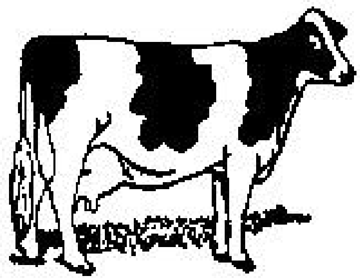

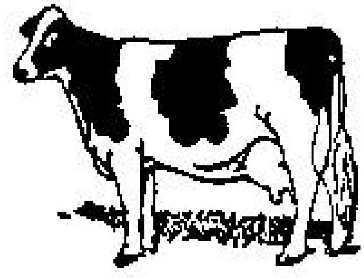

University of California Cooperative Extension
Dairy Manure Management Series

Dairying and Air Emissions

Tom Shultz and Carol Collar[1]

INTRODUCTION

Dairy animal wastes can impact air quality through the generation of various gases, visible and invisible dust particles, and airborne insects. Odors, dust and insects are inevitable on the dairy, but recommended management practices can minimize their occurrence. This publication deals primarily with emissions of gases and dust and their management control procedures. Associated insect problems will be covered in a separate publication in this series.

FEED, ANIMAL, ANIMAL WASTE

Odors associated with dairies principally come from manure and ensiled feeds. The more detectable odors include ammonia, hydrogen sulfide and other sulfurous compounds, amines, organic acids, and heterocyclic nitrogenous compounds. Table 1 lists the properties and effects of gases that may reach odor threshold level on the dairy. With the exception of manure storage pits or covered silos, the maximum allowable concentrations are not normally found on or near the farm. Because silage odor is not generally considered offensive when a normal fermentation process (mildly acidic) occurs, discussion here will focus on manure-related gases.

Moisture

Fresh and dried manures have distinct odors. Nuisance odors result from anaerobic bacterial activity which occurs during the fermentation of damp manure. A direct relationship exists between odor offensiveness and moisture conditions; nuisance complaints increase as manure moisture exceeds 35 percent (1).

Milking parlor wastewater and solids separated mechanically from liquid manure have little odor. The surface (aerobic) layer of feedlot manure physically covers the odor-causing layer. The odors caused by fermentation of the underlying (anaerobic) layer are quite noticeable. Increasing the aeration by frequent scraping speeds drying and eventually reduces odors. In addition, the surface layer of dory waste ponds and lagoons generally traps odors from the lower anaerobic layer. Surface floatage, such as weeds growing

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Table 1. Properties and effects of noxious gases on adult humans.

Gas	Odor	Explosive range %by volume min	Explosive range %by volume max	Odor Thres-hold ppm	Maximum Allowable Concentra tions, ppm	Level ppm	Exposed period minutes	Physiological Effects
		(a)	(b)	(c)	(d)	(e)	--	
								Asphyxiant
Carbon dioxide	None	--	--	--	5,000	20,000	--	Safe
					30,000	--		Increased (CO2) breathing
						40,000	--	Drowsiness, headaches
						60,000	30	Heavy breathing
						300,000	30	Could be fatal
								Irritant
Ammonia (NH_3)	Sharp, pungent	16	--	5	50	400	--	Throat irritant
						700	--	Eye irritant
						1,700	--	Coughing and frothing
						3,000	30	Asphyxiating
						5,000	40	Could be fetal poison
								Poison
Hydrogen Sulfide (H_2S)	Rotten egg smell, nauseati ng	4	46	0.7	10	100	Several hours	Eye and nose Irritant
						200	60	Headaches, dizziness
						500	30	Nausea, excitement, insomnia
						1000	-	Uncondciousness, death
								Asphyxiant
Methane (CH_4)	None	5	15	--	1,000	500,000	--	Headache, notoxic
								Poison
Carbon Monoxide (CO)	None	--	--	--	50	500	60	No effect
						1,000	60	Unpleasant, not dangerous
						2,000	60	Dangerous
						4,000	60+	Fatal

a A mixture of gas and air in this range can explode with a spark.
b About the lowest concentration at which odor is detected.
c Maximum allowable concentration allowed by health agencies for workers in 8 to 10 hr periods.
d Parts of pure gas per million parts of atmospheric air. Divide by 10,000 for % by volume: 20,000 ppm / 10,000 = 2% by volume.
e The time for the effects of the gas to be felt.
Source: Livestock Waste Facilities Handbook, 2nd Ed., 1985. Iowa State U.

on undigested manure solids, may increase the escape of odors.

Handling

It is difficult to eliminate all odors associated with holding ponds or lagoons. Efforts can be focused to minimize odor production during daylight hours. Agitation or dredging of ponds and lagoons to coincide with strong breezes helps to rapidly dissipate odors; agitating at night or during early morning hours when downwind neighbors are asleep is recommended. Field application of waste slurries or deep lagoon waters, or spreading of solid manure should be performed under the same guidelines if odors are a nuisance. Soil injection, dishing or plowing-in of the manure can be effective to reduce both odor and nitrogen loss. This technique requires additional resources other than irrigation techniques. Caution is necessary when handling dry material in windy conditions.

Feedlot odor intensity is increasingly stronger near the source (6), and odor concentration is 90 percent dissipated within 1,000 feet downwind (11). Downwind odor intensity indicators primarily include ammonia, hydrogen sulfide and organic acid.

No federal standards or laws exist for specific odor control. This may be due in part to the inability to consistently quantify odor annoyance by concentration measurements alone (1, 18). However, local windshed ordinances may exist for counties or municipalities. As an example of a local air quality control program, Tulare County requires that new dairy facilities not lie within the windshed area of any incorporated or unincorporated community. The windshed area is defined as one mile upwind or one-half mile downwind from the urban boundary, or within 1,000 feet of a public park boundary, or within 2,640 feet of a group of 10 or more dwellings. The dwellings portion of the policy is strictly adhered to while other portions are considered on a case-by-case basis (19).

CARBON DIOXIDE

Manure decomposition and animal respiration result in the release of carbon dioxide. This gas is odorless and is not considered of concern unless the concentration rises above 5,000 ppm in poorly ventilated buildings. Dairy waste lagoon gas contains from 25 to 30 percent carbon dioxide.

AMMONIA

Ammonia is one of the most beneficial gases liberated from animal feces and urine and is a prime ingredient in the life-sustaining animal-plant nitrogen cycle. Ammonia can also occur in amounts lethal to humans in liquid manure tanks or in enclosed areas. It has an unpleasant odor and causes a burning sensation to mucous membranes (eyes and lungs). Elevated ammonia concentrations (above 25 ppm) reduce feed conversion efficiency and cause respiratory problems in calves housed in poorly ventilated facilities.

Volatilization of ammonia gas is aided by the normally warm, alkaline, drying conditions of manure. Decomposing animal wastes liberate ammonia into the atmosphere as a weak base. In the atmosphere ammonia combines with moisture to form the ammonium ion. Undocumented reports suggest that as a weak base, ammonium could reduce acid rain by the following scenario: ammonium is scavenged by sulfate and nitrate in the atmosphere to form ammonium sulfate and ammonium nitrate, which may precipitate to form particulate matter in the atmosphere; deposition of these aerosols and particles allows the nitrogen sources to be used by soil microorganisms and plants, thus liberating ammonia again and leaving sulfuric and nitric acids in the soil. In this fashion, ammonia reduces the acidity of the rain. However, the net result to soil is an increase in acidity. A further concern is the deposition of ammonia into surface waters. The net liberation of nitrogen may disturb biological integrity of the water.

Animal ammonia is considered a major contributor to acid rain in Holland (20). However, non-animal acid rain constituents, particularly oxides of nitrogen and sulfur from fossil fuel burning, are considered the major components of acid precipitation in other areas. The amount of transformation of ammonia in cloud droplets to acidic compounds is variable and depends on both the concentration of sulfurous and nitrous pollutants and the air current transport of those pollutants (8).

Relatively few studies have quantified the transfer of cattle ammonia through the air to the ultimate enrichment of soil or bodies of water. However, airborne animal ammonia has been

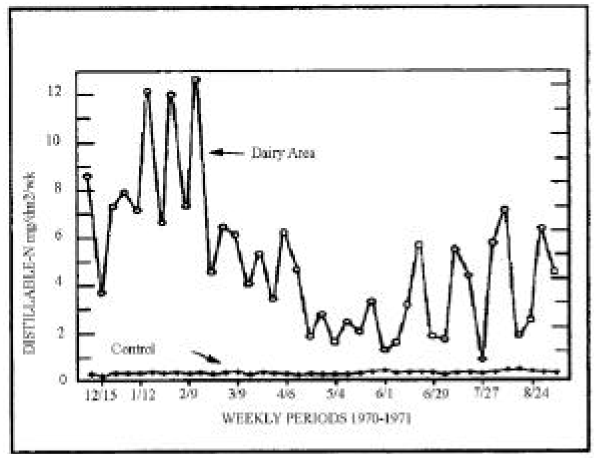

Figure 1. Distillable-N absorption from the atmosphere (12).

TABLE 2. Total distillable and nondistillable N absorbed by acid-surface traps during a rainless con (avg. of 14 weekly samplings)

Location	Proximity to dairy area	Total N	Distillable N	Nondistillable N
		Mg/dm^2/week	%	Mg/dm^2/week
A-3	9.6 km upwind	0.30	28	0.36
B-1	8.0 km downwind	1.36	81	0.29
A-10	In area	4.12	78	0.89
B-10	In area	4.66	81	0.87
B-4	In area	8.49	86	1.17

Reference: Luebs, H., K. Davis and A. Lang. 1973. Enrichment of the atmosphere with nitrogen compounds volatilized from a large dairy area. J. Envir. Quality 2:1 :137-141.

implicated in soil acidification problems in Holland (20). Reviewed literature uncovered no cause and effect data regarding atmospheric nitrogenous compound concentrations and eutrophication of water resources that may harm aquatic life.

Because water captures about 60 percent of the ammonia on acid surfaces, dilute sulfuric acid traps have been used to capture atmospheric ammonia near large dairy concentrations in the Chino area of California (12) and beef feedlots in northeastern Colorado (9). In the Chino-Corona dairy area, with 1,235 cows per square mile at the time of the observations, acid traps yielded 370 pounds per year of ammonium nitrogen for each acre of dilute acid surface (12). The results, shown in Figure 1, indicate a high weekly variation in distillable nitrogen trapped from the dairy area. Compared to an outside control area, values ranged from nearly equal to 28 times greater than the control. Lower values were generally recorded during windy conditions, while maximum readings occurred during a period of rapid corral drying following rains. For examples of acid trap readings during a rainless period from late April to the end of August see Table 2. The authors of the study have stated that most of the distillable N was probably ammonia.

Results from Colorado feedlot observations (Table 3) show the effect of cattle numbers and the acid trap site distance and orientation to the feedlot on ammonia collected. Acid trap absorption rates near feedlots measured up to 20 times greater than those at the control site. The authors stated that nitrogen borne by subsequent rain and snow during the year was insignificant compared to the estimated amount absorbed by water surfaces.

It is clear that animal ammonia can be carried by air currents. Subsequent precipitation can enrich both soil and water with nitrogen. Determining the proportion of nitrogen from animal and non-animal sources is currently considered speculative. Extrapolating guidelines from published observations, particularly where unique weather conditions may have existed, adds more potential for variation and has led to

TABLE 3. Descriptions of the seven experimental sites, weekly absorption (mean) of ammonia nitrogen by dilute acid traps during the period 27 July 1968 through 27 February 1969 except sites 4 and 5, where measurement began 27 September 1968; estimated annual absorption of ammonia nitrogen by water surfaces; and ammonia nitrogen in precipitation during the period 21 September through 21 November 1968.

		Ammonia nitrogen (kg/ha)		
		Absorption		Precipi tation
Site	Site description	Weekly	Annual	
1	No feedlots or irrigated fields within 3 km; no large feedlots or cities within 15 km	0.15	3.9	0.22
2	Only small (less than 200-unit) feedlots within 4 km, none closer than 0.8 km	0.34	9.1	0.29
3	About 0.2 km east of 800-unit feedlot and 0.6 km west northwest of another similar feedlot	0.57	15	0.32
4	On northeast shore of Clark Lake and 0.5 km southwest of 9,000-unit feedlot	0.62	17	0.29
5	On southeast shore of Seeley Lake and 2 km west northwest of 90,000-unit feedlot	1.3	34	0.53
6	About 2 km east of 90,000-unit feedlot	1.3	34	0.40
7	About 0.4 km west of 90,000-unit feedlot	2.8	73	0.61

Reference: Hutchinson, G. and F. Viets. 1969. Nitrogen enrichment of surface water by absorption of ammonia volatilized from cattle feedlots. Science 166:514-515.

contradictory evidence on the topic of acid rain.

METHAN

Methane gas, a key component in the global warming issue, is produced by both enteric feed fermentation in ruminating animals and by the anaerobic digestion of their manure. Estimates vary as to the contribution of cattle-related methane to total global greenhouse gases (2, 7, 10). Human activities which contribute to atmospheric methane concentrations are rice agriculture (110 Tg/yr; 27%), ruminant animals (80 Tg/yr; 20%), biomass burning (55 Tg/yr; 14%), coal mining (50 Tg/yr; 12%), oil and natural gas (45 Tg/yr; 11%), landfills (35 Tg/yr; 9%), and animal wastes (28 Tg/yr; 7%). Animal waste includes ruminants and nonruminants. Estimated contribution of U.S. animal waste to global methane emissions is 4.2 Tg/yr or 14.8% of the global livestock waste emissions. That translates into less than 1% of the methane emissions from human activities are a result of U.S. livestock waste. It is estimated that U.S. dairy cattle wastes are responsible for 30% (0.8 Tg/yr) of U.S. emissions or less than 0.3% of global methane emissions.

Both increased feed intake and improved dietary composition can reduce methane emissions from ruminants. Some biotechnological agents have reduced maintenance feed requirements of lactating cows by 3- to 5 percent (2). Reduction of rumen protozoa from lower feed requirements can lower digestive methane emissions, but the economics and practical consequences of this have not yet been defined (2).

A consensus of strategies to reduce anticipated global warming through technological means (7) suggests that a 25 percent reduction in ruminant methane would reduce global warming by only 1 percent, while increasing auto fuel efficiency to 40 miles per gallon would decrease warming by 8 percent.

Animal waste management practices involving anaerobic digester systems offer opportunities to recover methane for commercial energy production. Gases from organic wastes in dairy lagoons contain 65 to 70 percent methane and are estimated to produce from 6.7 to 40 standard cubic feet (SCF) of methane per pound of volatile organic solids (14). Observations of Tulare County dairy lagoons in California showed a range of 10 to 20 SCF per cow daily from drylot flush systems and 43 SCF from freestall flush systems (5). Values depended on inflow and outflow of solids, quantity of added fresh water in the ponds and seasonal temperatures.

The extent of methane emission from dairy waste deposits has not been quantified extensively. Survey observations indicate only trace amounts of methane from dairy drylots during the dry summer season. The monitoring of a pilot scale dry fermenter with 35 percent initial solids under controlled conditions gave 45 quarts of methane per pound of volatile dairy waste solids added during a 50-day period (4).

DUST

Early observations of dust problems focused primarily on beef feedlots.
There have been relatively few observations on confined dairies (1). Dust nuisances from dairy drylots include layered dust that hangs several feet off the ground and migrates with air currents in the early summer evening and dust particle collection on adjacent orchard and vineyard foliage (1). In a few cases, dairy producers have been legally obligated to control corral dust with sprinklers in summer months (19). Some fruit and nut harvester operations have also been cited, indicating that various types of farms have a dust problem which can be reduced by oiling or wetting perimeter and access roads used by trucks and tractors.

Relatively few quantified observations of dust emission have been made concerning stocking rate and surface moisture on corralled dairies. Table 4 shows the relationship of animal size and spacing to moisture on the feedlot surface. A feedlot surface with at least a 25 percent moisture content has been considered optimum to control blowing dust. Elevated moisture content (greater than 35 percent) can increase odors and insect pests. In the past, a beef feedlot stocking rate of 75 square feet per head was considered most beneficial, while 50 gave wetter, more odorous conditions and 100 square feet per head resulted in excessive dustiness. In contrast, modem dairy design for drylots calls for 400 to 600 square feet per cow and from 150 to 300 square feet in freestall housing in addition to stall team space (15, 21). These seemingly different recommendations reflect differences in animal behavior. Dairy corral space is used to minimize environmental stress on cows and to facilitate frequent scraping. Excessive dustiness seldom occurs.

PM-10

Particles of 10 microns median diameter or less are used by the EPA to determine airborne particulate standards. This size of particulate matter is sometimes referred to as "invisible" dust, but actually contributes to visible haze. The standard set by the EPA in 1987 is 150 micrograms of PM-10 per cubic meter over any 24hour period, with no more than one excessive reading per year and an annual average of less than 50 micrograms per cubic meter.

Observations at west Texas beef feedlots (17) show that at 200 feet from corrals, downwind average particle size was 14.2 microns, while upwind was 12.3. One-third of downwind total suspended solids (TSP) and 40 percent of upwind TSP were less than 10 microns. These results indicate that most large particles settle relatively quickly near the feedlot.

Visible dust and PM-10 control management practices include watering Derailing unpaved roads and adjusting drylot stocking rates according to precipitation and evaporation. Wetting drylot surfaces with either sprinklers or spray fan tanker vehicles must be done cautiously so as not to dampen shaded areas too much. Excess watering may promote growth of infectious mastitis-causing organisms or lead to stress from insects, odors or humidity. The practice of having a relatively large area per cow and weekly surface scraping to give rapid aeration appears to be a safer alternative to denser stocking rates or sprinkling. As with other environmental impacts, efforts to improve on-dairy factors that may affect air quality should be matched by comparable efforts by adjacent enterprises and a reasonable amount of public tolerance.

TABLE 4. Estimated moisture produced per year by fresh dairy corral manure with varied animal density. Average Animal Spacing, ft2/hd

	Average Animal Spacing, ft/hd		
	100	200	300
Animal Size Lbs/hd	Depth on Feedlot Surface In.	In.	In.
400	21	10	7
600	31	16	10
800	42	21	14
1000	52	26	17
1200	62	31	21
1400	72	36	24
1600	83	42	28

POTENTIAL TREATMENT

Chemical and aromatic agents may reduce odors from animal waste, but information on their effectiveness and long-term cost effectiveness is scarce. It is best to evaluate their cost, history and effectiveness before using such products. Ongoing and future research may lead to more efficient control of animal-produced odors through biotechnological advances. These advances, coupled with selective municipal waste treatment procedures, could further reduce odor nuisances. When considering the overall balance of a given windshed area, all sources contributing to air quality degradation must be kept in perspective (3).

SUMMARY

Minimizing odors, dust and insects through management practices can be beneficial to animal performance and can create positive neighborhood relationships. Micro-windshed conflicts can also be avoided or reduced by judicious community planning and adherence to predesigned development plans. Public agencies should make a careful and thorough evaluation of possible antagonisms before forming guidelines for windshed areas.

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This publication is part of a series on dairy manure management. The sections focus on specific issues relevant to the California dairy industry.

The purpose of individual sections is to provide current scientific information related to dairy manure management. Producers are required to integrate air, land, water, plant and animal resources. Each management decision may impact these separate but intertwined resources. Factual, scientific information is needed by producers, regulators, planning commissions members, and citizens concerned about their environment. This series is designed to provide foundation knowledge about dairying and the environment. Further information is available through University of California Cooperative Extension.