THE ORIGIN OF AMMONIA EMISSIONS TO THE ATMOSPHERE IN AN URBAN AREA

by

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Open File Report 82-6

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April 1982

An accurate description of ammonia emissions to the atmosphere of the South Coast Air Basin is needed to support air quality models for NH_4NO_3 formation. Such a study has been completed for the year 1974, and the principal results are summarized here. A grid system composed of 5 km x 5 km cells was superimposed on the South Coast Air Basin map shown in Figure 1. Ammonia emissions were estimated within each grid cell for the 53 classes of mobile and stationary source types listed in Table 1.

Source tests show that trace amounts of ammonia are present in the exhaust of both mobile and stationary combustion sources (Cadle and Mulawa, 1980; Gentel et al., 1973; Harkins and Nicksic, 1967; Henein, 1975; Hovey et al., 1966; Hunter, 1971; Muzio and Arand, 1976; Wohlers and Bell, 1956). Emission factors for ammonia release obtained from these and other references were combined with fuel use data reported by Cass (1978) to give total NH_3 emissions from autos, trucks, railroads, shipping, plus industrial, residential and commercial fuel use. Within each fuel use category, the NH_3 emissions shown in Table 1 were distributed spatially in the same manner as NO_x emissions. A number of industrial processes are known to emit ammonia (National Research Council, 1979; Miner, 1969), including refinery operations, ammonia-based fertilizer manufacturing, ammonia storage facilities, refrigeration plants, chemical plants and steel mill coke ovens. Estimates of NH_3 emissions from industrial facilities were derived from source test informaton and questionaires sent to individual companies.

Biological decay processes also produce ammonia and the release rates from a variety of soil surface types are avalable (Porter et al., 1975; Elliot et al., 1971; Denmead et al., 1978; Denmead et al., 1976; Miner, 1976). Using aerial photographs and maps available from the U.S. Geological Survey (1976) the land use within each grid square was summarized by type. Emissions from exposed land surfaces were estimated within each square by matching emission rate data to soil surface types.

Chemical fertilizers used in the air basin include ammonia, urea, ammonium nitrate and ammonium sulfate. Depending on fertilizer type and method of application, anywhere from a few percent to several tenths of the nitrogen content may be lost to the atmosphere as ammonia (Allison, 1966; Baker et al., 1959; Ernst and Massey, 1960; Gasser, 1964; McDowell and Smith, 1958; Stanley and Smith, 1955; Trickey and Smith, 1955; Wahhab et al., 1957; Walkup and Nevins, 1966). The ammonia loss characteristics of fertilizers were estimated by consultation with a local agricultural expert (Meyer, 1981). Fertilizer use statistics were obtained from the California Department of Food and Agriculture (1974) and from the U.S. Bureau of the Census (1977). Chemical fertilizer consumption, subdivided into cropland, orchard and non-farm use, was combined with the ammonia loss data to compute total NH_3 emissions.

Decomposition of livestock wastes is a major source of NH_3 emissions. Animal inventories by county were obtained from the U.S. Bureau of the Census (1977) and from state and county agricultural

agents. Waste production rates, nitrogen content and ammonia volatilization rates were estimated for each major commercial animal type from previous studies (Adriano, et al., 1971; Adriano et al., 1974; Fogg, 1971; Giddens and Rao, 1975; Lauer et al., 1976; Luebs et al., 1973ab; Stewart, 1970; Taiganides and Hazen, 1966; Viets, 1971). Emissions from range animals were distributed spatially in proportion to pasture and herbaceous range land areas. U.S. Geological Survey (1976) maps were used to locate emissions from animals raised in confinement (e.g. dairy cattle, feedlot cattle). NH_3 losses from domestic animals (cats and dogs only) plus human respiration, perspiration and household cleaning chemicals were distributed in proportion to residential land use.

The overall spatial distribution of NH_3 emissions in the South Coast Air Basin is shown in Figure 2. The largest spike in the NH_3 diagram is centered over the town of Chino on the prevailing upwind side of the city of Riverside, and results from the intensity of livestock operations in that area. Details of the ammonia emission inventory calculations are presented in the Appendix to this report.

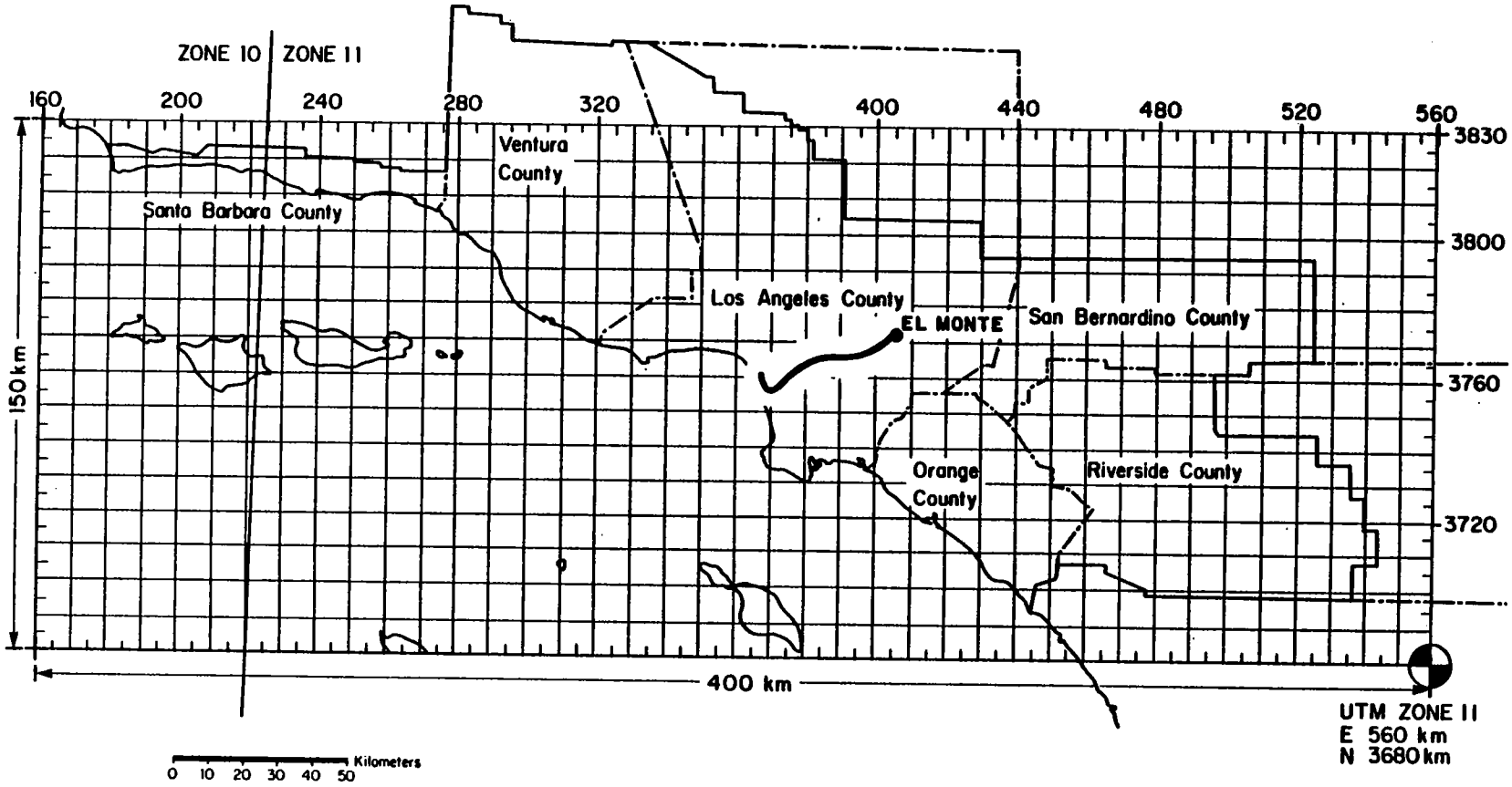

FIGURE 1

The South Coast Air Basin Showing the Grid System Used

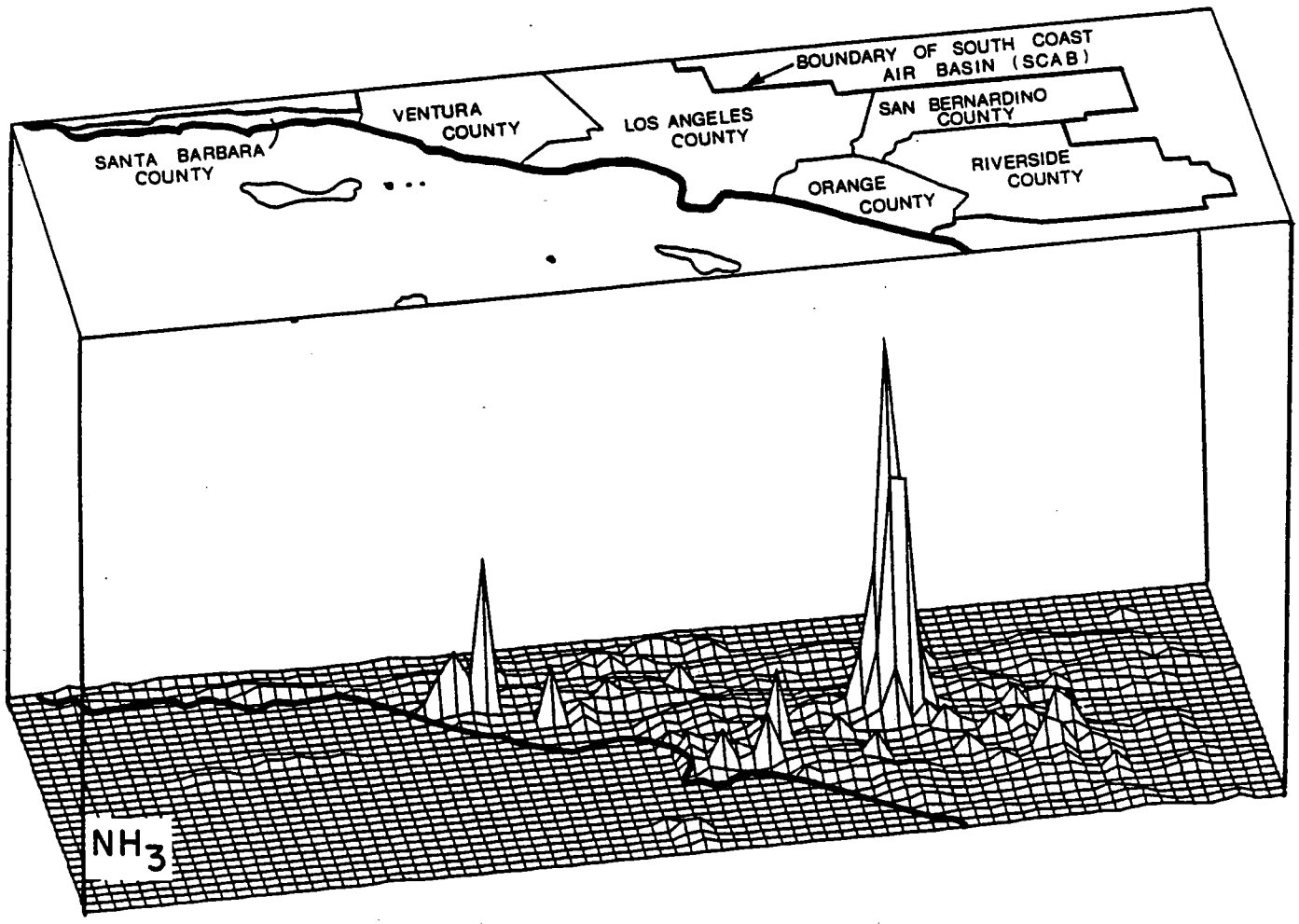

FIGURE 2

The Spatial Distribution of Ammonia Emissions
in the South Coast Air Basin - 1974

TABLE 1

Summary of Ammonia Emissions By Source Category
in the South Coast Air Basin
1974

SOURCE CATEGORY	TOTAL EMISSIONS (kg/day)	
Stationary Fuel Combustion		
Electric Utility		
Natural Gas	590.0	
Residual Oil	2000.0	
Digester Gas	0.5	
Refinery Fuel Burning		
Natural Gas	160.0	
Residual Oil	99.0	
Refinery Gas	420.0	
Industrial Fuel Burning		
Natural Gas	610.0	
Liquified Petroleum Gas (LPG)	4.0	
Residual Oil	150.0	
Distillate Oil	140.0	
Digester Gas	9.0	
Coke Oven Gas	15.0	
Residential/Commercial Fuel Burning		
Natural Gas	270.0	
Liquid Propane Gas (LPG)	4.0	
Residual Oil	62.0	
Distillate Oil	73.0	
Coal	20.0	
*** Sub totals ***	4626.5	(3.09%)
Mobile Source Fuel Combustion		
Automotive		
Non-catalyst Autos and Light Trucks	3309.0	
Medium and Heavy Duty Trucks	449.9	
Diesel Vehicles	370.0	
LPG for Carburetion	10.0	
Civilian Aircraft		
Jet	150.0	
Piston	2.9	
Shipping		
Residual Oil Boilers	70.0	
Diesel Ships	50.0	
Railroad-Diesel Oil	90.0	
Military		
Gasoline	10.0	
Diesel	60.0	
Jet Fuel	50.0	
Residual Oil	0.8	
Off Highway Vehicles	120.0	
*** Sub totals ***	4742.6	(3.17%)
Industrial Point Sources	2070.0	(1.38%)
Soil Surface	23790.0	(15.9%)
Fertilizer		
Farm Crop	2870.0	
Orchards	2390.0	
Handling	380.0	
Non-farm	7420.0	
*** Sub totals ***	13060.0	(8.72%)
Livestock		
Cattle		
Dairy	24390.0	
Feedlot	6880.0	
Range	12160.0	
Horses	16220.0	
Sheep	990.0	
Hogs	250.0	
Chickens	18200.0	
Turkeys	1120.0	
*** Sub totals ***	80210.0	(53.6%)
Domestic		
Dogs	10350.0	
Cats	3230.0	
Human Respiration	46.0	
Human Perspiration	7000.0	
Household Ammonia Use	600.0	
*** Sub totals ***	21226.0	(14.2%)
*** Total ***	149725.1	(100.0%)

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APPENDIX

Tabulation of Emission Factors, Activity Levels, and Ammonia Emission Rates

TABLE A.1

Emission Factors for Ammonia from Combustion Sources

	VALUE REPORTED	REFERENCE	EMISSION FACTOR (Kg $NH_3/10^9$ Btu)	VALUE ADOPTED FOR EMISSION INVENTORY USE (Kg $NH_3/10^9$ Btu)
STATIONARY SOURCES				
Fuel Combustion				
Natural Gas				
Average of Los Angeles Source Tests	0.4 mg/m^3 NH_3 in exhaust	(a)	0.119	
New York Emission Inventory Emission Factor	0.5 lb $NH_3/10^6$ ft^3 gas burned	(b)	0.214	
Literature Survey (1969)	0.3 to 0.56 lb $NH_3/10^6 ft^3$ gas	(c)	0.128-0.240	
Literature Review (1956)	0.010 tons $NH_3/10^6 ft^3$ gas	(d)	8.56	
Recent Source Test: 200,000 Btu/hr combustor				
(1) at 2% excess O_2; 17 test avg	14.44 ppm NH_3 in exhaust	(e)	3.25	3.25
(2) at 4% excess O_2; 23 test avg	6.00 ppm NH_3 in exhaust	(e)	1.351	1.35
(3) at 6% excess O_2; 15 test avg	1.00 ppm NH_3 in exhaust	(e)	0.225	0.22
Residual Fuel Oil				
Average of Los Angeles Source Tests	0.4 mg/m^3 NH_3 in exhaust	(a)	0.125	
New York Emission Inventory Emission Factor	1 lb/1000 gal oil	(f)	3.03	
Literature Survey (1956)	0.001 tons NH_3/ton oil	(g)	23.1	
Recent Source Test: 200,000 Btu/hr combustor at 2% excess air; avg of 2 tests	11.3 ppm in exhaust	(h)	2.8	2.8
Distillate Oil				
New York Emission Inventory Emission Factor	1 lb/1000 gal oil	(i)	3.29	3.3
Coal				
Literature Review (1956)	2 lb NH_3/ton coal	(j)	37.8	38
Mass Balance over N.W. Europe	1.21 g NH_3/920 g coal	(k)	50	
Recent Source Test: 200,000 Btu/hr combustor at 4% excess air, 1 test	85 ppm NH_3 in exhaust	(l)	≈20	
Wood				
Literature Review (1956)	2.4 lb NH_3/ton wood	(m)		

Notes:

(a) Magill and Benoliel (1952)
(b) Hovey, Risman and Cunnan (1966), Range reported 0.3 to 20 lb $NH_3/10^6 ft^3$ natural gas
(c) Miner (1969); literature survey
(d) Wohlers and Bell (1956)
(e) Muzio and Arand (1976)
(f) Hovey, Risman and Cunnan (1966); Range reported 0.06 lb/1000 gal to 8 lb/1000 gal; converted at 0.011 scf prod/btu; 6.11×10^6 btu/bbl
(g) Wholers and Bell (1956); value appears high but note that data may be rounded up to 0.001 tons NH_3/ton oil
(h) Muzio and Arand (1976); 2 tests range 20 ppm - 2.54 ppm
(i) Hovey, Risman and Cunnan (1966); converted at 0.011 scf prod/btu; 5.8×10^6 btu/bbl
(j) Wohlers and Bell (1956)
(k) Soderlund (1977)
(l) Muzio and Arand (1976); combustion product data unavailable, converted from ppm to $Kg/10^9$ btu in proportion to oil and natural gas data
(m) Wohlers and Bell (1956)

TABLE A.2

Emission Factors for Ammonia from Highway Vehicles

	VALUE REPORTED	REFERENCE	EMISSION FACTOR (Kg $NH_3/10^9$ Btu)	VALUE ADOPTED FOR EMISSIONS INVENTORY USE (Kg $NH_3/10^9$ Btu)
HIGHWAY VEHICLES				
Autos and Lt. Trucks (gasoline)				2.11 (m)
Non-Catalyst Equipped Pre-1975				
1. Typical auto (1952 data)	0.7 lb/ton gasoline	(a)	7.27 (l)	
2. Fleet average (1959 data)	2 lb/1000 gal gasoline	(b)	7.27 (l)	
3. 1956 Oldsmobile engine on driving cycle	2.2 ppm NH_3 in exhaust	(c)	0.44 (l)	
4. 1972 Hew driving cycle	0.008 g/mile driven	(d)	0.87 (l)	
5. 1972 Pontiac, unleaded fuel, 30 mph	6 ppm NH_3 in exhaust	(e)	1.2 (l)	
6. 1972 Pontiac, unleaded fuel, 60 mph	13 ppm NH_3 in exhaust	(f)	2.65 (l)	
7. 1972 Pontiac, unleaded fuel, driving cycle	12 ppm NH_3 in exhaust	(g)	2.43 (l)	
8. 1972 Pontiac, leaded fuel, driving cycle	13 ppm NH_3 in exhaust	(h)	2.62 (l)	
9. 1972 Pontiac, leaded fuel, 30 mph	8 ppm NH_3 in exhaust	(i)	1.56 (l)	
10. Aged auto, unleaded fuel, driving cycle	20.7 ppm NH_3 in exhaust	(j)	4.21 (l)	
11. Aged auto, unleaded fuel, 60 mph	17.4 ppm NH_3 in exhaust	(k)	3.52 (l)	
Catalyst Equipped Engines				1.6 (t)
1. California emission controls, 1975 FTP cycle	4.9 mg NH_3/mile	(n)	0.69 (r)	
2. Aged auto, unleaded fuel, driving cycle	10.4 ppm NH_3 in exhaust	(o)	2.07 (r)	
3. 1972 Pontiac, unleaded fuel, beaded base metal catalyst, driving cycle	10 ppm NH_3 in exhaust	(p)	2.01 (r)	
Medium and Heavy Duty Gasoline Trucks				2.11 (u)
Diesel Vehicles				
Peugot, diesel fuel, driving cycle	11.1 ppm NH_3 in exhaust	(q)	3.11 (s)	3.11
LPG for Carburetion				2.11 (u)

NOTES:

(a) Magill and Benoliel (1952)
(b) Chambers (1959)
(c) Harkins and Nicksic (1967)
(d) Hunter (1971)
(e) Gentel et al. (1973); Average of 3 tests
(f) Gentel et al. (1973)
(g) Gentel et al. (1973)
(h) Gebtel et al (1973)
(i) Gentel et al (1973); 1 test (a second test under lean combustion conditions showed 31 ppm NH_3 in exhaust)
(j) Henein (1975)
(k) Henein (1975)
(l) Emissions calculated assuming: Non-catalyst fleet fuel economy = 13.6 miles/gallon, 5248 x 10^3 Btu/bbl of gasoline; air/fuel ratio = 15; gasoline density = 6.19 lb/gal
(m) average of driving cycle tests (lines 3,4,7,8,10 within this category)
(n) Cadle and Mulawa (1980), Table V, average of 5 tests (runs 9 through 13), range 0.6 mg NH_3/mile to 14.8 mg NH_3/mile
(o) Henein (1975), average of 3 tests, range: 25.31 to 2.52 ppm, air;fuel ratio assumed to be 15
(p) Gentel et al. (1973), Table 27 air/fuel ratio assumed to be 15
(q) Henein (1975) air/fuel ratio assumed to be 22
(r) Calculated assuming catalyst fleet fuel economy of 17.8 miles/gallon; 5248 x 10^3 Btu/bbl gasoline, gasoline density 6.19 lb/gal.
(s) Calculated assuming 5812 x 10^3 Btu/bbl of diesel fuel; composition of diesel fuel assumed to be $CH_{1.5}$.
(t) Average of lines 1,2,3 within this category
(u) Assumed similar to non-catalyst gasoline automobiles

TABLE A.3

Ammonia Emission Estimates for Stationary Combustion Sources

	ESTIMATED 1974 FUEL USE (10^9 Btu/day)	EMISSION FACTOR (Kg $NH_3/10^9$ Btu)	NH_3 EMISSIONS (metric tons/day)
STATIONARY SOURCES			
Fuel Combustion			
Electric Utilities			
Natural Gas	398.31 (a)	1.47 (d)	0.59
Residual Oil	715.01 (a)	2.8 (e)	2
Digester Gas	0.37 (a)	1.47 (f)	0.0005
Refinery Fuel			
Natural Gas	134.06 (b)	1.17 (g)	0.16
Residual Oil	35.47 (b)	2.8 (h)	0.099
Refinery Gas	357.53 (b)	1.17 (i)	0.42
Non-Refinery Industrial Fuel			
Natural Gas	421.64 (c)	1.45 (j)	0.61
LPG	2.74 (c)	1.45 (k)	0.004
Residual Oil	53.42 (c)	2.8 (l)	0.15
Distillate Oil	42.74 (c)	~3.3 (m)	0.14
Digester Gas	6.30 (c)	1.45 (k)	0.009
Coke Oven Gas	37.53 (c)	0.40 (n)	0.015
Residential/Commercial			
Natural Gas	1181.92 (c)	0.225 (o)	0.27
LPG	18.08 (c)	0.225 (p)	0.004
Residual Oil	22.19 (c)	~2.8 (q)	0.062
Distillate Oil	22.19 (c)	~3.3 (q)	0.073
Coal	0.55 (c)	38 (q)	0.02
TOTAL			4.63

NOTES:

(a) June 1974 average daily use, from Cass, McMurry and Houseworth (1980), Table A2.3
(b) June 1974 average daily use, from Cass, McMurry and Houseworth (1980), Table A2.5
(c) 1973 annual average daily use, from Cass, McMurry and Houseworth (1980), Table A3.6
(d) Weighted average: 33% emission factor at 2% O_2 in stack, 22% factor at 4% O_2, 45% factor at 6% O_2 based on frequency of occurrence of O_2 levels given by Bartz et al. (1974; tests 279-289; 298-301)
(e) From Table A.1
(f) Assumed similar to utility boiler burning natural gas
(g) Weighted average: 19% emission factor at 2% O_2 in stack, 33% factor at 4% O_2, 48% factor at 6% O_2 based on frequency of occurrence of O_2 levels given by Bartz et al. (1974; tests 12-73; 95-103)
(h) From Table A.1
(i) Assumed similar to refinery equipment burning natural gas
(j) Weighted average: 35% emission factor at 2% O_2 in stack, 15% factor at 4% O_2, 50% factor at 6% O_2 based on frequency of occurrence of O_2 levels for industrial fuel burning equipment given by Bartz et al. (1974).
(k) Assumed similar to industrial equipment burning natural gas
(l) From Table A.1
(m) From Table A.1
(n) Weighted average: 2% emission factor at 2% O_2 in stack, 10% factor at 4% O_2, 88% factor at 6% O_2 based on frequency of occurrence of O_2 levels for steel mill equipment given by Bartz et al. (1974; tests 104-157)
(o) Source tests by Bartz et al. (1974) show that home heaters have high levels of excess O_2 in their exhaust
(p) Assumed similar to home heaters burning natural gas
(q) From Table A.1

TABLE A.4

Ammonia Emission Estimates for Mobile Combustion Sources

	ESTIMATED 1974 FUEL USE [a] (10^9 Btu/day)	EMISSION FACTOR (Kg $NH_3/10^9$ Btu)	NH_3 EMISSIONS (metric tons/day)
MOBILE SOURCES			
Highway Vehicles			
Non-catalyst Autos & Lt. Trucks	1566.58	2.11	3.31
Medium & Heavy Gasoline Vehicles	213.64	2.11	0.45
Diesel Vehicles	117.53	3.11	0.37
LPG for Carburetion	5.20	2.11	0.01
Civil Aviation			
Jet Aircraft	47.40	3.11	0.15
Aviation Gasoline	1.37	2.11	0.0029
Commercial Shipping			
Residual Oil-Fired Ship's Boilers	24.66	2.8	0.07
Diesel Ships	17.26	3.11	0.05
Railroad			
Diesel Oil	29.32	3.11	0.09
Military			
Gasoline	6.03	2.11	0.01
Diesel Oil	17.81	3.11	0.06
Jet Fuel	16.71	3.11	0.05
Residual Oil (Bunker Fuel)	0.27	2.8	0.0008
Miscellaneous			
Off-Highway Vehicles	39.73	3.11	0.12
TOTAL			4.74

Note:
(a) 1973 annual average fuel use from Cass, McMurry and Houseworth (1980).

TABLE A.5

Emissions from Industrial Process Sources

	NH_3 EMISSIONS (metric tons/day)
Ammonia Storage	0.06
Refinery FCC Units	0.67
Refinery Waste Water Treatment	0.35
Steel Industry	0.23
Chemical Plants	0.76

TABLE A.6

Emission Factors for Ammonia Release from Soil Surface

LAND SURFACE TYPE	VALUE REPORTED	REFERENCE	EMISSION FACTOR ADOPTED ($kg\ NH_3/km^2$-day)
Cropland	11 kg N/ha-yr	(a)	3.65
Lawn Surface (campus sidewalk)	0.5 to 1.5 mg NH_3/m^2-day	(b)	1
Bare Soil	1 to 2 mg NH_3/m^2-day	(c)	1 (f)
Ungrazed Grass-Clover Pasture	2 g N/ha-hr	(d)	5.81
Forest Land (estimate)		(e)	(1)
Pasture (near animals - no manure)			
Pasture Grass (>30 m from manure source)	1 to 2 mg NH_3/m^2-day	(b)	1.5
Grassland Near Swine Barn with no manure	2 to 3 mg NH_3/m^2-day	(b)	2.5
Pasture (with manure)			
Pasture with dried manure	2 to 5 mg NH_3/m^2-day	(b)	(g)
Pasture with recent liquid dairy manure	5 to 20 mg NH_3/m^2-day	(b)	(g)
Grazed Pasture	15 kg N/ha-yr	(a)	(g)
	13 g N/ha-hr	(d)	(g)

NOTES

(a) Porter et al. (1975) and Elliot et al. (1971). Note that Denmead et al. (1978) give much higher values over short periods of time.
(b) Miner (1976)
(c) Miner (1976; bare soil located more than 30 m from university dairy farm
(d) Denmead et al. (1976)
(e) Release from decomposition of organic matter in forests estimated as being low
(f) Taken at low end of range given in order not to exceed estimate for lawns
(g) Not used; emissions of NH_3 due to presence of animal wastes will be estimated separately

TABLE A.7

Ammonia Estimates for Release from Soil Surfaces

	LAND AREA DEVOTED TO THIS USE (km^2) (a)	FRACTION OF LAND NOT MASKED BY BUILDINGS AND PAVEMENT	EMISSION FACTOR (Kg NH_3/Km^2-day)	NH_3 EMISSIONS METRIC TONS PER DAY
SOIL SURFACE RELEASE (Excluding Chemical Fertilizers & Manures)				
Urban or Built-up Land				
11 Residential (single and multiple)	2884.41	44% (b)	1 (e)	1.27
12 Commercial and Services	826.21	34% (b)	1 (e)	0.28
13 Industrial	429.16	47% (b)	1 (e)	0.2
14 Transportation, Communication & Utilities	218.91	55% (b)	1 (e)	0.12
15 Industrial and Commercial Complexes	20.83	40% (c)	1 (e)	0.01
16 Mixed Urban or Built-Up Land	43.95	43% (d)	1 (e)	0.02
17 Other Urban or Built-Up Land	348.23	43% (d)	1 (e)	0.15
Agricultural Land				
21 Cropland and Pasture	1770.72		3.4 (f)	6.02
22 Orchards, Groves, Vineyards, Nurseries, and Ornamental	857.65		(3.6)(g)	3.09
23 Confined Animal Feeding Operations	47.26		estimated separately (h)	
24 Other Agricultural Land	25.32		(3.4)(i)	0.09
Rangeland				
31 Herbaceous Rangeland	686.48		(1) (j)	0.69
32 Shrub and Brush Rangeland	8053.08		(1) (j)	8.05
33 Mixed Rangeland	1165.01		(1) (j)	1.17
Forest Land				
41 Deciduous Forest Land	12.53		(1) (k)	$\leq$0.01
42 Evergreen Forest Land	2291.58		(1) (k)	$\leq$2.29
43 Mixed Forest Land	40.08		(1) (k)	$\leq$0.04
Wetland				
61 Forested Wetland	33.10			neglected
62 Non-Forested Wetland	53.89			neglected
Barren Land				
72 Beaches	16.21		$\leq$ (1) (l)	$\leq$0.02
73 Sandy Areas (other than beaches)	107.35		$\leq$ (1) (l)	$\leq$0.11
76 Transitional Areas	149.76		1 (m)	0.15
77 Mixed Barren Land	10.62		1 (m)	0.01
				$\leq$23.79

NOTES

(a) Obtained by counting areas in each category as shown on land use maps prepared by U.S. Geological Survey (1976a-e)
(b) Obtained by examination of aerial photographs (Fretz, 1980). Twenty-four zone photos distributed widely over Los Angeles County were overlayed with land use categories and examined to estimate the fraction of land in each category which had been paved or build-upon. Values shown are averages of the 24 photographs examined.
(c) Estimated by average of commercial and industrial categories shown above.
(d) Estimated by weighted average of land use categories 11 through 14
(e) Emission factor for lawn and bare soil from Table A.6
(f) Average of cropland, ungrazed clover, and two types of grass land without animals present on land
(g) Assumed same as cropland from Table A.6
(h) Emissions from livestock operations estimated separately based on animal head count and wastes produced
(i) Assumed similar to crop and pasture combination
(j) Assumed similar to bare soil/grass combination
(k) Estimate
(l) Less than or equal to bare soil data from Table A.6
(m) Bare soil data from Table A.6

TABLE A.8

Dry and Liquid Fertilizers for Farm Plus Non-Farm Use
(California Department of Agriculture, 1974)

COUNTY	FERTILIZER TOTAL NITROGEN (metric tons/yr)	PARTITION DRY[(a)]	LIQUID[(a)]
Los Angeles	7124	0.781	0.219
Orange	4619	0.751	0.249
Riverside	17614	0.445	0.555
San Bernardino	1984	0.919	0.081
Santa Barbara	7495	0.56	0.44
Ventura	7885	0.629	0.371

(a) Fraction of total N applied in liquid and dry form estimated by summing N content of those liquid and dry fertilizers for which nitrogen content data were given.

TABLE A.9

Percentage of N Applied, Apportioned Between Farm and Non-Farm Use
(California Department of Agriculture, 1974)

	FARM		NON-FARM	
COUNTY	DRY[a]	LIQUID	DRY	LIQUID
Los Angeles	36	10	42	12
Orange	48	16	27	9
Riverside	42	52	3	3
San Bernardino	69	6	23	2
Santa Barbara	52	40	4	4
Ventura	60	36	3	1

(a) Example: Fraction (farm N/total N) x fraction dry from Table A.8

TABLE A.10

Fertilizer Nitrogen Applied
(Tons N/Yr)

COUNTY	DRY		LIQUID	
	FARM	NON-FARM	FARM	NON-FARM
Los Angeles	2565	2992	712	855
Orange	2217	1247	739	416
Riverside	7398	528	9159	528
San Bernardino	1369	456	119	40
Santa Barbara	3897	300	2998	300
Ventura	4731	237	2839	79

Estimated by combining data of Tables A.8 and A.9

TABLE A.11

Partition of Farm Fertilizer Use Between Crops and Orchards[a]
(From U.S. Department of Commerce, 1977)

COUNTY	DRY (METRIC TONS/YR) CROP	DRY (METRIC TONS/YR) ORCHARD	LIQUID (METRIC TONS/YR) CROP	LIQUID (METRIC TONS/YR) ORCHARD	% OF FARM FERTILIZER APPLIED ON CROPS % DRY	% OF FARM FERTILIZER APPLIED ON CROPS % LIQUID
Los Angeles	3503	2039	1353	357	63	80
Orange	3603	2672	1067	2032	57	34
Riverside	17041	9842	13210	2428	63	84
San Bernardino	1545	3473	156	218	31	42
Santa Barbara	12099	3214	6927	400	79	95
Ventura	13521	8870	2405	3815	60	39

(a) The Census of Agriculture (U.S. Department of Commerce, 1977) shows lower total fertilizer applied than does the California Department of Food and Agriculture (1974).

TABLE A.12

Nitrogen Applied on Crops, Orchards, and Non-Farm Areas
(County Totals in Metric Tons/Year)

COUNTY	DRY			LIQUID		
	CROP[a]	ORCHARDS AND ORNAMENTALS	NON-FARM	CROP[a]	ORCHARDS AND ORNAMENTALS	NON-FARM
Los Angeles	1616	949	2992	570	142	855
Orange	1264	953	1247	251	488	416
Riverside	4661	2737	528	7694	1465	528
San Bernardino	424	945	456	50	69	40
Santa Barbara	3079	818	300	2848	150	300
Ventura	2839	1892	237	1107	1732	79

(a) Farm use split between crops vs. orchards and ornamentals using crop percentages of Table A.11 applied to total farm use given in Table A.10.

TABLE A.13

Percentage of Land Use in Each County Located Within the Gridded Inventory Map Area and Within the South Coast Air Basin

COUNTY	CROPLAND	ORCHARDS	NON-FARM FERTILIZED LAND[a]
Los Angeles	34	84	99
Orange	100	100	100
Riverside	53	43	74
San Bernardino	69	100	85
Santa Barbara	7	100	78
Ventura	95	100	100

(a) Estimated from percentage of county population living within the air basin in 1975.

TABLE A.14

Fertilizer Nitrogen Applied Inside the South Coast Air Basin
(Metric Tons/Year)[a]

COUNTY	DRY CROP	DRY ORCHARDS AND ORNAMENTALS	DRY NON FARM	LIQUID CROP	LIQUID ORCHARDS AND ORNAMENTALS	LIQUID NON FARM
Los Angeles	549	797	2962	194	120	846
Orange	1264	953	1247	251	488	416
Riverside	2470	1177	391	4078	630	391
San Bernardino	293	945	388	35	69	34
Santa Barbara	216	818	234	199	150	234
Ventura	2697	1892	237	1052	1732	79
TOTAL	7489	6582	5459	5809	3189	2000

(a) Data of Tables A.12 and A.13 combined

TABLE A.15

Ammonia Loss Due to Fertilizer Application by County - 1974
(handling loss given separately)

COUNTY	DRY						LIQUID						TOTAL NH_3 LOSS KG/DAY
	CROPLAND		ORCHARDS AND ORNAMENTALS		NON-FARM		CROPLAND		ORCHARDS AND ORNAMENTALS		NON-FARM		
	FERTILIZER N APPLIED MT/YR	NH_3 LOSS KG/DAY(a)	FERTILIZER N APPLIED MT/YR	NH_3 LOSS KG/DAY(a)	FERTILIZER N APPLIED MT/YR	NH_3 LOSS KG/DAY(b)	FERTILIZER N APPLIED MT/YR	NH_3 LOSS KG/DAY(c)	FERTILIZER N APPLIED MT/YR	NH_3 LOSS KG/DAY(c)	FERTILIZER N APPLIED MT/YR	NH_3 LOSS KG/DAY(b)	
Los Angeles	549	182	797	264	2962	2946	194	13	120	8	846	841	4254
Orange	1264	419	953	316	1247	1240	251	17	488	32	416	414	2438
Riverside	2470	819	1177	390	391	389	4078	270	630	42	391	389	2299
San Bernardino	293	97	945	313	388	386	35	2	69	5	34	34	837
Santa Barbara	216	72	818	271	234	233	199	13	150	10	234	233	832
Ventura	2697	894	1892	627	237	236	1052	70	1732	115	79	79	2021
TOTAL	7489	2483	6582	2181	5459	5430	5809	385	3189	212	2000	1990	12681

Total NH_3 Loss = 12681 kg/day
= 12.68 metric tons/day

(a) Assuming 10% of N applied is lost to atmosphere as NH_3 (Meyer, 1981)

(b) Assuming 30% of N applied is lost to atmosphere as NH_3 (Meyer, 1981)

(c) Assuming 2% of N applied is lost to atmosphere as NH_3 (Meyer, 1981)

TABLE A.16

Loss of Anhydrous Ammonia Due to Handling and Field Application

COUNTY	ANHYDROUS AMMONIA (metric tons N/yr) (County Total) [a]	% OF LIQUID FERTILIZER APPLIED ON CROPS	% OF CROPLAND IN BASIN	% OF ORCHARDS IN BASIN	ANHYDROUS AMMONIA IN BASIN [b] (metric tons N/yr)	1% LOSS DUE TO HANDLING [c] (tons N/yr)	3% LOSS DURING APPLICATION ON FIELD [c] (tons N/yr)
Los Angeles	918	80	34	84	404	4	12
Orange	2.73	34	100	100	2.73	0.03	0.08
Riverside	4151	84	53	43	2134	21	64
San Bernardino	102	42	69	100	89	0.9	3
Santa Barbara	524	95	7	100	61	0.6	2
Ventura	208	39	95	100	204	2	6
TOTAL	5906				2895	29	87

Total Loss = 116 tons N/yr

= 0.38 metric tons NH_3/day

(a) From liquid fertilizer sales classed as 82-00-00 by the California Department of Agriculture (1974)

(b) County total multiplied by [% of liquid fertilizer applied to crops (Table A.11) x % cropland in basin (Table A.13) + % of liquid fertilizer applied to orchards x % orchard land in basin]

(c) Walkup and Nevins (1966)

TABLE A.17

Summary of NH_3 Emissions from Fertilizer Application and Handling

COUNTY	LOSS FROM FARM APPLICATION OF FERTILIZER (metric tons/day) CROPS	ORCHARDS	LOSS FROM NON-FARM APPLICATION (metric tons/day)	LOSS DUE TO HANDLING (metric tons/day)
Los Angeles	0.195	0.272	3.79	0.05
Orange	0.436	0.348	1.65	4×10^{-5}
Riverside	1.09	0.432	0.778	0.28
San Bernardino	0.099	0.318	0.48	0.013
Santa Barbara	0.085	0.281	0.466	0.009
Ventura	0.964	0.742	0.315	0.027

TABLE A.18

Summary of Animal Waste Data

ANIMAL	SOURCE	ANIMAL WEIGHT (kg)	MANURE (TOTAL WASTE) kg/head-day	TOTAL NITROGEN EXCRETED kg/head-day
Dairy Cattle	Dale (1971)	680	49	
	Fogg (1971)	600	45	
	Luebs et al. (1973b)			0.17
	Adriano et al. (1974)			0.18
				0.19
Value Used		640	47	0.18
Beef Cattle	Fogg (1971)	400	34	0.24
	Peters & Blackwood (1977)	500	27	
	Taiganides & Hazen (1966)	450	29	0.17
	Scholz (1971)	500	45	
Value Used		450	32	0.21
Horses	Fogg (1971)	450	25	0.22
Hogs	Fogg (1971)	70	3.9	0.03
	Muehling (1971)	70	5.5	0.038
	Scholz (1971)	70	3.6	
	Taiganides & Hazen (1966)	45	3.2	0.023
Value Used		70	3.9	0.03
Sheep	Fogg (1971)	45	1.8	0.018
Chickens	Fogg (1971)	2	0.11	0.0014
	Scholz (1971)		0.185	
	Taiganides & Hazen (1966)	2	0.11	0.0019
Value Used		2	0.14	0.0016
Turkey	taken in proportion to chickens on body weight basis	5.5	0.39	0.0044

TABLE A.19a

1974 Livestock Inventory - Cattle

COUNTY	COUNTY TOTALS[a]			LOCATED IN SOUTH COAST AIR BASIN[b]		
	DAIRY	FEEDLOT	RANGE	DAIRY	FEEDLOT	RANGE
Los Angeles	20,160	18,488	15,007	18,144	11,093	15,007
Orange	3,592	49	11,287	3,592	49	11,287
Riverside	86,592	90,418	35,553	86,592	18,084	35,553
San Bernandino	148,882	15,123	22,936	144,415	15,123	22,936
Santa Barbara	10,187	54,564	52,105	---	---	8,337
Ventura	10,734	19,393	2,593	10,734	19,393	2,593
				263,477	63,742	95,713

(a) U.S. Bureau of the Census (1977)

(b) See Table A.20

TABLE A.19b

1974 Livestock Inventory - Continued

COUNTY	HORSES		SHEEP		HOGS	
	COUNTY TOTAL[c]	IN SOUTH COAST AIR BASIN[b]	COUNTY TOTAL[a]	IN SOUTH COAST AIR BASIN[b]	COUNTY TOTAL[a]	IN SOUTH COAST AIR BASIN[b]
Los Angeles	54,700	53,606	29,902	2,990	3,864	386
Orange	10,500	10,500	2,407	2,407	142	142
Riverside	30,300	29,694	43,289	21,645	5,780	5,202
San Bernandino	19,900	19,502	25,757	25,757	7,165	6,449
Santa Barbara	8,300	1,328	16,674	2,668	1,737	278
Ventura	7,200	7,200	35,465	35,465	892	892
		121,830		90,932		13,349

(a) U.S. Bureau of the Census (1977)

(b) See Table A.20

(c) Anderson (1979)

TABLE A.19c

1974 Livestock Inventory - Continued

COUNTY	CHICKENS		TURKEYS	
	COUNTY TOTAL[a]	IN SOUTH COAST AIR BASIN[b]	COUNTY TOTAL[a]	IN SOUTH COAST AIR BASIN[b]
Los Angeles	739,473	739,473	140,700	140,700
Orange	925,477	925,477	10	10
Riverside	7,378,963	7,378,963	100,869	100,869
San Bernardino	5,504,799	5,504,799	160,062	160,062
Santa Barbara	797,009	127,521	---	---
Ventura	4,130,477	4,130,477	18,705	18,705
		18,806,710		420,346

(a) U.S. Bureau of the Census (1977)

(b) See Table A.20

TABLE A.20

Fraction of Animals Located Inside South Coast Air Basin Portion of Each County

ANIMAL TYPE	PERCENTAGES					
	LOS ANGELES	ORANGE	RIVERSIDE	SAN BERNARDINO	SANTA BARBARA	VENTURA
Dairy Cattle	90[b]	100[a]	100[a]	97[b]	0[d]	100
Feedlot Cattle	(60)[c]	100	20	100	0[d]	100
Range Cattle	100	100	100	100	16[e]	100
Horses	98	100	98	98	16[e]	100
Sheep	10	100	(50)	100	16[e]	100
Hogs	10	100	90	90	16[e]	100
Chickens	100	100	100	100	16[e]	100
Turkeys	100	100	100	100	---	100

Estimates are by Addis (1981) unless noted otherwise:

(a) Bishop (1981)

(b) 2000 dairy cows in desert area of Los Angeles County and 3835 dairy cows located in desert portion of San Bernardino County (Bishop, 1981).

(c) Most Los Angeles County feedlot cattle are located within the South Coast Air Basin; Addis (1981) estimates more than 10,000 within the air basin (i.e. 54% or greater are in the air basin). We will estimate that 60% of the total are in the air basin.

(d) U.S. Geological Survey (1976) maps show negligible land area devoted to confined animal feeding in the South Coast Air Basin portion of Santa Barbara County.

(e) Estimated in rough proportion to the fraction of the county land area within the air basin boundary.

TABLE A.21

Total NH_3 Emissions From Livestock in the Modeling Region of the South Coast Air Basin - 1974

ANIMAL	INVENTORY IN SOUTH COAST AIR BASIN (HEAD)	TOTAL ANIMAL WASTE kg/head-day	NITROGEN EXCRETED kg/head-day	NH_3 EMISSIONS AT 50% RATE OF NITROGEN EXCRETED IN TOTAL WASTE[a] metric tons/day
Dairy Cattle	263,477	47	0.18	24.39[b]
Feedlot Cattle	63,742	32	0.21	6.88[b]
Range Cattle	95,713		0.21	12.16
Horses	121,830	25	0.22	16.22
Sheep	90,932	1.8	0.018	0.99
Hogs	13,349	3.9	0.03	0.25
Chickens	18,806,710	0.14	0.0016	18.2
Turkeys	420,346	0.39	0.0044	1.12
				80.21

(a) Adriano et al. (1971); Adriano et al. (1974); Giddens and Rao (1975); Leubs et al. (1973b); Viets (1971).

(b) Since only 85% of manure from these animals is spread on soil, totals have been multiplied by 0.85 (see Adriano et al., 1974).

TABLE A.22

Emission Factors for Ammonia Loss Due to Non-Farm Animals

NON-FARM ANIMALS	ANIMAL WEIGHT (kg)[a]	TOTAL N EXCRETED IN URINE[a] (mg/kg body wt-day)	NITROGEN EXCRETED IN URINE DAILY[b] (kg/head-day)	EMISSION FACTOR[c] (kg NH_3/head-day)
Cats	2.5	500 - 1100	$2x10^{-3}$	$2.2x10^{-3}$
Dogs	12	250 - 800	$6.3x10^{-3}$	$6.9x10^{-3}$
Goats	50	120 - 400	$1.3x10^{-2}$	$1.4x10^{-2}$
Monkey	12	140 - 400	$3.2x10^{-3}$	$3.5x10^{-3}$
Rabbits	2	120 - 300	$4.2x10^{-4}$	$4.6x10^{-4}$
Rats	0.33	200 - 1000	$2.0x10^{-4}$	$2.2x10^{-4}$

(a) From Altman and Dittmer (1968) p. 528.

(b) Based on body weight and mid-point of range of nitrogen excretion rates given in adjacent columns.

(c) Cattle data show that about half of the nitrogen excreted in manure is in urine and half is in feces, and that when manure is applied to dry alkaline soil half of the total nitrogen is lost to the atmosphere as NH_3 (i.e. total N lost as NH_3 is approximately equal to nitrogen content of urine). We will estimate that loss rate is similar for other animals and that in the absence of data on total animal waste a value equal to 90% of urine N will reasonably estimate loss of N from total animal wastes.

TABLE A.23

NH_3 Emissions from Human and Domestic Animal Populations

COUNTY	COUNTY POPULATION (1975)(a)	RATIO: PEOPLE TO DOGS	RATIO: PEOPLE TO CATS	SOUTH COAST AIR BASIN POPULATION(a)	SOUTH COAST AIR BASIN ANIMAL WASTE (tons NH_3/day)(i) DOGS	CATS	EMISSIONS HUMANS (tons NH_3/day) RESPIR.(j)	PERSPIR.(k)
Los Angeles	7,020,772	7.8(b)	7.0(g)	6,936,982	6.1	2.18	0.03	4.7
Orange	1,722,094	5.8(c)	(7.0)(h)	1,722,094	2.0	0.54	0.008	1.2
Riverside	531,679	(4.5)(d)	(7.0)(h)	393,972	0.6	0.12	0.002	0.27
San Bernardino	696,061	4.5(e)	(7.0)(h)	592,522	0.9	0.19	0.003	0.40
Santa Barbara	264,324	(5.8)(f)	(7.0)(h)	$\leq$ 206,291	0.25	0.06	0.001	0.14
Ventura	432,407	(5.8)(f)	(7.0)(h)	432,199	0.5	0.14	0.002	0.29
					10.35	3.23	0.046	7.00

(a) County population figures from Southern California Association of Governments (1977) except for Santa Barbara County, which is 1970 data from U.S. Bureau of the Census (1972) South Coast Air Basin population of Santa Barbara County estimated from county total less the cities of Lompoc and Santa Maria

(b) Richards, B. (1981)

(c) Hudson, R. (1981)

(d) Estimated from San Bernardino data

(e) San Bernardino (1981)

(f) Estimated from Orange County data

(g) Richards, B. (1981)

(h) Estimated from Los Angeles County response

(i) Computed using emission factors from Table A.22: (dogs, 6.9×10^{-3}kg NH_3/head day; cats 2.2×10^{-3} kg/head-day

(j) Respiration loss estimated at 4µl NH_3 per min per person (Kupprat et al., 1976) This implies 4.4×10^{-6} kg NH_3 respired/person-day

(k) 24.5 g urea produced in human body/day (Altman and Dittmer, 1968); 5% released in perspiration (Healy et al., 1970; all of that assumed lost as NH_3. This implies 0.68 g NH_3/person-day.

TABLE A.24

Ammonia Emission Estimates for Refrigerants and Household Cleaning Chemicals

COUNTY	SOUTH COAST AIR BASIN POPULATION[a]	NH_3 EMISSIONS[d] metric tons/day	
		CLEANING AGENTS(b)	REFRIGERATION(c)
Los Angeles	6,936,982	0.4	0.27
Orange	1,722,094	0.1	0.07
Riverside	393,972	0.02	0.02
San Bernardino	592,522	0.03	0.02
Santa Barbara	$\leq$ 206,291	0.01	0.01
Ventura	432,199	0.03	0.02

(a) See Table A.23

(b) U.S. Ammonia Production for 1974: 16.5×10^6 short tons/yr from Chem. & Eng. News (April, 1975); 0.03% of total synthetic ammonia is used in the manufacture of household ammonia from Kirk-Othmer Encyclopedia (1963)

(c) 0.02% of total synthetic ammonia is used for refrigeration (Kirk-Othmer Encyclopedia, 1963)

(d) Emissions were calculated based on ratio of air basin population to U.S. population in 1974. 100% NH_3 loss to the atmosphere was assumed. The population of the United States in 1974 was 211.389×10^6 persons from U.S. Bureau of the Census (1980).

TABLE A.25

Summary of Ammonia Emissions By Source Category in the South Coast Air Basin
1974

SOURCE CATEGORY	TOTAL EMISSIONS (kg/day)	
Stationary Fuel Combustion		
Electric Utility		
Natural Gas	590.0	
Residual Oil	2000.0	
Digester Gas	0.5	
Refinery Fuel Burning		
Natural Gas	160.0	
Residual Oil	99.0	
Refinery Gas	420.0	
Industrial Fuel Burning		
Natural Gas	610.0	
Liquified Petroleum Gas (LPG)	4.0	
Residual Oil	150.0	
Distillate Oil	140.0	
Digester Gas	9.0	
Coke Oven Gas	15.0	
Residential/Commercial Fuel Burning		
Natural Gas	270.0	
Liquid Propane Gas (LPG)	4.0	
Residual Oil	62.0	
Distillate Oil	73.0	
Coal	20.0	
*** Sub totals ***	4626.5	(3.09%)
Mobile Source Fuel Combustion		
Automotive		
Non-catalyst Autos and Light Trucks	3309.0	
Medium and Heavy Duty Trucks	449.9	
Diesel Vehicles	370.0	
LPG for Carburetion	10.0	
Civilian Aircraft		
Jet	150.0	
Piston	2.9	
Shipping		
Residual Oil Boilers	70.0	
Diesel Ships	50.0	
Railroad-Diesel Oil	90.0	
Military		
Gasoline	10.0	
Diesel	60.0	
Jet Fuel	50.0	
Residual Oil	0.8	
Off Highway Vehicles	120.0	
*** Sub totals ***	4742.6	(3.17%)
Industrial Point Sources	2070.0	(1.38%)
Soil Surface	23790.0	(15.9%)
Fertilizer		
Farm Crop	2870.0	
Orchards	2390.0	
Handling	380.0	
Non-farm	7420.0	
*** Sub totals ***	13060.0	(8.72%)
Livestock		
Cattle		
Dairy	24390.0	
Feedlot	6880.0	
Range	12160.0	
Horses	16220.0	
Sheep	990.0	
Hogs	250.0	
Chickens	18200.0	
Turkeys	1120.0	
*** Sub totals ***	80210.0	(53.6%)
Domestic		
Dogs	10350.0	
Cats	3230.0	
Human Respiration	46.0	
Human Perspiration	7000.0	
Household Ammonia Use	600.0	
*** Sub totals ***	21226.0	(14.2%)
*** Total ***	149725.1	(100.0%)