximum Reported</th><th>Minimum Reported</th><th>Range Includes Maximum</th><th>Range Includes Minimum</th><th>Maximum Reported</th></tr>
<tr><td>Turkeys for slaughter</td><td>248.34[a]</td><td rowspan="2">270.1[b]</td><td rowspan="2">84[c]</td><td>96.77[a]</td><td>94.97[a]</td><td rowspan="2">102.20[b]</td></tr>
<tr><td>Hens for breeding</td><td>204.38[a]</td><td>120.48[a]</td><td>69.31[a]</td></tr>
</table>

[a]USDA, 1998.
[b]USDA, 1992.
[c]ASAE, 1998.

Composition of Litter

The nutrient content of turkey litter is usually lower than that for broiler litter, and brooder litter contains less manure nutrients than grower house litter. Exact manure composition depends on length and type of storage, as well as other management practices specific to each farm. After stockpiling, litter may lose up to half of the total nitrogen excreted. When manure is combined with bedding materials, the waste litter absorbs water content from the manure. Table 6-29 displays the water absorption capacity of commonly used bedding materials. Because of different types of litter composition for turkey operations, nutrient quantities per ton of litter vary (Table 6-30).

Table 6-29. Water Absorption of Bedding

Bedding Material	Pounds of Water Absorbed per Pound of Bedding
Wood	
Tanning Bark	4.00
Fine Bark	2.50
Pine	
Chips	3.00
Sawdust	2.50
Shavings	2.00
Needles	1.00
Hardwood Chips, Shavings or Sawdust	1.50
Corn	
Shredded Stover	2.50
Ground Cobs	2.10
Straw	
Flax	2.60
Oats	
Combined	2.50
Chopped	2.40
Wheat	
Combined	2.20
Chopped	2.10
Hay, Chopped Mature	3.00
Shells, Hulls	
Cocoa	2.70
Peanut, Cottonseed	2.50
Oats	2.00

Source: MWRA, 1993.

Table 6-30. Turkey Litter Composition in pounds per ton of litter[a]

Manure Type	Nitrogen	Phosphorus	Potassium
Brooder house litter after each flock [b]	45	23	27
Grower house litter after annual cleanout [b]	57	31	33
Stockpiled litter [b]	36	30[e]-31	25[e]-27
Tom growout [c]	52	33	35
Hen growout [c]	73	38	38
Brood house [d]	51	14	27
Growout house [d]	65	28[e]-31	33[e]-38

[a]Zublena, 1993
[b]NCSU, 1999
[c]Pennsylvania
[d]Arkansas
[e]NCSU, 1994.
P_2O_5 converted to P by multiplication of 0.437
K_2O converted to P by multiplication of 0.83

In those cases where litter is recycled from the brooder barn and used in the growout barn, nutrient values of litter increase to roughly 60 pounds of available nitrogen and phosphorus per ton of litter. Table 6-31 presents some metal components of turkey litter.

Table 6-31. Metal Concentrations in Turkey Litter (pounds per ton of litter)

Manure type	Ca	Mg	S	Na	Fe	Mn	B	Mo	Zn	Cu
Turkey, brooder	28.0	5.7	7.6	5.9	1.4	0.52	0.047	0.00081	0.46	0.36
Turkey, grower	42.0	7.0	10.0	8.4	1.3	0.65	0.048	0.00092	0.64	0.51

Source: NCSU, 1999.

The physical characteristics and nutrient content of turkey manure types and litter types is variable. As seen in Table 6-32, manure characteristics significantly differ from litter characteristics. Fresh manure contains more nutrients than manure cakes, but litter from grower houses may exceed fresh manure potassium amounts. Table 6-33 shows metal quantities in excreted turkey manure and litter types by gender and age of bird.

Table 6-32. Waste Characterization of Turkey Manure Types (lb/yr/1,000 lb of animal mass)

Parameter	Turkey fresh manure	Turkey hen house manure cake[a]	Turkey tom house manure cake[a]	Turkey house litter[a]	Turkey poult (brooder) house litter[a]	Turkey breeder house litter[a]	Turkey stockpiled litter[a]
Manure	15,914[c]-17,155[d]	1905.3	1905.3	---	---	---	---
Litter	---	---	---	5960.5	6953.25	4967.65	5420.25
Volume (ft^3/yr/1000 lb)	251.85[c]	---	---	---	---	---	---
Density(lb/ft^3)	63[d]-63.49[a]	32.3	---	---	22.91	62.43	24.1
TS (%wb)	4,179[a]-4,380[d]	1041.6	1041.6	4365.4	5527.96	3893.35	3316.90
VS (%db)	3,205[a]-3,541[c]	845.2	845.3	3182.8	4297.07	-	-
TKN	226.3[d]-231.0[a]	42.74	42.74	165.13	138.12	87.97	85.67
NO_3N	-	-	-	0.40	1.31		1.31
P	84.0[d]-87.8[a]	19.38	19.38	82.38	65.77	51.17	82.42
K	83.2[a]-87.6[d]	23.69	23.69	98.77	77.64	37.05	67.74

[a] NCSU, 1994.
[b] USDA, 1998.
[c] USDA, 1992.
[d] ASAE, 1998.

Table 6-33. Metals and Other Elements Present in Manure (lb/yr/1,000 lb of animal mass)

Metals/Elements	Turkey fresh manure	Turkey hen house manure cake[a]	Turkey tom house manure cake[a]	Turkey house litter[a]	Turkey poult (brooder) house litter[a]	Turkey breeder house litter[a]	Turkey stockpiled litter[a]
Calcium	223.205[a]-230.0[b]	25.003	25.003	112.165	91.871	178.376	120.888
Magnesium	25.649[a]-26.6[b]	5.11	5.11	22.083	17.849	11.498	19.199
Sulfur	25.887[a]	5.986	5.986	25.477	21.207	18.287	20.039
Sodium	23.172[a]-24.0[b]	5.256	5.256	22.703	162.06	10.622	15.367
Chlorine	16.8407[a]	---	---	35.186	6.278	---	21.608
Iron	26.556[a]-27.4[b]	1.168	1.168	4.176	6.935	2.519	5.585
Manganese	0.853[a]-0.9[b]	0.548	0.5475	2.3725	1.825	1.059	2.044
Boron	0.452[a]	0.037	0.0365	0.146	0.146	0.073	0.110
Molybdenum	0.076[a]	0.001	0.001	0.004	0.003	---	0.003
Aluminum	---	0.694	0.694	2.263	5.037	---	---
Zinc	5.127[a]-5.5[b]	0.438	0.438	1.971	1.606	1.241	1.716
Copper	0.252[a]-0.3[b]	0.475	0.475	1.789	1.351	0.986	1.132
Cadmium	0.009[a]	---	---	0.001	0.001	---	0.001
Nickel	0.063[a]	---	---	0.018	0.007	---	0.007
Lead	0.190[a]	---	---	---	---	---	---

[a]NCSU, 1994.
[b]ASAE, 1998.

Data on bacterial concentrations in turkey manure or litter are generally sparse. However, Table 6-34 shows concentrations of fecal coliform and total bacteria for manure and litter. Land applied quantities of turkey manure nutrients are shown in Table 6-35.

Table 6-34. Turkey Manure and Litter Bacterial Concentrations (bacterial colonies per pound of manure)

Bacteria Type	Excreted Manure	House Litter
Fecal coliform bacteria	1.31E+08	---
Total bacteria	---	2.53E+12

Source: NCSU, 1994.

Table 6-35. Turkey Manure Nutrient Composition After Losses–Land Applied Quantities

Animal	Manure Composition (lb/yr/1,000 lb of animal mass)		
	Nitrogen	Phosphorus	Potassium
Turkeys for slaughter	132.35 (116.0)	82.29 (14.5)	85.40 (9.6)
Hens for breeding	102.14 (102.2)	102.42 (18.1)	62.38 (6.9)

Source: USDA, 1998.
In parentheses are the differences between fresh excreted manure content and after losses content.

6.3 Dairy Waste

This section describes the characteristics of dairy manure and waste. In this section, manure refers to the combination of feces and urine and waste refers to manure plus other material, such as hair, bedding, soil, wasted feed, and water that is wasted or used for sanitary and flushing purpose. Due to the nature of dairy operations, however, even fresh manure may also contain small amounts of hair, bedding, soil, feed, and water.

This section discusses the following:

- Section 6.3.1: The quantity of manure generated; and
- Section 6.3.2: Description of waste constituents and concentrations.

6.3.1 Quantity of Manure Generated

Numerous analyses have estimated average manure quantities from dairy cattle. Four major data sources that contain mean values for dairy manure characteristics are identified below:

- American Society of Agricultural Engineers (ASAE) Standard D384.1: Manure Production and Characteristics, 1999. This data source contains national fresh (as-excreted) manure characteristic values by animal type (e.g., dairy, beef, veal, swine).

- USDA, *Agricultural Waste Management Field Handbook*, Chapter 4, 1996. This data source contains national manure characteristic values for fresh and managed manure (e.g., lagoon supernatant, feedlot runoff) by animal type including subtypes such as lactating cow, dry cow, heifer, sow, and boar.

- North Carolina State University (NCSU), *Livestock Manure Production and Characterization in North Carolina*, 1994. This data source contains regional manure characteristic values for fresh and managed manure by animal type including subtypes.

- Midwest Plan Service-18 (MWPS): *Livestock Waste Facilities Handbook*, 1985. This data source contains national fresh manure characteristic values by animal type and animal weight.

A recent analysis conducted by Charles Lander, et al. of the USDA/NRCS used a composite of three of these data sources (Lander et al., 1998). Lander removed ASAE data before averaging to prevent double counting of the ASAE information that is included in the Midwest Plan Service data. This analysis assumed that the average weight of a lactating cow is 1,350 pounds and the average weight of a heifer is 550 pounds. Table 6-36 presents the fresh or "as-excreted" manure estimates from this analysis. North Carolina's updated data contains the as-excreted manure estimates for dairy calves which are assumed to weigh 350 pounds. Table 6-36 also presents the fresh manure estimates for dairy calves.

Table 6-36. Weight of Dairy Manure, "As-Excreted"

Quantity of Manure (wet basis)	Lactating Cow[a]	Heifer[a]	Calf[b]
Weight (lb/day/1,000-lb animal)	83.5	66	65.8
Weight (lb/year/1,000-lb animal)	30,478	24,090	24,017

[a] Source: Lander, 1998.
[b] Source: NCSU, 1994.

6.3.2 Description of Waste Constituents and Concentrations

The composition and concentrations of dairy waste varies from the time that it is excreted to the time it is ultimately used as a fertilizer and/or soil amendment. Nutrients and metals are expected to be present in dairy waste due to the constituents of the feed. This section discusses the following:

- Section 6.3.2.1: Composition of "as-excreted" manure;
- Section 6.3.2.2: Composition of stored or managed waste; and
- Section 6.3.2.3: Composition of aged manure/waste.

6.3.2.1 *Composition of "As-Excreted" Manure*

Data are presented for 16 nutrients and metals found in fresh dairy manure. Nitrogen is present in manure in four forms: ammonium-N, nitrate-N, nitrite-N, and organic-N. The total nitrogen (N) is the sum of these four components, while the total Kjeldahl nitrogen (TKN) is the sum of the organic-N and ammonium-N. Phosphorus is present in manure in inorganic and organic form and presented as total phosphorus. Colonies of the pathogens coliform and streptococcus bacteria have also been identified in dairy manure.

Manure characteristics for dairy cattle are highly variable and can be affected by animal size and age, management choices, feed ration, climate, and milk production. For example, dairy feeding systems and equipment often produce considerable feed waste, which in most cases is added to the manure. In addition, dairy stall floors are often covered with organic and inorganic bedding materials (e.g,. hay, straw, wood shavings, sawdust, soil, sand, ground limestone, dried manure) that improve animal comfort and cleanliness. Virtually all of this material will eventually be pushed, kicked, and carried from the stalls and added to the manure, and their characteristics imparted to the manure (Lander et al., 1998). In addition, the nutrient content (N, P, and K) of dairy manure can vary significantly due to differences in voluntary feed intake, differing supplemental levels, and differing amounts of nutrients removed during milking (USDA NRCS, 1992). The volatile solids content of dairy manure is often compared to milk production, which is also presented in USDA, *Agricultural Waste Management Field Handbook*, Chapter 4, 1996. The volatile solids content of manure for an entire dairy herd can be calculated by using data for lactating and dry cows. For example, EPA's analysis assumed the dairy herd is made up of 83 percent lactating and 17 percent dry cows at any given time. The volatile solids content for the dairy herd, using USDA data, therefore, was calculated as (8.5 lb/day/1,000 animal * 83 percent) + (8.1 lb/day/1,000 animal * 17 percent) = 8.45 lb/day/1,000 animal.

Table 6-37 presents averages for fresh dairy cow and heifer manure characteristics that are reported in the four major data sources identified above.

Table 6-37. Fresh (As-Excreted) Dairy Manure Characteristics Per 1,000 Pounds Live Weight Per Day

Parameter	Unit[a]	Mean	Standard Deviation
Moisture	%	87.2	-
Weight	lb	86	17
Total solids	lb	12	2.7
Volatile solids	lb	10	0.79
Biochemical oxygen demand (BOD), 5-day	lb	1.6	0.48
Chemical oxygen demand (COD)	lb	11	2.4
pH	unitless	7	0.45
Nitrogen (Total Kjeldahl)	lb	0.45	0.096
Nitrogen (Ammonia)	lb	0.079	0.083
Phosphorus (Total)	lb	0.094	0.024
Orthophosphorus	lb	0.061	0.058
Potassium	lb	0.29	0.094
Calcium	lb	0.16	0.059
Magnesium	lb	0.071	0.016
Sulfur	lb	0.051	0.010
Sodium	lb	0.052	0.026
Chloride	lb	0.13	0.039
Iron	lb	0.012	0.0066
Manganese	lb	0.0019	0.00075
Boron	lb	0.00071	0.00035
Molybdenum	lb	0.000074	0.000012
Zinc	lb	0.0018	0.00065
Copper	lb	0.00045	0.00014
Cadmium	lb	0.0000030	-
Nickel	lb	0.00028	-
Total coliform bacteria	colonies	500	1,300
Fecal coliform bacteria	colonies	7.2	13
Fecal streptococcus bacteria	colonies	42	63

[a]All values wet basis.
Source: ASAE, 1993.

Lander averaged values from the Midwest Plan Service, USDA, and NCSU data sets for N, P, and K. In all cases, EPA compared the averaged values to ASAE's data and determined them to be comparable to the lactating cow numbers. As stated earlier in this section, the milking status of dairy cattle can affect the excreted levels of N, P, and K. Lactating cows are expected to have a higher nutrient content in their manure because they typically are fed a higher energy diet. Table 6-38 presents the nutrient values in dairy manure from Lander's analysis.

Table 6-38. Average Nutrient Values in Fresh (As-Excreted) Dairy Manure

Parameter	Dairy Cow (lb/day/1,000-lb animal) [a]
Nitrogen (Total Kjeldahl)	0.45
Phosphorus (Total)	0.08
Potassium	0.28

Source: Lander, 1998.
[a] Lander's analysis relied on 1990 North Carolina State University data, while the North Carolina State University data presented in this report is from 1994.

6.3.2.2 *Composition of Stored or Managed Waste*

Dairy manure is often combined with large amounts of water and collected and stored in a number of different ways (see Section 4.3.5 for a detailed discussion of dairy waste management). This wastewater, therefore, has different physical properties than "as-excreted" manure. This section presents dairy waste values for waste from milking centers and waste managed in lagoons.

Milking Centers

Milking centers, which include the milk room, milking parlor, and holding area, produce about 15 percent of the total solids, at a dairy. Milking centers that do not practice waste flushing use about 1 to 3 gallons of fresh water per day for each cow milked. However, dairies that use flush cleaning and automatic cow washing use as much as 30 to 50 gallons/day/cow or more (Loudon et al., 1985).

Waste associated with milking centers varies among the different rooms. Milk room waste typically consists of wash water associated with cleaning pipelines and holding tanks. This waste could be disposed of via septic tank systems, but many dairies include it in their manure waste management systems. Milk parlor waste typically consists of some manure and wash water from cleaning the milking equipment. Holding area waste generally contains more manure than the milk parlor and also contains wash water from cleaning the cows and flush water from cleaning the area. Many dairies remove solids from milking center waste prior to storing the liquid waste in a lagoon. Table 6-39 presents USDA/NRCS data characterizing dairy waste from milking centers.

Table 6-39. Dairy Waste Characterization—Milking Center

Component	Units	Milking Center			
		Milk Room	Milk Room + Milk Parlor	Milk Room + Milk Parlor + Holding Area[a]	Milk Room + Milk Parlor + Holding Area[b]
Volume	ft^3/d/1,000#	0.22	0.6	1.4	1.6
Moisture	%	99.72	99.4	99.7	98.5
Total Solids	% wet basis	0.28	0.6	0.3	1.5
Volatile Solids	lb/1,000 gal	12.9	35	18.3	99.96
Fixed Solids	lb/1,000 gal	10.6	15	6.7	24.99
COD	lb/1,000 gal	25.3	41.7	-	-
BOD	lb/1,000 gal	-	8.37	-	-
N	lb/1,000 gal	0.72	1.67	1	7.5
P	lb/1,000 gal	0.58	0.83	0.23	0.83
K	lb/1,000 gal	1.5	2.5	0.57	3.33
C:N ratio	unitless	10	12	10	7

[a] Holding area scraped and flushed - manure removed via solids separator.
[b] Holding area scraped and flushed - manure included.
Source: USDA/NRCS, 1992.

Lagoons

Lagoons that receive a significant loading of waste (e.g., from the holding area, freestall barn, and dry lots) generally operate in an anaerobic mode. Anaerobic dairy lagoon sludge accumulates at a rate of about 0.073 ft^3/pounds of total solids. This is equivalent to about 266 ft^3/year/1,000-pound lactating cow, assuming that 100 percent of the waste is placed in the lagoon (USDA NRCS, 1992).

Typically, storage and/or treatment reduces nitrogen in dairy manure by 30 percent to 75 percent through volatilization with only minor decreases in potassium and phosphorus. Although the values of potassium and phosphorus are low in the supernatant, which is removed on a regular basis, a disproportionate amount of the phosphorus and potassium can be found concentrating in the bottom sludge in lagoons and storage areas (Lander, 1999). Table 6-40 presents data on dairy waste managed in lagoons.

Table 6-40. Dairy Waste Characterization—Lagoons

Component	Units	Lagoon		
		Anaerobic - Supernatant	Anaerobic - Sludge	Aerobic - Supernatant
Moisture	%	99.75	90	99.95
Total Solids	% wet basis	0.25	10	0.05
Volatile Solids	lb/1,000 gal	9.16	383.18	1.67
Fixed Solids	lb/1,000 gal	11.66	449.82	2.5
COD	lb/1,000 gal	12.5	433.16	1.25
BOD	lb/1,000 gal	2.92	-	0.29
N	lb/1,000 gal	1.67	20.83	0.17
NH4-N	lb/1,000 gal	1	4.17	0.1
P	lb/1,000 gal	0.48	9.16	0.08
K	lb/1,000 gal	4.17	12.5	-
C:N ratio	unitless	3	10	-
Copper	lb/lb	-	7.64×10^{-4}	-
Zinc	lb/lb	-	1.22×10^{-3}	-

Source: USDA/NRCS, 1992 and NCSU, 1994.

6.3.2.3 *Composition of Aged Manure/Waste*

Dairy manure characteristics after excretion vary from operation to operation, and within the same operation during the year. Manure undergoes many changes after excretion, including moisture change (dilution or consolidation), volatilization, oxidation, and reduction. These changes always affect the "as-excreted" manure characteristics. For example, it is estimated that as much as 50 percent to 60 percent of nitrogen in the urine portion of the manure can be lost during the first hours after excretion if some measure is not taken to preserve it (Lander, 1999). Phosphorus and potassium losses during storage are considered negligible except in open lots or lagoons. In open lots, about 20 percent to 40 percent of phosphorus and 30 percent to 50 percent of potassium can be lost by runoff and leaching. Up to 80 percent of the phosphorus in lagoons can accumulate in bottom sludges (USDA ARS, 1998).

Characteristics of stored manure either are altered over time, or they are conserved (mass). Nitrogen, for example, is volatilized in the form of ammonia and is lost from the system. On the other hand, most of the compounds in manure (e.g., phosphorus, metals) remain in the manure over time, and are considered to be conserved. Treating the manure often reduces the concentration of nonconservative elements, such as nitrogen and the organic compounds, thus reducing oxygen demands in further treatment (Lander, 1999). Table 6-41 presents North Carolina State University data on scraped dairy manure from a paved surface.

Table 6-41. Dairy Manure Characteristics Per 1,000 Pounds Live Weight Per Day From Scraped Paved Surface

Parameter	Unit[a]	Value
Total solids	lb	13.7
Volatile solids	lb	11.5
Nitrogen (Total Kjeldahl)	lb	0.32
Nitrogen (Ammonia)	lb	0.077
Phosphorus (Total)	lb	0.097
Potassium	lb	0.22

[a]All values wet basis.
Source: NCSU, 1994.

6.4 Beef and Heifer Waste

This section describes the characteristics of beef and heifer manure and waste. In this section, manure refers to the combination of feces and urine and waste refers to manure plus other material, such as hair, soil, and spilled feed. Due to the nature of beef and veal operations, however, even fresh manure may also contain small amounts of hair, soil, and feed.

This section discusses the following:

- Section 6.4.1: The quantity of manure generated; and
- Section 6.4.2: Description of waste constituents and concentrations.

6.4.1 Quantity of Manure Generated

Numerous analyses have estimated average manure quantities from beef cattle. Four major data sources that contain mean values for beef manure characteristics are identified below:

- American Society of Agricultural Engineers (ASAE) Standard D384.1: *Manure Production and Characteristics*, 1999. This data source contains national fresh (as-excreted) manure characteristic values by animal type (e.g., dairy, beef, veal, swine).

- USDA, *Agricultural Waste Management Field Handbook*, Chapter 4, 1996. This data source contains national manure characteristic values for fresh and managed manure (e.g., lagoon supernatant, feedlot runoff) by animal type including subtypes such as lactating cow, dry cow, heifer, sow, and boar.

- North Carolina State University (NCSU), *Livestock Manure Production and Characterization in North Carolina*, 1994. This data source contains regional manure characteristic values for fresh and managed manure by animal type including subtypes.

- Midwest Plan Service-18 (MWPS): *Livestock Waste Facilities Handbook*, 1985. This data source contains national fresh manure characteristic values by animal type and animal weight.

A recent analysis conducted by Charles Lander, et al. of the USDA/NRCS used a composite of three of these data sources (Lander et al., 1998). Lander removed ASAE data before averaging to prevent double counting of the ASAE information that is included in the Midwest Plan Service data. Table 6-42 presents the fresh or "as-excreted" manure estimates from Lander's analysis for beef and heifer cattle. In this analysis the average weight of a heifer was assumed to be 550 pounds and the only data source with heifer manure weight information was North Carolina State University.

Table 6-42. Weight of Beef and Heifer Manure, "As-Excreted"

Quantity of Manure (wet basis)	Steer, Bulls, and Calves	Beef Cows	Heifers
Weight (lb/day/1,000-lb animal)	58	63	66
Weight (lb/year/1,000-lb animal)	21,170	22,995	24,090

Source: Lander, 1998.

6.4.2 Description of Waste Constituents and Concentrations

The composition and concentrations of beef and heifer waste varies from the time that it is excreted to the time it is ultimately used as a fertilizer and/or soil amendment. Nutrients and metals are expected to be present in beef waste due to the constituents of the feed. This section discusses the following:

- Section 6.4.2.1: Composition of "as-excreted" manure;
- Section 6.4.2.2: Composition of beef feedlot waste;
- Section 6.4.2.3: Composition of aged manure; and
- Section 6.2.2.4: Composition of runoff from beef feedlots.

6.4.2.1 *Composition of "As-Excreted" Manure*

Data are presented in Table 6-43 for 13 metals and nutrients found in fresh beef cattle manure. Nitrogen is present in manure in four forms: ammonium-N, nitrate-N, nitrite-N, and organic-N. The total nitrogen (N) is the sum of these four components, while the total Kjeldahl nitrogen (TKN) is the sum of the organic-N and ammonium-N. Phosphorus is present in manure in inorganic and organic forms and presented as total phosphorus. Colonies of the pathogens coliform and streptococcus bacteria have also been identified in beef manure.

Manure characteristics for beef cattle are highly variable and greatly influenced by the diet and age of the animals. Differences in weather, season, degree of confinement, waste collection systems, and overall management procedures used by feedlots across the nation add to the variability of manure characteristics in feedlots. The largest variable in fresh manure is moisture content, which significantly decreases over time. Another major variable is the ash content, which depends on the amount of soil entrained in the manure. Ash content also depends on the degree to which the manure has been degraded, which is a function of time since deposition, moisture conditions, temperature, and oxygen saturation (Sweeten et al., 1997). Ash content for fresh manure has been reported as 15.3 percent dry basis (Sweeten, 1995), while ash content for aged feedyard waste has been reported as high as 66 percent dry basis (TAES, 1996).

The nitrogen content of manure can begin to decrease rapidly after excretion. The urea-nitrogen fraction part of the fecal protein rapidly converts to ammonia. Some measurements of ammonia concentrations in air around feedyards have indicated that about half of the nitrogen deposited in urine, or about one-fourth of the total N deposition of the feedlot surface, is lost to the atmosphere as ammonia gas (NH_3). The rate of ammonia emissions depends on temperature, pH, humidity, and moisture conditions, and it has been found to nearly triple as manure dries after rainfall (Sweeten et al., 1997).

Table 6-43 presents beef and veal manure characteristics data, which are averages reported in the scientific literature and compiled by ASAE. Lander averaged values from the Midwest Plan Service, USDA-NRCS, and North Carolina State data sets for N, P, and K. Table 6-44 presents Lander’s averaged values.

Table 6-43. Fresh Beef and Veal Manure Characteristics Per 1,000 Pound Live Weight Per Day

Parameter	Unit[a]	Beef		Veal	
		Mean	Standard Deviation	Mean	Standard Deviation
Moisture	%	88.4	-	97.5	-
Weight	lb	58	17	62	24
Total solids	lb	8.5	2.6	5.2	2.1
Volatile solids	lb	7.2	0.57	2.3	-
BOD (5-day)	lb	1.6	0.75	1.7	-
COD	lb	7.8	2.7	5.3	-
pH	lb	7.0	0.34	8.1	-
Nitrogen (Total Kjeldahl)	lb	0.34	0.073	0.27	0.045
Nitrogen (Ammonia)	lb	0.086	0.052	0.12	0.016
Phosphorous (Total)	lb	0.092	0.027	0.066	0.011
Orthophosphorus	lb	0.030	-	-	-
Potassium	lb	0.21	0.061	0.28	0.10
Calcium	lb	0.41	0.11	0.059	0.049
Magnesium	lb	0.049	0.015	0.033	0.023
Sulfur	lb	0.045	0.0052	-	-
Sodium	lb	0.0030	0.023	0.086	0.063
Iron	lb	0.0078	0.0059	0.00033	-
Manganese	lb	0.0012	0.00051	-	-
Boron	lb	0.00088	0.000064	-	-
Molybdenum	lb	0.000042	-	-	-
Zinc	lb	0.0011	0.00043	0.013	-
Copper	lb	0.00031	0.00012	0.000048	-
Total coliform bacteria	colonies	29	27	-	-
Fecal coliform bacteria	colonies	13	12	-	-
Fecal streptococcus bacteria	colonies	14	21	-	-

[a] All values wet basis.

Source: ASAE, 1993.

Table 6-44. Average Nutrient Values in Fresh (As-Excreted) Beef Manure

Parameter	Beef (lb/day/1,000-lb animal)[a]
Nitrogen (Total Kjeldahl)	0.32
Ammonia	Not provided
Phosphorus (Total)	0.098
Potassium	0.23

[a] Lander's analysis relied upon 1990 North Carolina State University data, while the North Carolina State University data presented in this report is from 1994.

Manure characteristics of heifers is limited to two data sources, North Carolina State University and USDA, *Agricultural Waste Management Field Handbook*, Chapter 4, 1996. Table 6-45 presents the fresh (as-excreted) manure characteristics for heifers.

6-45. Fresh Heifer Manure Characteristics Per 1,000 Pounds Live Weight Per Day

Parameter	Unit[a]	USDA Mean Value	NCSU Mean Value
Moisture	%	89.3	--
Weight	lb	85	68.4
Total solids	lb	9.14	7.35
Volatile solids	lb	7.77	5.34
Biochemical oxygen demand (BOD), 5-day	lb	1.3	0.89
Chemical oxygen demand (COD)	lb	8.3	5.68
Nitrogen (Total Kjeldahl)	lb	0.31	0.23
Phosphorus (Total)	lb	0.04	0.16
Potassium	lb	0.24	0.16

[a]All values wet basis.
Sources: USDA, 1996; NCSU, 1994

6.4.2.2 *Composition of Beef Feedlot Waste*

The characteristics of beef cattle feedlot wastes vary widely because of differences in climate, rainfall, diet, feedlot surface, animal density, and cleaning frequency. Wasted feed and soil in unpaved beef feedlots is readily mixed with the manure because of animal movement and cleaning operations (Arrington et al., 1981). Therefore, due to the incorporation of more solids and exposure to the elements, the moisture content of beef feedlot waste is significantly lower than for "as-excreted" beef manure.

Table 6-46 presents characteristics of beef waste, as collected, from unpaved and paved feedlots (USDA NRCS, 1992). Most feedlots are unpaved; however, for paved lots, concrete is the most common paving material, although other materials (e.g., fly ash) have been used (Suszkiw, 1999).

Table 6-46. Beef Waste Characterization—Feedlot Waste

Component	Units	Unpaved Lot[a]	Paved Lot[b]	
			High-Forage Diet	High-Energy Diet
Weight	lb/d/1000#	17.5	11.7	5.3
Moisture	%	45	53.3	52.1
Total Solids	% wet basis	55	46.7	47.9
Total Solids	lb/d/1000#	9.6	5.5	2.5
Volatile Solids	lb/d/1,000#	4.8	3.85	1.75
Fixed Solids	lb/d/1,000#	4.8	1.65	0.76
N	lb/d/1,000#	0.21	-	-
P	lb/d/1,000#	0.14	-	-
K	lb/d/1,000#	0.03	-	-
C:N ratio	unitless	13	-	-

[a] Dry climate (annual rainfall less than 15 inches); annual manure removal.
[b] Dry climate; semiannual manure removal.
Source: USDA NRCS, 1992.

Table 6-47 presents North Carolina State University data on scraped beef manure from an unpaved surface.

6-47. Beef Manure Characteristics Per 1,000 Pounds Live Weight Per Day From Scraped Unpaved Surface

Parameter	Unit[a]	Value
Total solids	lb	9.4
Volatile solids	lb	5.3
Nitrogen (Total Kjeldahl)	lb	0.20
Nitrogen (Ammonia)	lb	0.38
Phosphorus (Total)	lb	0.062
Potassium	lb	0.14

Sweeten, et al., compiled and compared feedlot waste data representing "as-collected" waste, composted waste, and stockpiled waste from one area of the country (Sweeten et al., 1997). Overall, the as-collected, composted, and stockpiled data were similar, indicating that once manure is exposed to the elements, its nutrient composition does not significantly change even if it is composted or stockpiled.

6.4.2.3 *Composition of Aged Manure*

Beef cattle feedlots typically scrape and remove the manure that is deposited on the ground about every 120 to 365 days, as opposed to dairy operations that scrape or remove manure as often as every day. During this "aging" process, nutrients are lost due to ammonia volatilization, runoff, and leaching. Mathers, et al., determined average nutrient concentrations in aged manure ready for land application from 23 beef cattle feedlots in the Texas High Plains (Mathers et al., 1972). Since national data on aged manure characteristics have not been identified, these local data are presented in Table 6-48 to demonstrate the significant difference in characteristics of fresh and aged manure.

These data show the aged beef manure nitrogen concentration is 40.3 percent of the fresh manure concentration, while phosphorus and potassium in aged manure are 50.9 percent and 64.5 percent of their concentrations, respectively, in fresh manure. Nitrogen losses as high as 50 percent have been reported in aged beef manure, due to temperature, moisture, pH, and C:N ratio. Phosphorus and potassium losses are primarily due to runoff but some leaching may also occur.

Table 6-48. Percentage of Nutrients in Fresh and Aged Beef Cattle Manure

Parameter	Unit	Fresh Manure	Aged Manure
Moisture	%	88	34
N	% dry basis	5.08	2.05
P	% dry basis	1.59	0.81
K	% dry basis	3.55	2.29

Source: Mathers, 1972.

6.4.2.4 *Composition of Runoff from Beef Feedlots*

Numerous analyses characterizing the runoff from beef feedlots have been conducted on a local level. However, manure characteristics data collected at a local level may not be representative of the beef industry as a whole. Since the constituent concentration of feedlot runoff varies among different areas of the country, this report presents only nationally available manure characteristics and regional estimates of feedlot runoff characteristics.

As with feedlot wastes, constituent characteristics of beef feedlot runoff also vary across the country. The factors that are responsible for runoff waste variations are similar to those for feedlot wastes (i.e., climate, rainfall, diet, feedlot surface, animal density, and cleaning frequency). Paved feedlots produce more runoff than unpaved lots and areas of high rainfall and low evaporation produce more runoff than arid areas.

The USDA/NRCS Agricultural Waste Management Field Handbook characterizes both the supernatant and sludge from beef feedlot runoff lagoons. Table 6-49 presents these waste characteristics.

Table 6-49. Beef Waste Characterization—Feedlot Runoff Lagoon

Component	Units	Runoff Lagoon	
		Supernatant	Sludge
Moisture	%	99.7	82.8
Total Solids	% wet basis	0.3	17.2
Volatile Solids	lb/1,000 gal	7.5	644.83
Fixed Solids	lb/1,000 gal	17.5	788.12
COD	lb/1,000 gal	11.67	644.83
N	lb/1,000 gal	1.67	51.66
NH_4-N	lb/1,000 gal	1.5	-[a]
P	lb/1,000 gal	-[a]	17.5
K	lb/1,000 gal	7.5	14.17
Copper	lb/lb	-	1.94×10^{-4}
Zinc	lb/lb	-	9.29×10^{-4}

[a] Data not available.
Source: USDA NRCS, 1992; NCSU, 1994.

6.5 Veal Waste

This section describes the characteristics of veal manure and waste. In this section, manure refers to the combination of feces and urine and waste refers to manure plus other material, such as hair, soil, and spilled feed. Due to the nature of veal operations, however, even fresh manure may also contain small amounts of hair and feed.

This section discusses the following:

- Section 6.5.1: The quantity of manure generated; and
- Section 6.5.2: Description of waste constituents and concentrations.

6.5.1 Quantity of Manure Generated

National data on veal waste characteristics are available from the following three data sources:

- American Society of Agricultural Engineers (ASAE) Standard D384.1: *Manure Production and Characteristics*, 1999. This data source contains national fresh (as-excreted) manure characteristic values by animal type (e.g., dairy, beef, veal, swine).

- USDA, *Agricultural Waste Management Field Handbook*, Chapter 4, 1996. This data source contains national manure characteristic values for fresh and managed manure (e.g., lagoon supernatant, feedlot runoff) by animal type including subtypes such as lactating cow, dry cow, heifer, sow, and boar.

- North Carolina State University (NCSU), *Livestock Manure Production and Characterization in North Carolina*, 1994. This data source contains regional manure characteristic values for fresh and managed manure by animal type including subtypes.

Table 6-50 presents the average as-excreted manure characteristics for veal from these three data sources.

6-50. Average Weight of Veal Manure, "As-Excreted"

Quantity of Manure (wet basis)	Veal Calves
Weight (lb/day/1,000-lb animal)	61
Weight (lb/year/1,000-lb animal)	22,265

Sources: ASAE, 1999; UDSA, 1996; NCSU, 1994.

6.5.2 Description of Waste Constituents and Concentrations

The composition and concentrations of veal waste varies from the time that it is excreted to the time it is ultimately used as a fertilizer and/or soil amendment. Nutrients and metals are expected to be present in veal waste due to the constituents of the feed. This section discusses the composition of "as-excreted" manure.

Data are presented in Table 6-51 for nine metals and nutrients found in fresh veal manure. Veal manure is very fluid, with the consistency of a sloppy mortar mix, and is often diluted by large volumes of wash water (Meyer, 1987). The moisture content of fresh veal manure is approximately 98 percent (USDA NRCS, 1992).

Veal manure is typically stored in tanks, basins, and pits until it is pumped out on the land as fertilizer. However, most of the fertilizer value of veal manure remains in the solids in a settling tank (Meyer, 1987). Over time, the most significant compositional change in veal manure, stored in pits, is the conversion of organic-N in fresh manure to ammonium and loss of total nitrogen to the atmosphere in the form of ammonia. Much of the high ammonia loss is due to microbial degradation of the organic matter including total nitrogen components (Sutton et al., 1989).

6-51. Fresh Veal Manure Characteristics Per 1,000 Pound Live Weight Per Day

Parameter	Unit[a]	Mean Values from Data Sources		
		ASAE	USDA	NCSU
Moisture	%	97.5	97.5	--
Weight	lb	62	60	61.8
Total solids	lb	5.2	1.5	4.0
Volatile solids	lb	2.3	0.85	2.1
BOD (5-day)	lb	1.7	0.37	0.83
COD	lb	5.3	1.5	1.5
pH	lb	8.1	--	7.7
Nitrogen (Total Kjeldahl)	lb	0.27	0.20	0.24
Nitrogen (Ammonia)	lb	0.12	--	0.11
Phosphorous (Total)	lb	0.066	0.03	0.053
Potassium	lb	0.28	0.25	0.27
Calcium	lb	0.059	--	0.059
Magnesium	lb	0.033	--	0.33
Sodium	lb	0.086	--	0.16
Iron	lb	0.00033	--	0.00033
Zinc	lb	0.013	--	0.013
Copper	lb	0.000048	--	0.000048

[a] All values wet basis.
Source: ASAE, 1999; USDA, 1996; NCSU, 1994.

6.6 References

Arrington, R.M. and C.E. Pachek. 1981. *Soil Nutrient Content in Manures in an Arid Climate.* In: Livestock Waste: A Renewable Resource, Proceedings of the Fourth International Symposium on Livestock Waste, 1980. pp. 15-152. American Society of Agricultural Engineers, St. Joseph, Michigan.

ASAE, 1998. ASAE Standards 1998, 45th Edition. American Society of Agricultural Engineers, St. Joseph, MI.

ASAE, 1999. *Manure Production and Characteristics*. American Society of Agricultural Engineers, St. Joseph, MI.

Blume and McCleve. 1997. *Disposal of Swine Wastewater Using Spray Nozzle*. ASAE Paper No. 974072. Presented at the ASAE Annual International Meeting. American Society of Agricultural Engineers, Minneapolis, Minnesota, August 10-14, 1997.

Boland et al. 1997. *Analysis of Manure Management Systems and Phytase Adoption by Pork Producers.* Livestock Environment 5, Volume 2. Proceedings of the Fifth International Symposium, Bloomington , Minnesota, USA, May 29-31, 1997. Pp. 702-709.

Fulhage. 1998. *Composting Dead Animals- The Missouri Experience.* Presented at the ASAE Annual International Meeting. American Society of Agricultural Engineers, Orlando, Florida, July 12-16, 1998.

Jones, Don D., and Alan Sutton. 1994. *"Treatment Options for Liquid Manure" in Liquid Manure Application Systems: Design, Management, and Environmental Assessment, Proceedings from the Liquid Manure Application Systems Conference*. Rochester, New York, Dec. 1-2, 1994.

Lander, C.H., D. Moffitt, and K. Alt. 1998. *Nutrients Available from Livestock Manure Relative to Crop Growth Requirements*. U.S. Department of Agriculture. Natural Resources Conservation Services. Washington, D.C.

Lander, C.H. 1999. *Dairy Manure Characteristics*. National Milk Producers Federation submittal to EPA.

Loudon, T.L., et. al. 1985. *Livestock Waste Facilities Handbook*, 2nd ed., Midwest Plan Service.

Mathers, A.C., B.A. Stewart, J.D. Thomas, and B.J. Blair. 1972. *Effects of Cattle Feedlot Manure on Crop Yields and Soil Conditions*. USDA Southwestern Great Plains Research Center Tech. Rep. No. 11, Bushland, TX.

Meyer, D. J. 1987. *Animal Manure—Veal Calf Management*. Prepared under the direction of the Manure Management Work Group of the Agricultural Advisory Committee to the Pennsylvania Department of Environmental Resources, Robert E. Graves, Ed. <http://www.inform.umd.edu:8080/EdRes/topic/AgrEnv/ndd/watermgt/ANIMAL_MANURE_VEAL_CALF_MANAGEM.html>

Midwest Planning Service. *Livestock Waste Facilities Handbook*, 1985.

MWPS. 1993. MWPS-18: *Livestock Waste Facilities Handbook - 3rd Edition*. Midwest Plan Service, Iowa State University, Ames, IA.

NCSU. 1994. *Livestock Manure Production and Characterization in North Carolina*. North Carolina Cooperative Extension Service. Raleigh, NC.

Suszkiw, J. 1999. *Low-Cost Way to Pave Feedlots*. Agricultural Research.

Sutton. A.L., M.D. Cunningham, J.A. Knesel, and D.T. Kelly. 1989. *Veal Calf Waste Production and Composition*. Applied Engineering in Agriculture, Vol 5, No. 1.

Svoboda. 1995. *Nitrogen Removal from Pig Slurry by Nitrification and Denitrification*. Proceedings of the Seventh International Symposium on Agricultural and Food Processing Wastes, Chicago, Illinois, USA, June 18-20, 1995. Pp. 702-709.

Sweeten, J.M. and S.H. Amosson. 1995. *Total Quality Manure Management*, Texas Cattle Feeders Association. Chapter 4: Manure Quality and Economics.
USDA ARS. 1998. *Agricultural Uses of Municipal, Animal and Industrial Byproducts*. U.S. Department of Agriculture (SDA), Agricultural Research Service (ARS). <http://www.ars.usda.gov/is/np/agbyintro.htm>

Sweeten, J.M., S.H. Amosson, and B.W. Auvermann. 1997. *Manure Quality and Economics*. Proceedings of Texas Biomass Energy Opportunities Workshop Series #1: Livestock Waste Streams: Energy and Environment. Texas A&M University Agricultural Research and Extension Center.

TAES. 1996. *Manure Analysis Summary—Coal Ash Surfacing vs Control Treatments for Beef Cattle Feedyards*. Result Demonstration Report. Texas Agricultural Extension Service (TAES).

USDA. 1992. National Engineering Handbook: Agricultural Waste Management Field Handbook. United States Department of Commerce, National Technical Information Service. Springfield, VA. Handbook also revised July 1996.

USDA. 1998. Nutrients Available from Livestock Manure Relative to Crop Growth Requirements. U.S. Department of Agriculture, Natural Resources Conservation Service, Resource Assessment and Strategic Planning Working Paper 98-1. <http://www.nhq.nrcs.usda.gov/land/pubs/nlweb.html>. Accessed August 23, 1998.

USDA. 1999. 1997 Agricultural Resource Management Study (ARMS). Economic Research Service, 2/18/99.

USDA APHIS. 1995. *Swine '95 Part I: Reference of 1995 Swine Management Practices*. <http://www.aphis.usda.gov/vs/ceah/cahm/>. File sw95des1.pdf accessed October 15, 1998. U.S. Department of Agriculture, Animal and Plant Health Inspection Service.

USDA NRCS. 1992. *Agricultural Waste Management Field Handbook, National Engineering Handbook (NEH),* Part 651. U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS). <http://www.ncg.nrcs.usda.gov/awmfh.html>

Van Horn, H.H., G.L. Newton, R.A. Nordstedt, E.C. Krench, G. Kidder, D.A. Graetz, and C.F. Chambliss. 1998. *Circular 1016: Dairy Manure Management: Strategies for Recycling Nutrients to Recover Fertilizer Value and Avoid Environmental Pollution.* Dairy and Poultry Sciences Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida.

Zublena, J. P., Barker, Parker, and Stanislaw. 1993. *Soil Facts*. North Carolina Cooperative Extension Service.

CHAPTER 7

POLLUTANTS OF INTEREST

7.0 INTRODUCTION

Pollution generated at feedlot operations can arise from multiple sources. These sources, including animal waste, process wash waters, litter, animal carcasses, spills of pesticides, and pharmaceuticals, are the primary sources of potential environmental contamination.

Excreted animal waste contains undigested and partially digested feed, partially metabolized organic material, dead and living microorganisms from the digestive tract, cell wall material and other organic debris from the digestive tract, excess digestive juices, and other organisms that might have grown in the wastes after excretion. Depending on the type of feed provided to the animals and whether feed additives have been used, animal wastes can also contain pharmaceuticals and inorganics such as trace elements.

Animal carcasses, which may contain pathogens, nutrients, and chemical toxicants, can pose an environmental problem, especially in the poultry industry where many operations have historically used burial as a means for disposal. For example, during 1990, several state agencies in Arkansas tested the management of dead-bird disposal pits and found high soil concentrations of ammonium (USEPA, 1999). Improper disposal of poultry carcasses has been implicated in ground water contamination; however, in recent years, greater regulation of animal disposal has reduced the risk of environmental contamination from buried animal carcasses. Arkansas, for example, has outlawed the use of dead-bird disposal pits. Other states have also issued guidelines or regulations for disposal of animal carcasses and require operators to use specific practices such as composting.

In the preliminary study on environmental impacts from animal feedlot operations, EPA (1998) identified and described the major animal waste constituents that can adversely affect the environment. Additional information on potential impacts can be found in the *Environmental Assessment of Proposed Revisions to the National Pollutant Discharge Elimination system Regulation and Effluent Limitations Guidelines for Concentrated Animal Feeding Operations* (USEPA, 2000). As demonstrated in Chapter 6, the physical and chemical characteristics of manure differ between animal sectors as well as within animal sectors. The following pollutants of interest identified by EPA in its preliminary feedlots study are described below:

- Biochemical oxygen demand (BOD)
- Chemical oxygen demand (COD)
- Total suspended solids
- Nutrients (nitrogen, phosphorus)
- Pathogens
- Other contaminants, including salts, trace elements, and pharmaceuticals

7.1 Conventional Waste Pollutants

Biochemical Oxygen Demand

BOD is a measure of the oxygen-consuming requirements of organic matter decomposition. When animal waste is discharged to surface water, it is decomposed by aquatic bacteria and other microorganisms. Decomposing organic matter consumes oxygen and reduces the amount available for aquatic animals. Severe reductions in dissolved oxygen levels can lead to fish kills. Even moderate decreases in oxygen levels can adversely affect waterbodies through decreases in biodiversity as manifested by the loss of fish and other aquatic animal populations.

Total Suspended Solids

Suspended solids can clog fish gills and increase turbidity. Increased turbidity reduces penetration of light through the water column, thereby limiting the growth of desirable aquatic plants that serve as a critical habitat for fish, shellfish, and other aquatic organisms. Solids that settle out as bottom deposits can alter or destroy habitat for fish and benthic organisms. Solids also provide a medium for the accumulation, transport, and storage of other pollutants, including nutrients, pathogens, and trace elements. Sediment-bound pollutants often have an extended interaction with the water column through cycles of deposition, resuspension, and redeposition.

Fecal Coliform Bacteria

Manure contain diverse microbial populations. Included are members of the normal gastrointestinal tract flora, such as members of the fecal coliform and fecal streptococcus groups of bacteria. These are the groups of bacteria commonly used as indicators of fecal contamination and the possible presence of pathogenic species. A discussion of the different types of pathogens found in the waste of AFOs is given in section 7.2.

7.2 Nonconventional Pollutants

Nutrients (Nitrogen, Phosphorus)

Because of its nutrient content, animal manure can serve as a valuable agricultural resource. In an area where the amount of nutrients in manure generated from animal feedlot operations is greater than the nutrient requirements of the crops grown in the area, excess land application might occur, leading to increased nutrient runoff and seepage and subsequent degradation of water resources.

As noted in Chapter 6, wastes contain significant quantities of nutrients, particularly N and P. Manure N occurs primarily in the form of organic N and ammonia-N compounds. In organic form, N is unavailable to plants. However, through bacterial decomposition, organic N is transformed into ammonia, which is oxidized (by nitrification) to nitrite and ultimately nitrate. Ammonia and nitrate are bioavailable and therefore have fertilizer value. These forms can also produce adverse environmental impacts when they are transported in excess quantities to the environment.

Ammonia. "Ammonia-N" includes the ionized form (ammonium) and the un-ionized form (ammonia). Ammonium is produced when microorganisms break down organic N products, such as urea and proteins, in manure. This decomposition can occur in both aerobic and anaerobic conditions. Both forms are toxic to aquatic life, although the un-ionized form (ammonia) is much more toxic.

Ammonia is of environmental concern because it exerts a direct biochemical oxygen demand on the receiving water. Ammonia can lead to eutrophication, or nutrient overenrichment, of surface waters. Ammonia itself is a nutrient and is also easily transformed to nitrate (another nutrient form of N) in the presence of oxygen. Although nutrients are necessary for a healthy ecosystem, the overabundance of nutrients (particularly N and P) can lead to nuisance algae blooms.

Nitrate. In the biochemical process of nitrification, aerobic bacteria oxidize ammonium to nitrite (NO_2) and then to nitrate (NO_3). Nitrite is toxic to most fish and other aquatic species, but it usually does not accumulate in the environment because of its rapid conversion to nitrate in an aerobic environment.

Nitrate is a valuable fertilizer because it is biologically available to plants. Excessive levels of nitrate in drinking water, however, can produce adverse human health and environmental impacts. For example, human infants exposed to high levels of nitrate can develop methemoglobinemia, commonly referred to as "blue baby syndrome" because the lack of oxygen can cause the skin to appear bluish in color. To protect human health, EPA has set a drinking water maximum contaminant level (MCL) of 10 mg/L for nitrate-N.

Phosphorus. Animal wastes contain both organic and inorganic forms of P. As with N, the organic form must mineralize to the inorganic form to become available to plants. Mineralization occurs as the manure ages and the organic P hydrolyzes to inorganic phosphate-containing compounds. Phosphorus is of concern in surface waters because it is a nutrient that can lead to eutrophication and the resulting adverse impacts—fish kills, reduced biodiversity, objectionable tastes and odors, increased drinking water treatment costs, and growth of toxic organisms. At concentration levels greater than 1.0 mg/L, P can interfere with coagulation in drinking water treatment plants (Bartenhagen et al., 1994).

Phosphorus is of particular concern in fresh waters, where plant growth is typically limited by phosphorous levels. Under high pollutant loads, however, fresh water may become nitrogen-limited (Bartenhagen et al., 1994). Thus, both N and P loads may contribute to eutrophication.

Chemical Oxygen Demand

COD is another measure of oxygen-consuming pollutants in water, but it measures the amount of oxygen required to oxidize all organic material present. COD differs from BOD in that it test oxidizes organic material regardless of how biological assimilability of the substance. BOD only measures the oxygen required to oxidize the biologically degradable material. COD is based on the fact that all organic compounds, with few exceptions, can be oxidized by the action of strong oxidizing agents under acidic conditions. COD is usually coincident with BOD, exacerbating the adverse effects of organic matter degradation.

Pathogens

Manure contains diverse microbial populations. There are many examples that demonstrate that pathogens from manure can be a problem. Other studies show that manured fields do not pose a significant threat to surface waters. Most pathogens are from the gastrointestinal tract and can be divided into those pathogens that are highly host-adapted and not considered to be zoonoses (diseases naturally transmissible between vertebrates and man) and those that are capable of causing infection in humans. For example, most *Salmonellae* are zoonoses, but *S. pulloram* and *S. gallinarum*, which might be present in poultry manures, are not. However, both may be included in gross estimates of *Salmonella* densities. The pathogens that might be present in poultry and swine manures also can be divided into those microorganisms which commonly are present and those which are less common. For example in poultry manures, *Campylobacter jejuni* is commonly present while *Mycobacterium avium* is less common. These distinctions are important in assessing the potential public health risks associated with poultry and swine operations, as well as other animal feeding operations.

The interactions between pathogens, cattle, and the environment are not well understood but current literature suggests that dairy and beef cattle shed pathogens that are known to be infectious to humans. The threat posed by pathogens in animal manure is influenced by the source, pH, dry matter, microbial, and chemical content of the feces. Solid manure that is mixed with bedding material is more likely to undergo aerobic fermentation in which temperature increases reduce the number of viable pathogens. However, some pathogens grow under a wide range of conditions that makes their control very difficult. Quantifying the risk associated with these pathogens is thus challenging. Rapidly changing pathogen numbers, changes in the infective status of the host, and survivability of the pathogens all make it increasingly difficult to determine how much of a threat animal-excreted pathogens are to society. Moreover, methods of pathogen detection produce varying results, making it difficult to compare studies that use different analyses (Pell, 1997).

Although manures may contain a variety of pathogens capable of causing infectious diseases in humans, it appears that *Salmonellae*, *Campylobacter jejuni*, *Clostridium perfringens* type A, and possibly *Pasteuralla multocida* should be of greatest concern. Only swine manure is a potential source of either *Giardiasis* or *Cryptosporidiosis* infections in humans, and swine manure appears to be far less significant than cattle manure as a source of the responsible protozoans.

Other Potential Contaminants

Animal wastes can contain other chemical constituents that could adversely affect the environment. These constituents include salts, trace elements, and pharmaceuticals, including antibiotics. Although salts are usually present in waste regardless of animal or feed type, trace elements and pharmaceuticals are typically the result of feed additives to help prevent disease or promote growth. Accordingly, concentrations of these constituents will vary with operation type and from facility to facility.

Salts and trace elements. Animal manure contains dissolved mineral salts. The major cations contributing to salinity are sodium, calcium, magnesium, and potassium; the major anions are chloride, sulfate, bicarbonate, carbonate, and nitrate. In land-applied wastes, salinity is a concern because salts can accumulate in the soil and become toxic to plants; they can also deteriorate soil quality by reducing permeability and contributing to poor tilth. Direct discharges and salt runoff to fresh surface waters contribute to salinization and can disrupt the balance of the ecosystem. Leaching salts can deteriorate ground water quality, making it unsuitable for human consumption. Trace elements such as arsenic, copper, selenium, and zinc are often added to animal feed as growth stimulants or biocides (Sims, 1995). When applied to land, these elements can accumulate in soils and become toxic to plants, and they can affect human and ecological health.

Antibiotics and hormones. A number of pharmacologic agents are used in the production of poultry and swine, among them a variety of antibiotics. Nonantibiotic antimicrobials, such as sulfonamides, and some antibiotics, such as streptomycin, are used primarily for therapeutic use. However, most of the antibiotics used in both the swine and the poultry industries are used both therapeutically and as feed additives to promote growth or improve feed conversion efficiency or both. When antibiotics are used to promote growth or improve feed conversion, the dosage rates are substantially lower than when they are administered for therapeutic use.

While specific hormones are used to increase productivity in the beef and dairy industries, hormones are not used in the poultry or swine industries. Thus, hormones present in poultry and swine manures are only in naturally occurring concentrations.

Despite the fact that there is little information in the literature about concentrations of antibiotics in poultry and swine manures, it is known that the primary mechanisms of elimination are in urine and bile (Merck and Company, 1998). Essentially all of an antibiotic administered is eventually excreted. The form excreted, the unchanged antibiotic or metabolites or some combination thereof, is antibiotic specific, as is the mass distribution among mechanisms of excretion. These compounds may pose risks to humans and the environment. For example, chronic toxicity may result from low-level discharges of antibiotics. In addition, estrogen hormones have been implicated in the drastic reduction in sperm counts among men (Sharpe and Skakkebaek, 1993) and reproductive disorders in a variety of wildlife (Colburn et al., 1993).

7.3 Priority Pollutants

The Clean Water Act (CWA) requires states to adopt numeric criteria for priority toxic pollutants if the USEPA has published criteria guidance and if the discharge or presence of these pollutants could reasonably be expected to interfere with the designated uses of the state's waters. The USEPA currently lists a total of 126 toxic priority pollutants in 40 CFR 122, Appendix D. Other metal and organic chemicals, however, can cause adverse impacts.

Animal wastes may contain a variety of priority pollutants, including the potentially toxic metals: arsenic, cadmium, chromium, copper, lead, molybdenum, nickel, selenium, and zinc (Overcash et al., 1983; ASAE, 1999). In promulgating standards for the disposal of sewage sludges by land application, USEPA has established maximum allowable concentrations and cumulative loading limits for each of these metals. Although information about the concentrations of these metals in poultry and livestock manures, and its variability, is quite limited, it generally has been assumed that these concentrations are well below those allowable for land application of wastewater treatment sludges. However, the issue of cumulative loading has been raised periodically in light of long-term use of cropland for manure disposal, especially in areas where poultry and livestock production is concentrated (Sims, 1995).

Given the degree of vertical integration that has occurred in both the poultry and the swine industries, much of the feed manufacturing for these industries is controlled by integrators. Thus, information about the current use of trace mineral supplements in formulating both poultry and swine feeds is difficult to obtain because the integrators consider it proprietary. However, it appears to be a reasonable assumption that arsenic, copper, selenium, and zinc are typically added to poultry feeds and that copper, selenium, and zinc are common components of trace mineral premixes used in the manufacturing of swine feeds. It is probable that commonly used feed supplements also contain some manganese.

Feed amendments of selenium (0.3 part per million) and arsenic (90 grams per ton of feed) are regulated by the U.S. Food and Drug Administration (Title 21, Part 573.920 of the Code of Federal Regulations). Levels of other trace minerals as feed supplements are regulated only indirectly by the FDA through maximum allowable concentrations in specified tissues at slaughter or in eggs.

Currently available information about metal concentrations in poultry and swine manures almost exclusively dates back to the 1960s and 1970s (Barker and Zublena, 1995). Kornegay's (1996) data are also somewhat dated, because they are averages over a 14-year period prior to 1992. When compared with Barker and Zublena's data for swine, Kornegay's data suggest that the concentrations of copper and zinc in swine manure have increased significantly over time. However, little is known about the current concentrations of trace metals in poultry and swine manures except that the variations in concentrations are substantial.

7.4 References

ASAE 1999. Manure production and characteristics. AS Data: AS D384.1. American Society of Agricultural Engineers, St. Joseph, Michigan.

Barker, J.C., and J.P. Zublena. 1995. Livestock manure assessment in North Carolina. In *Proceedings of the Seventh International Symposium on Agricultural and Food Processing Wastes*, American Society of Agricultural Engineers, St. Joseph, Michigan, pp. 98-106.

Bartenhagen, Kathryn, et al. 1994. *Water, Soil, and Hydro Environmental Decision Support System (WATERSHEDS*) NCSU Water Quality Group, <http://h20sparc.wq.ncsu.edu/info /phos.html. Accessed September 6, 1999.

Colburn, T., F.S. vom Sall, and A.S. Soto. 1993. Developmental effects of endocrine-disrupting chemicals in wildlife and humans. *Environmental Health Prospect*, 101:178. Cited in: Shore et al., 1995.

Kornegay, E.T. 1996. Nutritional, environmental, and economic considerations for using phytase in pig and poultry diets. In *Nutrient Management of Food Animals to Enhance and Protect the Environment*, ed. E.T. Kornegay, pp. 277-302.

Merck and Company, Inc. 1998. *The Merck Veterinary Manual.* 18th ed. Merck and Company, Inc., Whitehouse Station, New Jersey.

Overcash, M.R., F.J. Humenik, and J.R. Miner. 1983. *Livestock Waste Management.* Vol. I. CRC Press, Inc., Boca Raton, Florida.

Pell, Alice, 1997. Manure and Microbes: Public and Animal Health Problem? *Journal of Dairy Science* 80:2673-2681.

Sharpe, R.M., and N. Skakkebaek. 1993. Are Estrogens involved in falling sperm count and disorders of the male reproductive system? *Lancet* 341:1392. Cited in USEPA, 1998.

Sims, J.T. 1995. Characteristics of animal wastes and waste-amended soils: An overview of agricultural and environmental issues. In *Animal Wastes and the Land-Water Interface*, ed. K. Steele, pp. 1-13. CRC Lewis Publishers, Boca Raton, Florida.

USEPA. 1998. Appendix IV. Environmental data summary. In *Environmental impacts of animal feeding operations*. U.S. Environmental Protection Agency, Office of Water, Washington, DC. December 31, 1998.

USEPA. 1999. Success stories, Arkansas. U.S. Environmental Protection Agency, Washington, DC. http://www.epa.gov/owow/NPS/Success3l9/AR.html. December 31, 1998. Accessed September 7, 1999.