5.0 LIVESTOCK WASTE

This emission source category characterizes fugitive hydrocarbon emissions from the natural decomposition of farm animal manures. Ammonia emissions are also evaluated for this category. The specific livestock included in this emission source category are cattle, horses, sheep, poultry, and pigs.

5.1 Activity Data for Livestock Waste

Basic animal populations are available from the California Crop and Livestock Reporting Service. Activity data for beef and dairy cattle as well as the number of hogs on farms in California were taken from this data source for the year 1986. To further distinguish between dairy and beef cattle, certain assumptions were necessary. The California Crop and Livestock Reporting Service estimates there were approximately 5 million cattle in California in 1986. They do not provide an indication of what fraction of these cattle were beef or dairy. However, they do report that 1,030,000 dairy cattle and 950,000 beef cattle calved in 1986. The ratio of these two numbers was applied to the total number of cattle in California to estimate the number of beef and dairy cattle.

Poultry populations were taken from the 1982 census of Agriculture's Poultry Inventory and Sales. Horse and sheep population data were taken from the 1982 Census of Agriculture's Sheep and Horses Inventory and Sales. Table 5-1 summarizes the livestock inventory data available for the state of California.

In the case of livestock waste, it is important to further identify the location and number of livestock in feedlots. Feedlots represent a concentrated emission source in comparison to livestock kept on pasture or rangeland. The Bureau of Agricultural Statistics does not tract the number of cattle on feedlots by county, only by agricultural district. According to the Bureau of Agricultural Statistics, approximately eight percent of the

TABLE 5-1. LIVESTOCK POPULATION ESTIMATES

	Number of Animals
Cattle[a]	
Beef cattle	2,400,000
Dairy cattle	2,600,000
Poultry[b]	
Laying hens	39,456,033
Broiler chickens	23,858,777
Turkeys	5,187,215
Ducks, geese, and other poultry	2,703
Horses[c]	
Horses	129,310
Sheep[c]	--
Sheep and lambs	1,214,585
Pigs[a]	
Hogs on farms	145,000

[a] 1986 population estimates from the California Crop and Livestock Reporting Service.

[b] 1982 population estimates from the Census of Agriculture's Poultry Inventory and Sales.

[c] 1982 population estimates from the Census of Agriculture's Sheep and Horses Inventory and Sales.

cattle in the state are kept on feedlots (Akan, 1987). Imperial Valley District (comprised entirely of Imperial County) has the largest number of cattle on feedlots at 73 percent. The Bureau of Agricultural Statistics maintains similar county-by-county statistics for the other livestock.

Using Dun's Market Identifiers® (a publicly available computerized database), we identified approximately 46 cattle feedlots in the State of California. In addition, there are five and ten feedlots for hogs and sheep/goats, respectively. A complete listing from this database, or a similar one, could be used in the spatial disaggregation of livestock emissions.

5.2 Emission Factors for Livestock Waste

To refine the emission factors used in the preliminary emission estimates, a literature search was conducted at the University of California at Davis Health Sciences Library. We also contacted the staff of the Animal Science Departments of UC Davis and UC Riverside. From the various reports, studies, reviews, and telephone contacts that were pursued, we found that the following information is generally available for each livestock species:

- Mass of feces produced per animal;
- Water content of feces;
- Total solids content of feces;
- Volatile solids content of feces;
- Nitrogen content of feces;
- Ammonium (NH_4) content of feces; and
- Elemental inorganic constituents of feces.

Volatile solids is a term used in manure management to describe the total organic content of feces. Manure is placed in a muffle furnace and heated for a specific amount of time to remove all organic matter. A gravimetric analysis is then used to determine the weight of inorganic matter in the feces.

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We identified no literature that described organic gas emissions from livestock excrement. A literature search that focused on odors and odor control for livestock waste could possibly identify some data that could be used to better characterize livestock organic gas emissions. In lieu of any new data, we used the same emission factors that were used to calculate the preliminary emission estimates. These are the same emission factors used by the South Coast AQMD (Halberg, 1984).

Sufficient data were identified and used to refine the livestock ammonia emission factors. A summary of the ammonia emission factor development is presented in Table 5-2. As can be seen, we relied extensively on the data presented by Overcash (1983). Other data presented in the literature indicate similar values to those presented by Overcash and support the use of these data. Overcash presents a summary of manure characteristic data for a wide variety of species from over 400 literature references. Therefore, we chose to rely on the Overcash data because sufficient data were presented from which to calculate statistical confidence intervals.

The ammonia emission factors presented in Table 5-3 characterize the emissions that result from the natural decomposition of animal excrement. As a result of this decomposition, it was necessary to make certain assumptions regarding the percentage of total nitrogen that is converted and emitted as ammonia.

Ammonia is emitted to the atmosphere as a natural component of the nitrogen cycle. Complex organic nitrogeneous compounds are decomposed to a number of simpler compounds such as amino acids. Soil bacteria and certain fungi then convert amino nitrogen to ammonia in a process known as ammonification. This ammonia can then react with carbon dioxide and water present in the soil to form ammonium salts such as ammonium carbonate. Finally, nitrification takes place where certain soil bacteria oxidize the ammonia of the ammonium salts to nitrite (NO_2^-) or nitrate (NO_3^-). This is the form in which inorganic nitrogen is utilized by higher plants.

TABLE 5-2. SUMMARY OF LIVESTOCK AMMONIA EMISSION FACTOR DEVELOPMENT

Animal Type	Nitrogen Data Source(s)	Determination of NH_3 Emission Factor
Dairy and Beef Cattle	Overcash, 1983	Data presented by Gasser (1980) Adriano et al. (1974) and Luebs et al., (1973) indicates that approximately 50% of nitrogen excreted from cattle is present in the urine. This nitrogen is reported to be "easily" converted to NH_3 within a short period time. Therefore, it was assumed that 50% of the nitrogen excreted volatilizes as NH_3.
Chickens	Overcash, 1983	Most of the nitrogen in poultry manure is in the form of uric acid, a simple organic compound that is rapidly converted to ammonia (Meek, 1975). Overcash (1983) presents data showing that 9.2% of total nitrogen is excreted as ammonium (NH_3). Therefore, it was assumed that 90% the total nitrogen excreted volatilizes as NH_3.
Turkey and other Poultry	Overcash, 1983	Total nitrogen data presented as percent of waste generation. Therefore, 98% confidence intervals were calculated for percent of nitrogen in waste and waste generation per animal. Confidence intervals were combined to yield total nitrogen excreted per animal at 96% confidence. Based on chicken data, we assumed that 90% of total nitrogen excreted volatilizes as NH_3.

(Continued)

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TABLE 5-2. (Continued)

Animal Type	Nitrogen Data Source(s)	Determination of NH_3 Emission Factor
Pigs	Meek, 1975; Overcash, 1983; and Cass et al., 1982	Overcash (1983) presents data that indicates 50% of the total nitrogen volatilizes as NH_3. Therefore, the NH_3 emission factor assumes that 50% of the total nitrogen excreted volatilizes as NH_3.
Horses	Overcash, 1983	Forty percent of nitrogen excreted from horses is in urine (Overcash, 1983). Based on cattle data, nitrogen contained in the urine is easily converted to NH_3. Therefore, the emission factor for horses assumes that 40% of total nitrogen excreted volatilizes as NH_3.
Sheep	Overcash, 1983	We assumed that 50% of the nitrogen excreted volatilizes as NH_3 based on cattle, horse, and pig data.

TABLE 5-3. EMISSION FACTORS FOR LIVESTOCK ANIMAL WASTES (LB/YR HEAD)

Animal Type	Mean TOG Emission Factor[a]	TOG Emission Factor Confidence Interval[b]	Mean NH_3-N[c] Emission Factor	NH_3-N Emission Factor Confidence Interval[d]
Beef Cattle	160	80 - 240	100	75 - 125
Dairy Cattle	160	80 - 240	130	110 - 150
Pigs	58	29 - 87	43	40 - 46
Horses	84	42 - 126	52	31 - 76
Sheep	12	6 - 18	10	8 - 12
Turkey and other Poultry	2.4	1.2 - 3.6	1.9	1.2 - 2.7
Broiler Chickens	2.4	1.2 - 3.6	0.79	0.72 - 0.90
Laying Chickens	2.4	1.2 - 3.6	1.6	1.4 - 1.8

[a] Source: Halberg, 1984.

[b] 95 percent confidence intervals based on an assumed accuracy of ± 50%.

[c] Source: See Table 7-11.

[d] Statistical confidence intervals calcualted using Equation 8-5.

Ammonia accumulation in the soil depends on rate of generation and loss of ammonia to the atmosphere. The rate of ammonia release is greatest when the manure-soil mixture is first moistened (Meek, 1975). A number of researchers have reported that ammonia emissions tend to increase during the drying of moist manure (data summarized by Luebs et al., 1973). This suggests, therefore, that ammonia emissions will be at a peak during spring and early summer as moistened manure dry out.

With the exception of livestock sheep, sufficient information was identified in the literature to estimate the percentage of total nitrogen that can be converted to ammonia. Typically, this is the nitrogen contained in urine. We then assumed that this ammonia is emitted to the atmosphere. Table 5-2 summarizes the development of the livestock emission factors; the actual factors are presented in Table 5-3. Appendix A presents the detailed calculations.

5.3 Emission Estimates For Livestock Waste

Using the activity data and emission factors described above, we calculated livestock emissions on a statewide basis (see Table 5-4). Without any specific data indicating otherwise, the TOG emissions are expected to occur evenly throughout the year with little temporal variation. Research data have shown that ammonia emissions increase after manure has been wetted and allowed to dry. This suggests that livestock ammonia emissions in California will be greatest in the spring and early summer as moist manures dry out from the winter rains (see Section 5.2). A discussion of the relative accuracy of emission estimates is presented below.

Very little information is available regarding the accuracy of the livestock inventories. For this document, we have assumed these population estimates are accurate to within ± 25 percent (with 95 percent confidence). With respect to applicability, activity data have not been approximated by an indirect measurement technique. That is, specific information regarding livestock populations is directly available. Therefore, these population data are 100 percent applicable to the source category.

TABLE 5-4. EMISSION ESTIMATES FROM LIVESTOCK WASTES (TON/DAY)

Animal Type	Mean TOG Emissions	TOG Confidence Interval[a]	Mean NH_3-N Emissions	NH_3-N Confidence Interval[a]
Dairy Cattle	570	214 - 1,068	460	290 - 668
Beef Cattle[b]	530	197 - 986	330	180 - 510
Pigs	12	4.5 - 22	8.5	6 - 11
Horses	15	5.3 - 26	9.2	4 - 17
Sheep	20	7.4 - 37	17	10 - 25
Laying Chickens	130	49 - 244	86	57 - 120
Broiler Chickens	78	29 - 147	26	18 - 37
Turkey and other Poultry	17	6.4 - 32	14	6.4 - 24
TOTAL	1,372	513 - 2,560	950	570 - 1,410

[a] 90 percent confidence intervals.

[b] Approximately 451,000 cattle were kept on feed lots in 1986. With an estimated 2,400,000 beef cattle, approximately 19 (451,000/2,400,000) percent of these emissions, therefore, result from feed lots.

There is insufficient information available to calculate rigorous statistical confidence intervals for the TOG emission factors. The confidence intervals presented in Table 5-4 assume that the emission factors have an accuracy of ± 50 percent (with 95% confidence).

For the ammonia emission factors, confidence intervals were calculated for the total nitrogen data presented in the literature. These confidence intervals were then used in the emission calculations. The confidence intervals do not account for the assumptions regarding the percentage of total nitrogen that is converted and emitted as ammonia.

As with the activity data, the emission factors were developed for individual species with no data transfer. Therefore, the emission factors were considered 100 percent applicable.

5.4 TOG Speciation Data for Livestock Emissions

Much of the data presented in the literature for animal wastes focuses on the mass of solids produced, ammonia content, and percent volatile solids. As such, there is limited information available regarding the speciation of TOG emissions from livestock waste. Table 5-5 presents a summary of volatile compounds that have been identified in decomposing animal wastes.

The EPA's Volatile Organic Compound Species Data Manual (EPA, 1980) provides a profile for decomposing animal waste (see Table 5-6). We were also able to identify data that illustrate the concentrations of some volatile compounds in liquid chicken manure. These data are presented in Table 5-7. These same data reportedly resemble the TOG species emitted from pig manure (Gasser, 1980).

TABLE 5-5. VOLATILE COMPOUNDS IDENTIFIED IN DECOMPOSING ANIMAL WASTES[a]

Type of Animal Waste	Class	Common Name Formula
Poultry, swine, cattle	Sulfides	hydrogen sulfide
Poultry	Sulfides Mercaptans	methyl sulfide methyl mercaptan ethyl mercaptan n-propyl mercaptan
Cattle	Thioethers	dimethyl sulfide diethyl sulfide
Poultry, swine, cattle	Inorganic	ammonia
Poultry, swine	Aliphatic	methyl amine
Poultry, swine, cattle	Amines	ethyl amine
Cattle		trimethyl amine
Poultry, swine	—	triethyl amine
Poultry	Heterocyclic amines	benzo(b)-pyrols (indole) 3-methyl-indole (skatole)
Poultry, swine	Alcohols	ethanol n-propanol iso-propanol n-butanol iso-butanol iso-pentanol
	Aldehydes	formaldehyde acetaldehyde propanaldehyde iso-butanaldehyde heptaldehyde valeraldehyde decaldehyde
Poultry, swine, cattle	Organic acids	acetic acid propionic acid
Poultry		2-methyl propionic acid

(Continued)

TABLE 5-5. (Continued)

Type of Animal Waste	Class	Common Name Formula
Poultry, swine, cattle		n-butynic acid n-valeric acid iso-valeric acid
Poultry		iso-butynic acid
Cattle	Acetates	propylacetate n-butylacetate

[a] Table is adopted from Ifeadi, 1972.

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TABLE 5-6. TOG SPECIES PROFILE FOR ANIMAL WASTE DECOMPOSITION

Substance	MOIR	Weight Percent
Acetone	~~.005~~	2.0
Ethyl acohol	.36	2.0
Isopropyl alcohol	.22	2.0
Propyl acetate		2.0
Ethyl amine	NL	1.0
Trimethyl amine	NL	1.0
Methane	.005	70
Ethane	.078	20

Source: U.S. EPA, 1980. Data Confidence Level III - Based on data which seem reasonable and should be more or less representative of the population.

MOIR Scale

Maximum ozone integrated reactivity -