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Odor and Dust From Livestock Feedlots

John M. Sweeten*

This report discusses the relationship of livestock production to air pollution and assesses the technology and management practices which can reduce pollution from livestock and poultry operations.

Intensive Animal Production Systems

The major types of livestock and poultry production facilities, their design and the manure management systems associated with them are described in several reports (MWPS, 1987; U.S. EPA, 1973; White and Forster, 1978; Foster and Mayrose, 1987). Roofed or total confinement facilities are common for poultry and swine and to a lesser extent, dairy and beef production (National Research Council, 1979). However, open feedlots (non-roofed) are most commonly used for beef cattle production. They are also widely used for dairy, swine and sheep production in the southwestern United States.

Intensive livestock production systems are regarded as "animal feeding operations." The U.S. EPA defines such operations (for purposes of water pollution control) as areas where animals are "stabled or confined and fed or maintained for a total of 45 days or more in any 12-month period, and . . . crops, vegetation, forage growth or post-harvest residues are not sustained in the normal growing season over any portion of the lot or facility" (U.S. EPA, 1976). The definition is not specific as to animal species, type of confinement facility or animal density, but essentially integrates these factors (along with climate and soils) into a single criterion - the absence of vegetation - which occurs where manure production and/or animal traffic are high.

Van Dyne and Gilbertson (1978) estimated the total collectable (economically recoverable) manure from all livestock and poultry production to be 52 million tons per year (dry matter basis). The percentages from various species were: dairy cattle 39 percent; feeder cattle 31 percent; hogs 11 percent; laying hens 6 percent; broilers 5 percent; sheep 3 percent; turkeys 2 percent; and other 3 percent.

These manure production estimates are based on an engineering standard adopted by the American Society of Agricultural Engineers (ASAE, 1976) which defines constituent production per unit weight of live animal. These standard values were recently updated to reflect current research data (ASAE, 1988). In most cases, average values of dry manure and nutrients (pounds per day per 1,000 pounds liveweight) were revised upward.

Cattle feedlots

The United States has 9.4 million beef cattle in feedlots, averaging 850 pounds per head liveweight. Each animal that is fed in a normal 130- to 150-day fattening period produces about 1 dry ton of collectable manure solids. This equals about 2 dry tons of collected manure per year per head of feedlot capacity. The animal spacing per head varies according to rainfall and temperature, slope and other factors. For example, there are 100 to 125 square feet per head in the desert southwest where there is less than 10 inches of annual rainfall; 175 to 200 square feet per head in the southern and central Great Plains where there is 15 to 25 inches of

* Extension Agricultural Engineer, The Texas A&M University System

rain per year, and 300 to 400 square feet per head in the eastern and northern Great Plains where there is 25 to 35 inches per year. Most cattle feedlots are concentrated in the southern and central Great Plains.

Most of the manure deposited on the feedlot surface is compacted by cattle into a manure pack of 35 to 50 percent moisture content (wet basis). At higher moisture contents odors can develop, especially in warm weather. Such odors may be a nuisance to employees and downwind neighbors. Cattle hooves may pulverize surface manure during prolonged dry weather to only 10 to 25 percent moisture. When surfaces are excessively dry, as is often the case in arid areas of Arizona, California and Texas, there is a potential for dust problems (National Research Council, 1979).

Dust from cattle feedlot surfaces, alleys and roads can annoy neighbors, irritate feedlot employees, possibly impair cattle performance and create a traffic hazard on adjacent highways (Sweeten, 1982). The amount of dust produced is affected by feedlot area, cattle density in pens, wind speed and precipitation and evaporation patterns (Peters and Blackwood, 1977).

Odors from livestock feeding operations

Although odors from livestock feeding facilities are sometimes an annoyance, odorous gases are not toxic at concentrations found downwind. However, nuisance lawsuits can threaten the survival of an operation (George et al., 1985), and livestock producers need to control the evolution of odorous compounds (Miner, 1975; National Research Council, 1979).

Odorous gases arise from feed materials (food-processing wastes and fermented feeds), fresh manure and stored or decomposing manure (National Research Council, 1979). The odor from fresh manure is generally less objectionable than that from anaerobically decomposing manure. Fresh manure has large quantities of ammonia, but little of the other decomposition products that have the most objectionable characteristics. Odorous compounds which develop in manure treatment facilities are a function of the material as excreted, the biologic reactions occurring in the material and the configuration of the storage or treatment unit.

Roofed confinement facilities usually have significant odor potential because of the high animal density involved, the large amount of manure in storage and the limited rate of air exchange (National Research Council, 1979). Manure-covered surfaces (e.g., building floors and animals), manure storage tanks beneath slotted floors and anaerobic lagoons used for manure storage and treatment are important odor sources.

When open feedlot surfaces become wet, particularly in warm weather, anaerobic decomposition occurs over a large surface area for the evolution of odorous gases (National Research Council, 1979). Feedlot odor problems are most frequent in warm, humid areas and in feedlots constructed where there is inadequate drainage or poor drying conditions.

Animal manure odor is comprised of gaseous compounds that are the intermediate and final products of biodegradation, and includes these groups: ammonia and amines; sulfides; volatile fatty acids; alcohols; aldehydes; mercaptans; esters; and carbonyls (Table 1) (Ashbacher, 1972; Miner, 1975; Barth et al., 1984; ASAE, 1987; National Research Council, 1979).

Table 1. Compounds Resulting From the Anaerobic Decomposition of Livestock and Poultry Manure

Alcohols	Amines Methylamine Ethylamine Trimethylamine Diethylamine
Acids Butyric Acetic Propionic Isobutyric Isovaleric	Esters
Carbonyls	Fixed Gases Carbon Dioxide (odorless) Methane (odorless) Ammonia
Sulphur compounds Hydrogen Sulfide Dimethyl Sulfide Diethyl Sulfide Methylmercaptan Disulfides	Nitrogen Heterocycles Indole
	Skatole

Concentrations of these compounds are usually low and downwind from feedlots. However, some may exceed olfactory threshold values and create a nuisance.

There is almost universal acceptance of sensory approaches, using trained human panelists, for the measurement of odor. However, the instruments and techniques used in sensory odor measurement may vary. Odor measurement technology applicable to livestock operations includes determining:

- Concentrations of specific compounds (ammonia, hydrogen sulfide, volatile organic acids, etc);

- Dilutions to threshold with a dynamic forced-choice olfactometer or scentometer; and
- Equivalent concentration of butanol vapor (using a butanol olfactometer) that matches the ambient odor intensity.

Several states and municipalities have property-line odor standards based on these and other measurement methods (Sweeten, 1988).

The odor caused by anaerobic decomposition of swine manure was measured by Meyer and Converse (1981), who found that hydrogen sulfide and ammonia concentrations were, respectively, 218 percent and 118 percent higher at 73 degrees F than at 60 degrees F. In European research (Klarenbeek, 1985), the odor emission rate from swine houses with anaerobically stored manure increased 20 fold for each 18 degree rise in manure temperature and, including ventilation rate influences, was more than four times greater in summer than in winter. Emissions were 73 percent greater with fully slotted floors than with partially slotted floors.

In the same study, odor intensity observations were made with scentometers both upwind and downwind of feedlots. Upwind odor intensities were usually in the range of 0 to 2 dilutions to threshold, while downwind concentrations averaged 13 to 49 dilutions to threshold.

Dust emissions from livestock feeding operations

In 1971, the U.S. EPA (1987) defined primary and secondary ambient air-quality standards for total suspended particulate matter (TSP). The primary standards were set at 260 µg per m^3 for a 24-hour average, not to be exceeded more than once per year, with an annual geometric mean of 75 µg per m^3. Secondary standards were set at 150 µg per m^3 for a 24-hour sampling period, not to be exceeded more than once per year.

Effective July 31, 1987, the U.S. EPA replaced TSP as the indicator (PM-10) for the ambient standards in favor of a new indicator that includes only those particulates with an aerodynamic particle diameter less than or equal to a nominal 10 mm (U.S. EPA, 1987). The new standard: 1) replaced the 24-hour primary TSP standard with a PM-10 standard of 150 µg per m^3; 2) replaced the annual geometric mean with an arithmetic mean PM-10 standard of 50 µg per m^3; and 3) replaced the secondary TSP standard with 24-hour and annual PM-10 standards that are identical to the primary standards. These standards, of course, apply to livestock feeding operations.

Elam et al. (1971) collected feedlot dust samples inside 65 pens at 10 California feedlots, using a Staplex high-volume air sampler and operating in 1- to 3-hour increments during 24-hour sampling periods. Peak particulate concentrations, which were collected between 7:00 and 10:00 p.m., ranged from 1,946 to 35,536 µg per m^3 and averaged 14,200 µg per m^3. Lowest concentrations occurred in early morning and were only 130 to 250 mg per m^3 in some feedlots.

Algeo et al. (1972) measured total suspended particulates in 24-hour samplings both upwind and downwind in 25 California feedlots (Table 2). Net particulate concentrations (downwind minus upwind) for a 24-hour period ranged from 54 to 1,268 µg per m^3. The average value for all 25 feedlots was 654 $\pm$ 376 µg per m^3. Upwind concentrations averaged 25 percent of the downwind concentrations. Both upwind and downwind particulate levels usually exceeded the U.S. EPA ambient air-quality standards for TSP.

Table 2. Summary of 24-Hour Particulate (TSP) Concentrations at 25 California Cattle Feedlots (Algeo et al., 1972).

	Downwind (n=25)	Upwind (n=24)	Net, Downwind minus Upwind (n=24)
Mean	836	206	654
Std. Deviation	±437	±116	±376
Range:			
Minimum	100	46	54
Maximum	1,599	460	1,268

Peters and Blackwood (1977) cited major limitations in these results:

- All sampling was performed in the dry season; and
- Details such as feedlot size, cattle number, distances from samplers to feedpens and climate conditions were not reported.

Nevertheless, using the California data from Algeo et al. (1972), Peters and Blackwood (1977) developed what they considered to be **worst-case projections** for cattle feedlots. According to their projections, feedyards with more than 500 head, at 140 square feet per head, would emit more than 100 tons of particulates per year, not including the feedmill.

Based on Peters and Blackwood's (1977) treatment of the California data, the U.S. EPA published emission factors (AP-42) for cattle feedlots as being crude estimates at best (U.S. EPA, 1986).

These emission factors were based on the assumption that feedlots would generate 280 pounds of particulates per day per 1,000 head, and 27 tons of particulates per 1,000 head fed. Other emissions factors were similarly written for ammonia, amines and total sulfur compounds.

The U.S. EPA emission factors ignored the major climatic differences among cattle feeding regions of California, the Great Plains and the Midwest. Both total rainfall and seasonality of rainfall are different. Also, California has less than 4 percent of the United States cattle on feed, as compared to Texas and Nebraska which combined have 40 percent.

To obtain a broader data base, dust emissions were measured at three cattle feedlots in Texas, ranging in size from 17,000 to 45,000 head. Measurements were made on 15 occasions in 1987 to determine both the total suspended particulates (TSP) and the particulates below 10μm aerodynamic particle size (PM-10) (Sweeten et al., 1988). Net feedlot dust concentrations (downwind minus upwind) ranged from 16 to 1,700 μg per m^3 and averaged 412 $\pm$ 271 μg per m^3 (which is 37 percent less than the earlier California data). Dust concentrations were generally highest in early evening and lowest in early morning, and upwind concentrations averaged 22 percent of downwind concentrations.

Using two types of PM-10 sampler (Wedding and Anderson-321A), the PM-10 dust concentrations were 19 to 40 percent, respectively, of mean TSP concentrations. There was good correlation between PM-10 and TSP concentrations with r^2 = 0.634 and 0.858 for Wedding and Anderson's 321-A samplers, respectively (Sweeten et al., 1988).

Mean particle sizes of feedlot dust were 8.5 to 12.2 mm on a population basis, while respirable dust (below 2μm) represented only 2.0 to 4.4 percent of total dust on a particle volume basis (Hebner and Parnell, 1988).

When the Wedding sampler was used for PM-10 measurements, feedlots were below the new EPA standard, and peak concentrations did not coincide with the expected early evening peaks caused by cattle activity. Hence, comparatively little of the actual feedlot manure dust may have been captured in Wedding's instruments.

Analysis with a Coulter Counter showed aerodynamic particle size distribution curves for TSP and PM-10 samplers (Figure 1) (Sweeten and Parnell, 1989). The PM-10 sampler over-sampled particles larger than 10μm, since 34 percent of the particles trapped on the PM-10 sampler filters were larger than 10μm and 66 percent were smaller than 10μm. Mass median diameters (MMD) of dust particles

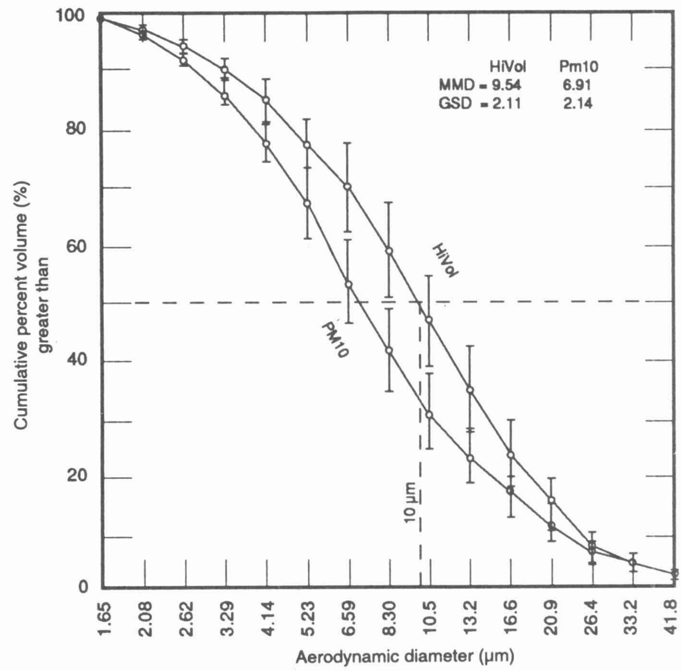

Figure 1. Cumulative volume fraction of feedlot dust particles of given size captured on filters of High Volume and PM10 samplers; downwind samplers at feedlots A, C and B (Experiments 11, 14 and 16). (Sweeten and Parnel, 1989.)

captured on high volume samplers averaged 14.2μm downwind and 12.3μm upwind of feedlots (Sweeten and Parnell, 1989). Thirty-three percent of the downwind TSP were smaller than 10μm, while 40 percent of upwind TSP was smaller than 10μm.

Air Pollution Control Methods

Controlling dust

Feedlot dust is usually controlled by sprinkling surfaces with water at strategic times and in proper amounts (Andre, 1985; Gray, 1984; Simpson, 1970; Sweeten, 1982). Carroll et al. (1974) compared two feedlots, one unsprinkled and the other sprinkled each day on a schedule of 2 hours on, 2 1/2 hours off and 1 1/2 hours on. He reported that sprinkling reduced dust emissions by at least half.

Elam et al. (1971) reported that feedlot manure moisture content of 20 to 30 percent was needed for dust control. Particulate concentrations

(24-hour averages) increased from 3,150 to 23,300 μg per m^3 when daily water sprinkling was terminated for 7 days.

Sweeten et al. (1988) found that feedlot dust concentrations decreased with increasing moisture content in the top 1 inch of feedlot surface, although odor intensity (dilutions to threshold) increased. Regression equations indicated that the manure moisture needs to be 26 to 31 percent (wet basis) in the loose surface manure and 35 to 41 percent at a 1-inch depth in order to control feedlot dust to allowable TSP limits of 150 and 260 μg per m^3.

Controlling odor

Odor control methods for livestock facilities include: (1) manure treatment - aeration, anaerobic digestion or biochemical treatment; (2) capture and treatment of odorous gases using covered storage pits or lagoons, soil incorporation, soil absorption beds or filter fields, or packed beds; and (3) odor dispersion, accomplished by selecting a site that is far enough away from neighbors and that takes advantage of topography, wind direction frequency and atmospheric stability data (Sweeten, 1988).

Manure Treatment. Controlled anaerobic digestion of liquid swine manure at 90 degrees F reduced the odor emission rate by 90 percent as compared to pit-stored slurry (Klarenbeek, 1985). Anaerobic digestion also reduced the time for odor dissipation from 72 hours to 24 hours.

Anaerobic lagoons must have adequate capacity (i.e., low loading rate) to produce relatively little odor. Design criteria have been developed based on the volatile solids loading rate, which is proportional to the volume per pound of liveweight (Barth, 1985; Humenik and Overcash, 1976; Sweeten et al., 1979; ASAE, 1990).

Mechanical aeration of liquid manure in oxidation ditches or lagoons is an effective odor control method (Humenik et al., 1975; Jones et al., 1971). Aerating only the top third or half of swine lagoon contents proved successful and reduced power requirements as compared with complete mixing (Humenik et al., 1975). Converse et al. (1971) used limited aeration of liquid swine manure without a measurable dissolved oxygen residual and reduced odor as compared to non-aerated storage. Phillips et al. (1979) rapidly reduced hydrogen sulfide and methanol emissions from swine manure by aeration, but less volatile and less offensive compounds such as phenols persisted. Aeration just prior to land spreading could reduce odors from field application.

Frequent manure collection by flushing, cable scraping or pit drainage recharge helps absorb odorous gases and elimate anaerobic storage conditions in confinement buildings (Korsmeyer et al., 1981; Meyer and Converse, 1981; Raabe et al., 1984).

Biochemicals for odor control include masking agents, counteractants, digestive deodorants, chemical deodorants, adsorbents and feed additives (Ritter, 1980). Digestive deodorants are the most widely used. They must be added frequently to allow selected bacteria to become predominant. Potassium permanganate (100-500 ppm), hydrogen peroxide (100-125 ppm) and chlorine are oxidizing chemicals capable of controlling hydrogen sulfide emissions.

Warburton et al. (1981) significantly reduced odors from anaerobic swine manure slurry with four treatments - aeration, chlorination and two biochemical formulations. Lindvall et al. (1974) reduced odors from liquid swine manure with ammonia persulfate, and Miner and Stroh (1976) determined that zeolites (clinoptilolite and erionite) were somewhat effective in reducing odors from a dirt-surfaced cattle feedlot.

Odor capture and treatment. Installing a cover on an outside manure storage pit, tank or lagoon is an effective means of odor control because it reduces the ventilation rate and hence the rate of odor emission. However, rigid covers are expensive, and flexible membrane covers over large surfaces are subject to photodegradation and wind damage.

Wet scrubbers that involve spraying exhaust air with water or oxidizing chemicals are widely used for industrial and food processing plant odors, and some researchers have adapted them to livestock confinement buildings. Van Geelen and Van Der Hoek (1977) obtained an 88 percent reduction in odor concentration with wet scrubbing of exhaust from a swine house, although captured dust formed a sludge which made it difficult to recirculate the scrubbing water. Schirz (1977) cited problems with the clogging of spray nozzles when scrubbing with recycled water, and biological treatment was required. Licht and Miner (1978) built a horizontal cross-flow, packed-bed wet scrubber for a swine confinement building and achieved 50 and 90 percent removal of particulates larger than 1 and 5 microns, respectively; and ammonia reduction of 8 to 38 percent; and an 82 percent reduction of odor intensity.

A packed-bed dry scrubber filled with a zeolite (clinoptilolite) reduced ammonia emissions from a poultry house by 45 percent initially, but efficiency dropped to only 15 percent in 18 days (Koebliker et al., 1980).

The soil is an excellent odor scrubbing medium because it chemically absorbs, oxidizes and aerobically biodegrades organic gases (Bohn, 1972). Lindvall et al. (1974) determined that soil injection reduced odor emissions (measured as dilutions to threshold) from liquid swine manure by 90 to 99 percent as compared to surface spreading. Odor from a soil-injected manure site was about the same as from a nonmanured soil surface. Disk harrowing or plowing of surface spread manure reduced odor by 67 to 95 percent.

Soil filters with perforated pipe in a shallow soil bed have proved effective for scrubbing odors from exhaust air. Kowalewsky (1981) removed 52 to 78 percent of the ammonia and 46 percent of the organic constituents from ventilation air from a swine confinement building using a soil filter system. Prokop and Bohn (1985) reported 99.9 percent odor reduction when a soil filter was used to treat high intensity odors in exhaust from rendering plant cookers. Soil filters require a moderately fine-textured soil, sufficient moisture and a pH of 7 to 8.5. The land area required is 2,500 to 4,600 square feet per 1,000 cfm, depending upon the air flow rate (Prokop and Bohn, 1985). Sweeten et al. (1988) measured a 95 to 99 percent reduction in ammonia emissions and a 30 to 82 percent reduction in odor intensity (matching butanol concentrations) using a 1/4-acre sand filter field to scrub air from a poultry manure composting operation.

Odor dispersion. The farther odorous gases travel downwind from their source the more they are diluted, depending on atmospheric turbulence and odorant reactions. An odor panel observed a 90 percent reduction in odor intensity, as determined by a matching butanol olfactometer (Sorel et al., 1983), over a distance of half a mile downwind from a cattle feedlot in Texas (Sweeten et al., 1983).

Atmospheric dispersion models are sometimes used to predict the travel of odor emissions (Janni, 1982) and the impact on communities. However, the use of dispersion models is limited to short distances and to nonreactive odorous gases (National Research Council, 1979). One or more versions of the Gaussian diffusion model are used in most regulatory applications. The prediction models require that atmospheric stability, wind speed and odor emission rates are known.

Based in part on dispersion model results, required minimum separation distances for livestock feeding operations (based on number of head) have been developed for swine facilities in the Netherlands (Klarenbeek, 1985) and for cattle feedlots in Australia (QDPI, 1989). These relationships are being used to determine the size of operation that should be allowed in a particular location. The research base is not yet well enough developed to support heavy reliance on dispersion models for livestock odors.

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