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SOURCE ASSESSMENT: BEEF CATTLE FEEDLOTS

Industrial Environmental Research Laboratory
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SOURCE ASSESSMENT: BEEF CATTLE FEEDLOTS

by

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PREFACE

The Industrial Environmental Research Laboratory (IERL) of EPA has the responsibility for insuring that pollution control technology is available for stationary sources to meet the requirements of the Clean Air Act, the Water Act, and the Solid Waste legislation. If control technology is unavailable, inadequate, uneconomical or socially unacceptable, then financial support is provided for the development of the needed control techniques for industrial and extractive process industries. Approaches considered include: process modifications, feedstock modifications, add-on control devices, and complete process substitution. The scale of the control technology programs ranges from bench- to full-scale demonstration plants.

The Chemical Processes Branch of the Industrial Processes Division of IERL has the responsibility for investing tax dollars in programs to develop control technology for a large number (>500) of operations in the chemical industries. As in any technical program, the first question to answer is, "Where are the unsolved problems?" This is a determination which should not be made on superficial information; consequently, each of the industries is being evaluated in detail to determine if there is, in EPA's judgment, sufficient environmental risk associated with the process to invest in the development of control technology. This report contains the data necessary to make that decision for the air emissions from beef cattle feedlots.

Monsanto Research Corporation has contracted with EPA to investigate the environmental impact of various industries which represent sources of pollution in accordance with EPA's responsibility as outlined above. Dr. Robert C. Binning serves as Program Manager in this overall program entitled, "Source Assessment," which includes the investigation of sources in each of four categories: combustion, organic materials, inorganic materials, and open sources. Dr. Dale A. Denny of the Industrial Processes Division at Research Triangle Park serves as EPA Project Officer. In this study of beef cattle feedlots, Mr. D. K. Oestreich served as EPA Project Leader.

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LIST OF SYMBOLS

Symbol	Definition
d	Number of dry days per year
exp	Natural log base, e = 2.72
F	Hazard factor for a pollutant
H	Effective height of emission
LD_{50}	Dose of a substance that causes death in 50% of the animals which have ingested the substance
LDLo	Lowest dose of a substance, other than the LD_{50}, introduced by any route other than inhalation, over any given period of time and reported to have caused death in man, or the lowest single dose introduced in one or more divided portions and reported to have caused death in animals
M	Molecular weight of gaseous compound
M_o	Molecular weight of water
NO_x	Nitrogen oxides
p	Vapor pressure of gaseous compound
P_o	Vapor pressure of water at standard conditions
P_M	Monthly precipitation
P	Persistance factor of odorous substance
ppm	Parts per million
P-E	Thornthwaite's precipitation-evaporation index
Q	Mass emission per time of a continuous point source
Q_L	Mass emission rate per length of a continuous line source
S	Source severity
SO_x	Sulfur oxides
t	Averaging time for ambient air quality standard
t_0	Sampling time for 3 min concentration measurement
t_k	Sampling time for concentration measurement
t_s	Actual sampling time of experimental data
T	Air temperature
T_o	Temperature of water vapor at standard conditions

LIST OF SYMBOLS (continued)

Symbol	Definition
T_M	Monthly mean temperature
TLV	Threshold limit value
u	Average wind speed
x	Downwind distance from emitter
π	Constant = 3.1416
σ_y	Standard deviation in the horizontal of the plume concentration distribution
σ_z	Standard deviation in the vertical of the plume concentration distribution
χ	Concentration for a 3 min sampling time
χ_k	Concentration for sampling time, t_k
χ_s	Concentration for sampling time, t_s
$\bar{\chi}$	Time-averaged ground level concentration which is the maximum to which a population can be exposed

SECTION I

INTRODUCTION

Beef cattle feedlots contribute fugitive dust and gaseous emissions to the atmosphere. The objective of this work was to assess the air environmental impact of beef cattle feedlots in sufficient detail to enable the EPA to determine the need for the development of control technology.

This document summarizes information relating to the emissions from beef cattle feedlots. The areas studied and described in this document are:

- Number of beef cattle feedlots
- Size distribution of the feedlot capacities
- Locational distribution of the beef cattle feedlots with more than 1,000-head capacity
- Areas of industry expansions and decreases
- Controlled and uncontrolled rates of emissions
- Composition of emissions
- Hazard potential of emissions
- Hazard potential of odorous emissions
- Types of control technology used and proposed
- Historical and projected growth and anticipated developments in the industry.

SECTION II

SUMMARY

Beef cattle feedlots are open sources of atmospheric emissions of fugitive dust and volatile products which vary due to meteorological and topographical influences. Of the 146,000 beef cattle feedlots in the U.S. in 1973, 2,040 feedlots had a capacity of more than 1,000 head and marketed 65% of all finish-fed beef cattle. The seven leading states in the industry are Texas, Nebraska, Iowa, Kansas, Colorado, California, and Illinois. These states contribute 75% of all fed cattle marketed and contain 72% of the over 1,000-head-capacity feedlots. Only these larger feedlots were investigated in this study.

Of the criteria pollutants, particulates are generated primarily by cattle movement inside feedlot pens and secondarily by wind erosion of the feedlot surface. The areas of the U.S. most affected by feedlot particulate emissions lie in southern California, Arizona, and the panhandle region of Texas. The period of dust problems occurs mainly during the dry season, from April through August.

Ammonia is emitted as the predominant volatile product, constituting 70% to 90% of the total gaseous emissions investigated (methane excluded), and contributing to odoriferous emissions. Gaseous, odoriferous emissions are the result of anaerobic decomposition and volatilization of wastes from beef cattle.

The emissions for the cattle feeding industry in 1972 were 20,500 metric tons[a] (22,600 tons) of total suspended particulates. Ammonia emissions were 3,480 metric tons (3,840 tons). Total amine and sulfur compound emissions were 139 metric tons (153 tons) and 522 metric tons (575 tons), respectively.

Emissions from the beef cattle feeding industry constituted 0.11% of the national emissions of total suspended particulates. Four states had particulate emissions from beef cattle feedlots which exceeded 1.0% of the total suspended particulate emissions in each state. These states were Arizona (7.7%), New Mexico (1.5%), Colorado (1.4%), and Nebraska (1.3%). Nine other states exceeded 0.1% of the state totals.[b]

The source severity, S, was defined to indicate the hazard potential of the emission source:

$$S = \frac{\overline{\chi}}{F} \qquad (1)$$

where $\overline{\chi}$ is the time-averaged maximum ground level concentration to which a population may be exposed of each pollutant emitted from a representative beef cattle feedlot, and F is the primary ambient air quality standard for criteria pollutants (SO_x, NO_x, CO, hydrocarbons and particulates) or a modified threshold limit value (i.e., TLV® • 8/24 • 1/100) for noncriteria pollutants.

[a]1 metric ton = 10^6 grams = 2,205 pounds = 1.1 short tons (short tons are designated "tons" in this document); other conversion factors and metric system prefixes are presented in Section IX.

[b]NEDS totals do not include beef cattle feedlots or most other fugitive sources.

The representative source was defined as a feedlot of 8,000-head capacity on 0.11 km^2 (27.5 acres), feeding and marketing 14,800 head per year, and located in a dry climate (south-western U.S.) during the dry season in order to approximate worst-case conditions. The particulate severity of this source was 0.17; the ammonia severity was 0.033; the total amines severity was 0.00057; and the total sulfur compounds severity was 0.013. The distribution of source severities for particulate emissions from beef cattle feedlots in the dryland states showed that nearly 50% of all such feedlots have a severity $\leq$0.1 and 90% have a severity <0.16. There is no population affected above a severity of 1.0.

Specific air pollution control techniques for cattle feedlots have been established by some state regulatory agencies for odors. With the exception of good housekeeping activities, no specific present or future control techniques are under consideration. From the literature surveyed it is obvious that particulate, gaseous and odoriferous emissions from beef cattle feedlots can be controlled by conventional methods now available. These simple methods and procedures require an expenditure of managerial dedication and expertise as well as the monetary investment to purchase, install and maintain such systems.

The cattle feeding industry is presently growing at the rate of 4.5% per year due to the strong demand for beef, but this is expected to slow down in the mid-1970's. The trend of the industry is toward larger concentrations of beef animals and fewer feedlots. The growth factor for the industry (1978 emissions/1972 emissions) is projected (2.0% growth per year) to be 1.13.

SECTION III

SOURCE DESCRIPTION

A. PROCESS DESCRIPTION

1. Emission Sources

A beef cattle feedlot is an area within which beef animals are confined for finish feeding, with grain and/or forage that is transported to the animals for the purpose of fattening prior to marketing. The beef cattle industry can be divided into several stages; calf production, backgrounding, finish feeding, and slaughtering. Production of beef calves usually consists of raising calves to weaning weights of 145 kg to 218 kg (320 lb to 480 lb) as part of a range-pasture cow-calf program.

Common methods of growing out or backgrounding the calves from weaning to weights of 250 kg to 320 kg (550 lb to 700 lb) include: (1) grazing them on range pasture, small grain pastures, or corn or sorghum stalks and other crop aftermath; and (2) backgrounding the calves in feedlots, where they are fed mostly harvested roughage with a little grain. Development from newborn calf to adult beef animal ready for finish feeding requires approximately 20 months.

During the finish feeding stage, the beef cattle, which are either steers (castrated males) or heifers (young females that have never calved), are placed in feedlots and fed a high energy ration consisting mostly of feed grains for about 120 to 150 days until they reach slaughter condition and weight, which is about 500 kg (1,100 lb). This involves over 146,000 feedlots which range from several-head up to 100,000-head capacity and which market over 2.5 x 10^7 cattle each year.

The processing and selling phase involves 2,400 meat packing plants that process over 3.0 x 10^7 cattle each year. After 26 months, the cycle is completed.

In the U.S., 65% of the cattle were fed in lots which had a capacity of 1,000 head or more.[1] There were 2,040 such feedlots in 1973. These feedlots were investigated for atmospheric emissions in this study.

In all but rare cases, the feedlot is open to the atmosphere. The animal density on the feedlot is generally in the range of 12,500 to 125,000 head/km^2 (50 to 500 head/acre), or 75 to 7 m^2/head (800 to 80 ft^2/head). During its stay in a feedlot a beef animal will produce over 450 kg of manure on a dry weight basis. Wet manure production is about 27 kg/day (60 lb/day), usually deposited on less than 20 m^2 of surface.

Air pollution from feedlots consists of odors, dust, and ammonia. Fugitive dust is emitted from the open feedlot pens via wind forces acting on the surface, cattle movement over dried surfaces, and access alleyway vehicular traffic. Particulates are composed of soil dust and dried manure. Gaseous emissions evolve from wet manure and urine deposited in the pens. Odor may be attributed to both. Feedlot pens

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[1]Number of Cattle Feedlots and Fed Cattle Marketed -- By Size and Feedlot Capacity, by States. Crop Reporting Board. Statistical Research Service, U.S. Department of Agriculture. Washington. 1962 up to 1973.

are cleaned regularly to remove cattle wastes, but often these wastes are temporarily stockpiled on another open site. Particulate and gaseous emissions occur by evolution and wind force from these stockpiles.

Old established feeding areas, such as the Corn Belt states and northeastern Colorado, have little difficulty disposing of manure, but newer feeding areas such as southern California and the panhandle of Texas do encounter problems. Cattlemen in the latter areas had preferred to build mountains of manure, but the advent of fertilizer shortages has resulted in this manure becoming saleable as a soil conditioner/fertilizer.

The general method of manure disposal is to spread the solid manure on adjacent feed grain production, although other methods are used which vary from location to location as illustrated in Table 1.[2]

Table 1. DISPOSAL OF BEEF CATTLE WASTE[2]

State	Feeders reporting methods of disposal, % of total[a]					
	Solids spread on place	Slurry or spray	Lagoon	Sold	Dumped on wasteland	Incinerated, limed, or pitted
California	75.2	4.4	4.3	6.5	17.2	6.1
Colorado	88.2	1.6	0.4	2.7	6.7	0.7
Illinois	97.0	2.5	0.3	0.7	1.9	0.2
Iowa	97.8	2.0	0.5	0.6	1.1	0.3
Kansas	88.7	4.6	2.3	3.2	9.1	1.8
Nebraska	93.9	2.4	1.3	1.0	4.8	0.8
Texas	59.6	11.7	11.8	13.4	38.5	11.8

[a]Totals may not add up to 100% due to the reporting of more than one method per feeder.

[2]Census of Agriculture, 1969. Volume V, Special Reports. Part 9, Cattle, Hogs, Sheep, Goats. Washington, U.S. Bureau of the Census, 1973. 667 p.

Manure removal frequencies are dictated in part by climatic conditions, animal comfort, labor scheduling, and air and water pollution potentials. Usually, however, solid wastes are collected from the feedlot surface after each pen of cattle has been shipped, which is approximately twice per year.

The magnitude of the potential of feedlot surfaces for gaseous atmospheric contamination with nitrogen compounds can be rated in the estimate that 360 cattle on a 4,000 m^2 lot annually deposit 10.9 metric tons (12 tons) of urea-N_2 in urine. This is about half of the total nitrogen that cattle excrete. The urea in urine is rapidly hydrolyzed to ammonia, up to 90% of which can be volatilized.[3]

2. Source Composition

The source of the particulate and gaseous emissions from beef cattle feedlots is the open feedlot pen surface, which is usually a native soil surface but can be a concrete surface. Concrete surfaces facilitate waste removal and aid in channeling and controlling runoff problems. However, few feedlots have had the capital necessary for such an investment. Manure from the animals accumulates rapidly on the feedlot surface due to high animal density (up to 125,000 head/km^2 or 500 head/acre), and the feedlot surface becomes a padded mixture of soil and manure because of animal movement. Although the pens are cleaned regularly, the manure pad remains at a thickness of 30 mm to 80 mm (1 in. to 3 in.). Under warm, dry weather conditions the feedlot surface becomes a dry mixture/loose pad of soil and manure.

[3]Stewart, B. A. Volatilization and Nitrification of Nitrogen from Urine Under Simulated Cattle Feedlot Conditions. Environmental Science and Technology. 4:579-582, July 1970.

The physical, chemical, and biological characteristics and composition of cattle feedlot wastes cannot be readily determined because the characteristics of animal wastes are affected by the physiology of the animal, the feed ration, and environmental conditions to which the animal is subjected.[4] Although the characteristics of fresh beef cattle wastes may be of general interest, they are of minimal value in the assessment of air emissions from beef cattle feedlots. The quantities and characteristics of the wastes deposited on the feedlot surface bear only a slight resemblance to the emissions which actually enter the environment outside the feedlot.

Data on the surfaces of beef cattle feedlots in California are shown in Tables 2 and 3.[5] Table 2 contains a proximate constituent analysis, with phosphorus and potassium included, from three different regions of multiclimatic California. Little difference in surface constituents can be noted between regions. Older feedlot pens have slightly more organic matter, nitrogen, and protein accumulated on the surface than newer feedlot pens. Newer feedlots have 3% to 8% more ash content than older feedlots due to added ash present in the newer feed mixtures.

Table 3 displays the chloride salt content and the nitrate-nitrogen content of the same California feedlots. Chloride salt contents varied widely throughout California, but nitrate-nitrogen compositions in feedlot surface soils were

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[4]Taiganides, E. P., and T. E. Hazen. Properties of Farm Animal Excreta. Transactions, American Society of Agricultural Engineers. 9:374-376, 1966.

[5]Elam, C. J., J. W. Algeo, T. Westing, and A. Martinez. Feedlot Air, Water and Soil Analysis. California Cattle Feeders Association. Bakersfield. Bulletin D. June 1972. 75 p.

Table 2. PROXIMATE CONSTITUENTS, PHOSPHORUS, AND POTASSIUM IN THE DRY MATTER OF FEEDLOT PEN SURFACE SOILS IN CALIFORNIA AREAS[5]
(percent by weight)

Item	Central valley		North and central coast		Desert area		Mean	
	Old[a]	New[b]	Old	New	Old	New	Old	New
Protein	14.23	13.20	13.95	13.71	16.52	15.42	14.90	14.11
Fat	1.06	0.76	1.41	1.08	2.34	1.40	1.60	1.08
Ash	36.80	44.30	43.86	46.60	28.63	34.28	36.43	41.73
Fiber	17.67	18.14	15.23	14.79	18.29	17.28	17.06	16.74
Nonfibrous elements	30.24	23.59	25.56	23.82	34.21	31.63	30.00	26.35
Phosphorus	0.72	0.64	0.56	0.68	0.82	0.78	0.70	0.70
Potassium	2.34	2.42	2.03	1.89	3.07	2.43	2.48	2.25
Nitrogen	2.27	2.09	2.23	2.19	2.63	2.47	2.38	2.25
Organic matter	63.20	55.70	56.14	53.40	71.36	65.72	63.57	58.27

[a]Old feedlot pens (more than 10 years of use).
[b]New feedlot pens (less than 10 years of use).

much the same, probably due to the addition of organic matter to the soil. No ammonia-nitrogen was detected. Analyses were performed using boric acid absorption followed by: titrimetric analysis of the acid for ammonia-nitrogen, the potentiometric method for chlorides, the phenoldisulfonic acid method for nitrate-nitrogen, a colorimetric method for phosphorus, atomic absorption spectrophotometry for potassium, and AOAC analytical methods for proximate constituents.

Table 3. CHLORIDE SALT, NITRATE-NITROGEN AND AMMONIA-NITROGEN CONTENT OF SURFACE SOIL SAMPLES FROM 26 CALIFORNIA FEEDLOTS[5]
(dry basis)

Component	Mean	Standard deviation	Range
Chlorides	0.54%	1.57%	0.0 to 7.48%
Nitrate-nitrogen (as NO_3)	0.01683%	0.00597%	0.00697 to 0.03305%
Ammonia-outcrops (as NH_4)	-[a]	-[a]	-[a]

[a]None detected.

B. FACTORS AFFECTING EMISSIONS

A schematic diagram of a beef cattle feedlot system is presented in Figure 1. The major factors affecting the emissions which were studied in this assessment are indicated by superscripts and footnotes in Figure 1.

Of the factors indicated in Figure 1 the humidity, precipitation and temperature can be combined into one factor which has known values for different regions of the U.S. This factor is Thornthwaite's precipitation-evaporation (P-E) index. The P-E index is determined from total rainfall and

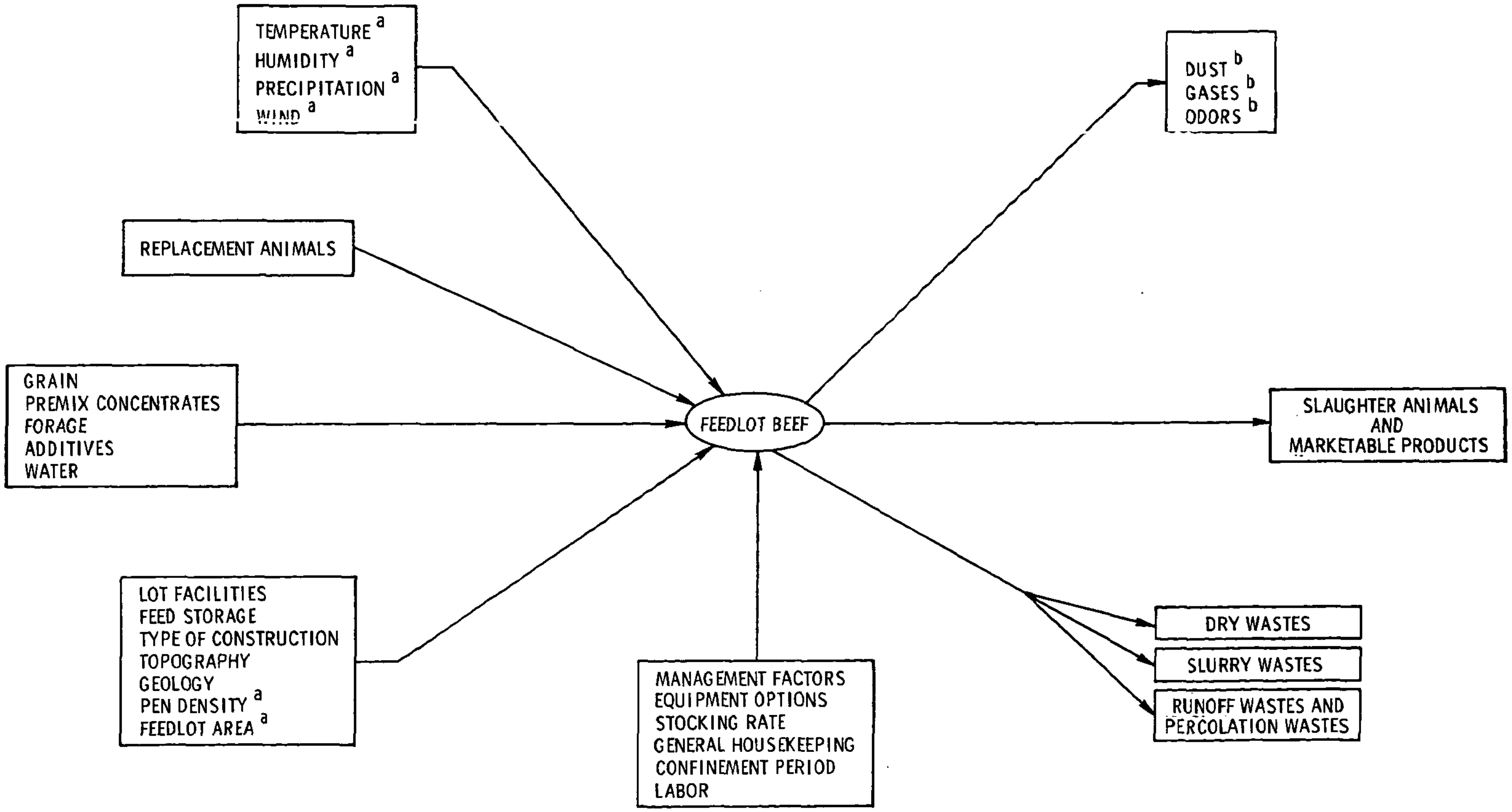

Figure 1. Schematic of an animal feedlot system

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[a] Major factors affecting atmospheric emissions.

[b] Emissions studied in this assessment.

mean temperature.[6] A map of P-E values for state climate divisions is shown in Figure 2. The P-E index is calculated as follows:

$$\text{Monthly P-E ratio} = 11.5\left(\frac{P_M}{T_M-10}\right)^{10/9} \qquad (2)$$

$$\text{P-E index} = \sum_{i=1}^{12} (\text{Monthly P-E ratios}) \qquad (3)$$

where[a] P_M = monthly precipitation, in.
T_M = monthly mean temperature, °F, adjusted to a constant of 30°F for all values below 30°F

Particulate emissions from feedlots are affected by wind speed. This factor includes two separate but indistinguishable mechanisms: (1) cattle movement in the pen stirs up dust which the wind then carries; and (2) the wind itself erodes the feedlot surface. Both of these mechanisms must be considered as one measurable transport factor: mean wind speed. Feedlot size (area) affects particulate emissions directly; the larger the feedlot, the greater the emissions. Pen density, in head per area, has an inverse relationship to particulate emissions. As more cattle become crowded closer together, their waste production tends to keep the pens more moist and less susceptible to dust production.

Depending upon location of the feedlot, dust problems from dry weather occur for a minimum of 60 days to more than 120

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[a] Nonmetric units are designated for Equation 2 to conform to the system of units reported by the author[6] and commonly used.

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[6] Thornthwaite, C. W. Climates of North America According to a New Classification. Geographical Review. 21:633-655, 1931.

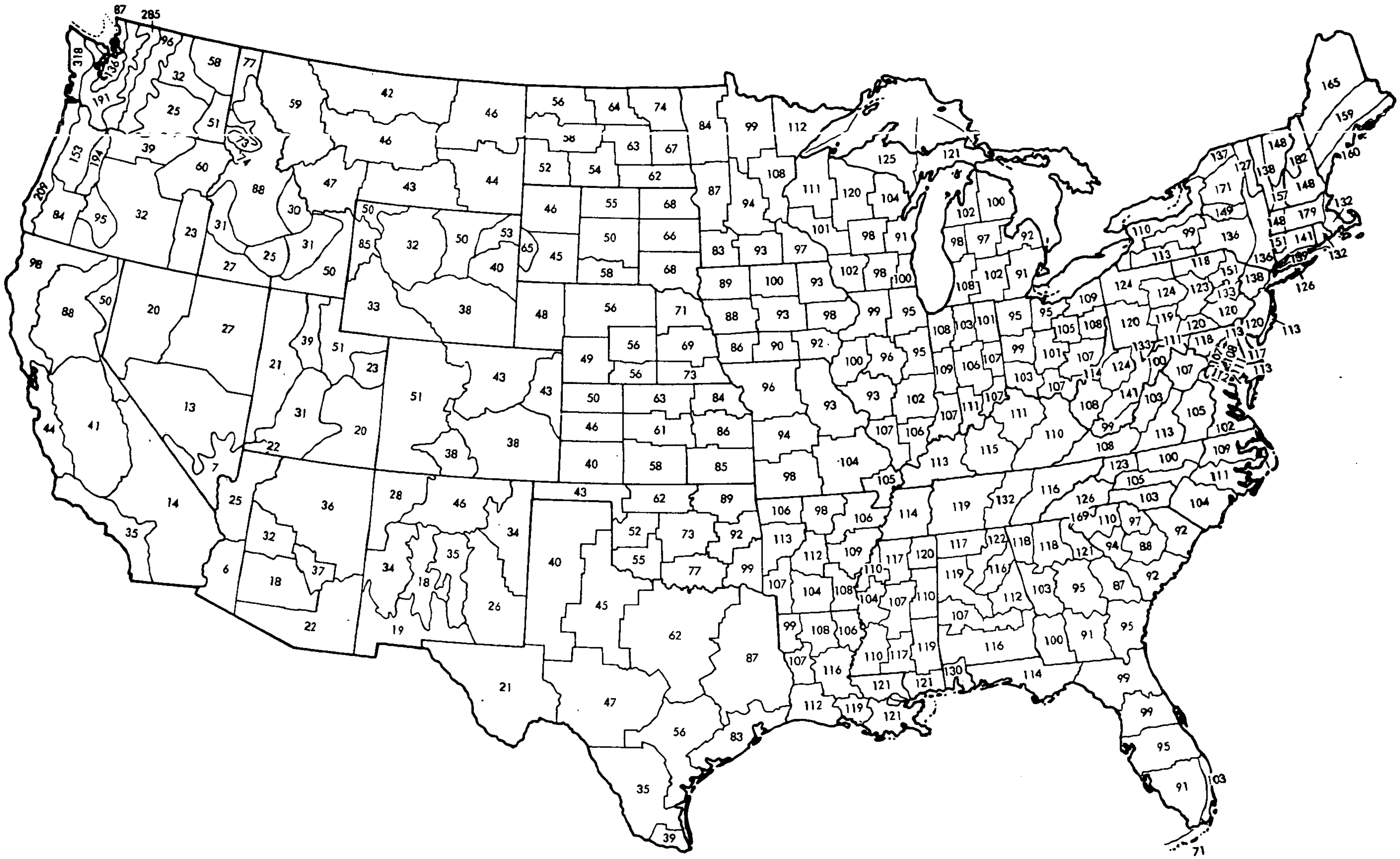

Figure 2. Map of P-E values for state climatic divisions[6]

days annually. Usually this occurs from late spring to midsummer in the Southwest. Dust control is a periodic rather than perennial need.

Ammonia, evolved by anaerobic manure decomposition, is the most widely studied odorous gas. Ammonia is also evolved or volatilized from the urine which beef animals excrete and, thus, is emitted whether aerobic or anaerobic digestion of feedlot wastes occurs. The evolution of ammonia was investigated not only because of its contribution to the odoriferous mixture of products emitted, but also because of the potential for absorption by nearby surface water bodies.

The factors affecting gaseous and odoriferous emissions other than ammonia from volatilization and decomposition of feedlot surfaces and manure piles are not necessarily the same from one location to another. The feces, urine, and feed deposited on the feedlot undergo continuing physical, chemical, and biological change. Research has shown[7] that changes in housekeeping techniques will result in changes in the volatile, odoriferous products emitted. The extent of such changes on feedlot surfaces is variable from one location to another and from time to time at the same location. Natural drying can be an important factor at one location and time but not necessarily at another place or time. Biological decomposition may proceed under either aerobic or anaerobic conditions (or both) at different times or locations on the same feedlot.

Odor from a feedlot occurs in three places:

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[7]Narayan, R. S. Identification and Control of Cattle Feedlot Odors. Texas Technological University. Lubbock. M.S. thesis. 1971. 41 p.

- Ammonia escapes from the dry surface of the feedlot
- Complex odorous compounds (mercaptans, amines) from anaerobic metabolism come from the solid manure beneath the surface of the feedlot
- Odorous compounds are emitted from the runoff holding ponds because of anaerobic decomposition.

In general, anaerobic decomposition causes feedlot odor. Cattle manure contains the energy for metabolism. Microorganisms in the manure accomplish this metabolic process which converts complex carbohydrates, proteins, and fats into simpler compounds. When oxygen is present, the end basic products of metabolism are heat, CO_2 and H_2O. This process, called aerobic metabolism, depends upon temperature, oxygen, and moisture. Some management of the last two factors is possible for beef cattle feedlots.

In order to prevent odor, the oxygen transfer rate into manure must exceed the bacterial demand.[8] Microorganisms consume oxygen in proportion to their growth rate, which depends upon the amount of nutrients. The nutrients in manure may result in an oxygen demand greater than the rate of transfer. When this occurs, anaerobic microorganisms take over and metabolism can be as much as 0.073 kg/day per cow, or 73 kg/1,000 head per day.[3] Figure 3 describes the biological (inorganic-organic) phase of the nitrogen cycle that is possible on a feedlot surface.

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[8]Paine, M.D. Feedlot Odor. In: Great Plains Beef Cattle Feeding Handbook. Cooperative Extension Service - Great Plains States, 1972. 2 p.

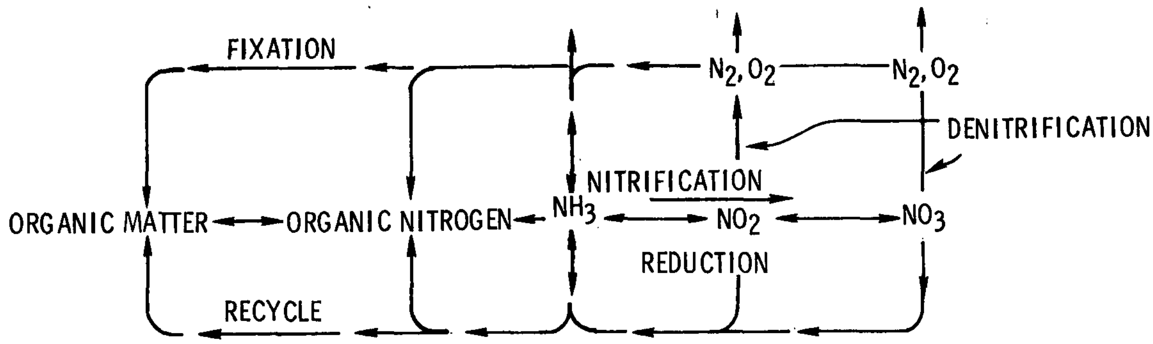

Figure 3. Feedlot nitrogen cycle

The optimum conditions for the production of odoriferous gases consist of a fairly deep accumulation of manure with the amount of moisture equal to that of a slurry. Unfavorable weather conditions, poor runoff drainage and low spots in pens ("ponding") will contribute to the formation of slurry conditions. Feedlot operators consider unfavorable weather conditions as similar to "upset" conditions in a chemical plant; namely, inevitable, intermittent, and generally unpredictable.

The cleaning of solid wastes from feedlot surfaces causes odor emissions because of the release of anaerobic layers at the bottom of the feedlot manure pack. Unless the manure surface becomes a slurry, most operators will not remove the manure more often than one to three times a year.

Feedlot disturbances, such as mounding and manure removal, greatly increase the release of ammoniacal compounds to the atmosphere. Also, precipitation seems to be followed by increased ammonia gas release.[9] In recent research the data

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[9]Elliott, L. F., G. E. Schuman, and F. G. Viets, Jr. Volatilization of Nitrogen-Containing Compounds from Beef Cattle Areas. Soil Science Society of America Proceedings. 35:752-755, 1971.

collected indicate that ammonia evolved from a feedlot surface is closely associated with the temperature of the surface. Humidity also had a direct effect on ammonia emissions; following a rainy day, the evolution from an initially dry surface nearly tripled.[10]

While temperature, oxygen and moisture content affect odor emissions, wind velocity, atmospheric stability and humidity influence the transport of odoriferous gases. The diffusion of odors from a feedlot is commonly accepted to be similar to that of plume diffusion. However, some researchers[11,12] suggest that there can be rings of odor around a feedlot, particularly in the case of heavier molecular weight compounds such as skatole and indole. These odor rings are similar to the rings formed by dropping a pebble in a puddle, the quantity and quality of the smell depending on the distance to the source, particularly under atmospheric inversion conditions.

Improved management practices for the control of feedlot odor can only be empirical until the factors of quantitative odor determination and olfactory response are better understood. A principal problem associated with odor analysis is that of sampling, because compounds beyond the minimum analytical detection limit can be odorous. In addition, odorous compounds can behave in an additive manner, i.e., an odor

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[10]Miner, J. R. Evaluation of Alternative Approaches to Control of Odors from Animal Feedlots. Idaho Research Foundation, Inc. Moscow. Grant No. ESR 74-23211, National Science Foundation. December 1975. 83 p.

[11]Personal communication. Dr. R. M. Bethea, Department of Chemical Engineering, Texas Technological University. Lubbock. November 1974.

[12]Personal communication. Dr. J. M. Sweeten, Extension Agricultural Engineer, Texas Agricultural Extension Service, Texas A&M University System. College Station. October 1974.

may be detected when individual compounds are present in subthreshold concentrations. In any odor study, analytical evaluation must be correlated with sensory evaluation.

C. GEOGRAPHICAL DISTRIBUTION

The seven leading beef cattle feeding states in order of rank are Texas, Nebraska, Iowa, Kansas, Colorado, California, and Illinois. They comprised nearly 75% of the U.S. fed cattle marketed in 1973.[1] In 1963, this value for these states was 67%. Generally, the feedlots are not located in or close to major metropolitan areas, but in low population density regions with access to major truck routes.

Because of the abundance and closeness of feed grain supplies, cattle feeding is concentrated in four areas. One area is in southern California and Arizona, where about 3×10^6 head are fed annually. The area that has grown most spectacularly is centered in the panhandles of Texas and Oklahoma, extending into New Mexico and southwestern Kansas, where more than 5×10^6 cattle are fed annually. The third area of concentrated cattle feeding lies from eastern Colorado through Nebraska to the South Dakota line. About 6×10^6 cattle are fed there yearly. The fourth area is in the central corn belt, where about 8×10^6 head are fed annually, mostly on small (less than 1,000 head) lots.

Figure 4 displays the distribution of cattle, other than milk cows, from which feeder cattle are drawn to feedlots.[13] Figure 5 locates the areas where finish feeding of cattle occurs.[13]

[13]Census of Agriculture, 1969. Volume V, Special Reports. Part 15, Graphic Summary. Washington, U.S. Bureau of the Census, 1973. 145 p.

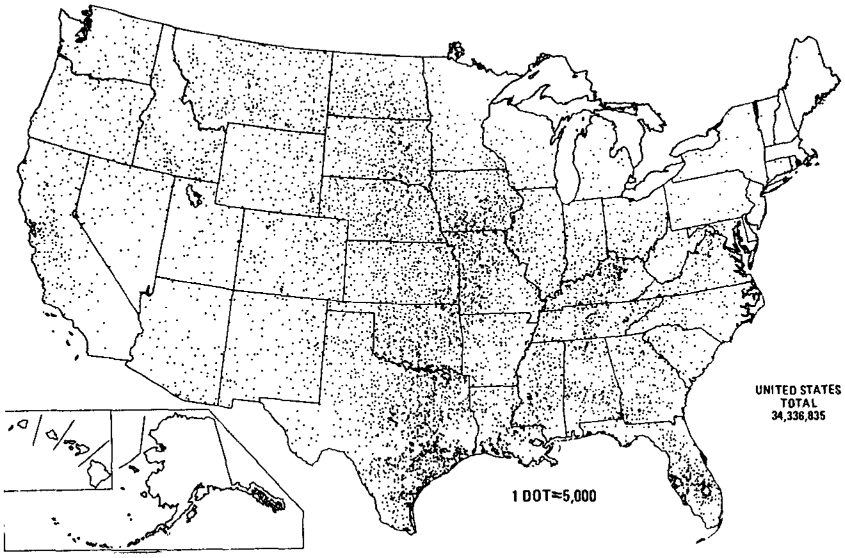

Figure 4. Cows other than milk cows, 1969[13]

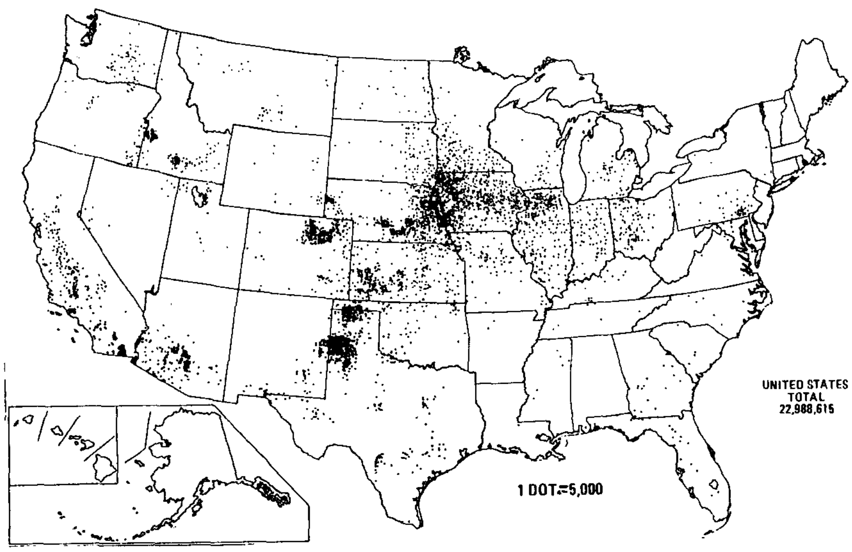

Figure 5. Cattle, excluding calves, fattened on grain concentrates and sold for slaughter, 1969[13]

SECTION IV

EMISSIONS

A. SELECTED POLLUTANTS

Fugitive dust from feedlot surfaces is considered a "nuisance" dust, in contrast to fibrogenic dusts which cause scar tissue to be formed in lungs when inhaled in excessive amounts. Nuisance dusts have a long history of little adverse effect on lungs and do not produce significant organic disease or toxic effect when exposures are kept under reasonable control. The nuisance dusts have also been called (biologically) "inert" dusts, but the latter term is inappropriate to the extent that there is no dust which does not evoke some cellular response in the lung when inhaled in sufficient amount.[14]

A threshold limit value (TLV) of 10 mg/m^3 is assigned to "inert" fugitive dust. The fact that fugitive dusts, or particulate pollutants, are one of five criteria pollutants supplies an additional basis for their selection.

Although numerous compounds which comprise the gaseous emissions from cattle feedlots have been identified, because

[14]TLV's® Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes for 1975. American Conference of Governmental Industrial Hygienists. Cincinnati, 1975. 97 p.

ammonia predominates in mass (methane excluded), it was selected for quantitative determination in this source assessment. Although probably not one of the prime odorants associated with feedlots, ammonia has been measured and used as an indicator of odor transport.[10] Table 4 lists the compounds which have been identified as odor contributors from cattle feedlots. The TLV for ammonia is currently 18 mg/m^3; it has been undergoing reduction over the last 15 years. In 1962, it was 70 mg/m^3; in 1963 it was changed to 35 mg/m^3; and its present value of 18 mg/m^3 was established in 1973.

Based on preliminary field sampling results (Appendix C), total amine emissions and total sulfide and mercaptan (sulfur compounds) emissions were also included for assessment. A TLV of 35.7 mg/m^3 was assumed for amines. A TLV of 5.8 mg/m^3 was assumed for sulfur compounds (Appendix A).

B. MASS EMISSIONS

The emission rates for particulates, ammonia, amines, and sulfur compounds have been estimated for dry season conditions at average-sized California feedlots (Appendix A). Because data on particulate emissions were available only for California, annual statewide emission estimates for all other states were made by dividing the number of fed cattle marketed in California in 1972 by the number of over 1,000-head capacity feedlots. This resulted in an average feedlot size (number of fed cattle marketed in 1 year per feedlot). Then, dividing the average feedlot size into the number of fed cattle marketed for each state yielded the number of average-sized feedlots.

Thornthwaite's P-E index[6] was used to correct emission rates for geographical differences in soil moisture, in a manner

Table 4. COMPOUNDS IDENTIFIED IN ODORS FROM CATTLE FEEDLOTS

Pollutant	TLV, μg/m³	(ppm)	Odor threshold,[15,16] ppm	
Ammonia	18	(25)	46.8;	0.037
Methylamine[17]	12	(10)		0.021
Dimethylamine[17]	18	(10)		0.047
Trimehtylamine[17]				0.00021
Ethylamine[17]	18	(10)		
Diethylamine[17]	75	(25)		
Triethylamine[17]	100	(25)		
Isopropylamine[17]	12	(5)		
Pyridine[18]	15	(5)		0.021
Skatole[7,19]				0.000000075
Hydrogen sulfide[18,20]	15	(10)		0.0047
Ethyl mercaptan[18]	1	(0.5)	0.001;	0.000016
Tert.-butyl mercaptan[18]	1.5	(0.5)		0.00009
Acetic acid[18]	25	(10)		1.0
Butyric acid[18]				0.001
Formaldehyde[18]	3	(2)		1.0
Indole[7,19]				
n-Propylamine[a]				
n-Butylamine[a]				
n-Hexylamine[a]				
Methanol[7,19]	260		100	
Ethanol[7,19]	1,900		10	
i-Butyraldehyde[7]				
Isopropanol[7,19]	980		40	
Isobutyl acetate[7,19]	950		4	
Ethyl formate[7,19]	300			
Propionaldehyde[7]				
Methyl acetate[7,19]	610		200	
Isopropyl acetate[7,19]	950		30	
Isopropyl propionate[7,19]				
Carbonyl sulfide[20]				

[a]Identified by presurvey sampling (see Appendix C).

Note: Blanks indicate data not reported.

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[15]Leonardos, G., D. Kendall, and N. Barnard. Odor Threshold Determinations of 53 Odorant Chemicals. Journal of the Air Pollution Control Association. 19:91-95, February 1969.

[16]Summer, W. Methods of Air Deodorization. New York, Elsevier Publishing Co. 1963. p. 46-47.

[17]Mosier, A. R., C. E. Andre, and F. G. Viets, Jr. Identification of Aliphaic Amines Volatilized from Cattle Feedyard. Environmental Science and Technology. 7:642-644, July 1973.

[18]Stephens, E. R. Identification of Odors from Cattle Feedlots. California Agriculture. 25:10-11, January 1971.

[19]White, R. K., Ohio State University, and J. R. Ogilive, McGill University. Developments in the Control of Air Pollution Problems Associated with Livestock Production. (Paper No. 73-103, presented at the 66th Annual Meeting of the Air Pollution Control Association. Chicago. June 24-28, 1973.) 21 p.

[20]Elliott, L. F., and T. A. Travis. Detection of Carbonyl Sulfide and Other Gases Emanating from Beef Cattle Manure. Soil Science Society of America Proceedings. 37(5):700-702, September-October 1973.

analogous to that used in an earlier study[21] which estimated emissions inventory. This correction factor consists of dividing the emission rate of a particular pollutant by the term $(P\text{-}E/25)^2$ for each state to be computed. A P-E index of 25 was chosen to represent the dry season conditions experienced when the pollutant measurements were taken. The methodology behind this correction factor is discussed in the earlier study.[21] An additional correction factor which relates the number of dry days, d, per year (i.e., average number of days with less than 0.25 mm [0.01 in.] of precipitation) was included, simply by multiplying by the term d/365. A summarization of the calculation procedure is outlined below:

$$\frac{\left(\begin{array}{c}\text{Fed cattle marketed}\\ \text{for state in 1972}\end{array}\right)}{\left(\begin{array}{c}\text{California}\\ \text{fed cattle marketed}\end{array}\right)\Big/\left(\begin{array}{c}\text{Number}\\ \text{of California}\\ \text{feedlots}\end{array}\right)} \times \left(\begin{array}{c}\text{Emissions of}\\ \text{pollutant for}\\ \text{California feedlot/yr}\end{array}\right)$$

$$\times \frac{(d/365)}{(P\text{-}E/25)^2} = \text{Statewide emissions in 1972} \quad (4)$$

State and national emissions and emission burdens (percent of total emissions per state) are given in Table 5. Naturally, states with the driest climates produce more particulate dust emissions and evaporate more ammonia and related gases from feedlot surfaces. All estimates assume control technology in operation in dry climate cattle feeding states because cattle feeders in those areas routinely sprinkle water for dust suppression if only to ease cattle discomfort and improve weight gain performance. Since a decrease in particulate

[21] Cowherd, C. C., C. M. Guenther, and D. D. Wallace. Emissions Inventory of Agricultural Tilling, Unpaved Roads and Airstrips, and Construction Sites. Midwest Research Institute. Kansas City. Environmental Protection Agency, EPA-450/3-74-085 (PB 238 919). November 1974. 41 p.

Table 5. STATE AND NATIONAL EMISSIONS, 1972

State	Fed cattle marketed in 1972[1]	Number of 1,000-headlots in 1972[1]	Number of California-sized lots	State-wide P-E index	Number of dry days per year[22]	1972 Particulate emissions, metric tons	Percent of total emissions	1972 Ammonia emissions, metric tons	1972 Amine emissions, metric tons	1972 Sulfur compound emissions, metric tons
Pennsylvania	9,000	3	0.61	120	232	10.9	0.0006	0.24	0.0096	0.036
Ohio	62,000	28	4.20	105	225	95.9	0.005	2.10	0.084	0.31
Indiana	70,000	24	4.74	106	244	107	0.014	2.49	0.10	0.37
Illinois	117,000	60	7.92	95	250	244	0.021	5.33	0.21	0.80
Michigan	51,000	25	3.45	93	218	97.4	0.014	2.13	0.085	0.32
Wisconsin	26,000	13	1.76	98	244	49.6	0.012	1.08	0.043	0.16
Minnesota	52,000	35	3.52	106	241	83.4	0.031	1.82	0.073	0.27
Iowa	430,000	170	29.1	93	260	971	0.45	21.3	0.85	3.20
Missouri	48,000	26	3.25	95	263	106	0.052	2.13	0.092	0.32
North Dakota	25,000	18	1.69	63	269	127	0.16	2.78	0.11	0.42
South Dakota[a]	107,000	54	7.24	64	272	61.2	0.12	11.55	0.46	1.73
Nebraska[a]	2,375,000	543	161	66	267	1,260	1.30	237	9.48	35.6
Kansas[a]	1,916,000	131	130	73	282	891	0.26	168	6.72	25.2
Oklahoma[a]	579,000	41	39.2	77	284	240	0.26	45.5	1.82	6.82
Texas[a]	4,210,000	230	285	79	290	1,700	0.31	320	12.8	48.0
Montana[a]	221,000	72	15	51	266	195	0.07	36.9	1.48	5.53
Idaho[a]	391,000	88	26.5	47	274	418	0.75	79.1	3.16	11.9
Colorado[a]	2,118,000	191	143	42	278	2,830	1.39	536	21.4	80.4
New Mexico[a]	369,000	43	25	25	307	1,540	1.48	291	11.6	43.7
Arizona[a]	890,000	46	60.2	21	330	6,020	7.65	1,137	45.5	170
Washington	330,000	25	22.3	129	227	339	0.21	7.40	0.30	1.11
Oregon	118,000	30	7.99	153	213	80.8	0.047	1.76	0.070	0.26
California[a]	2,054,000	139	139	43	314	2,990	0.30	566	22.6	84.8
U.S. Total	16,568,000	2,035	1,121.7			20,500	0.11	3,480	139	522

[a]Dryland state; particulate control technology used.

[22]Statistical Abstract of the United States: 1973 (94th Edition). Washington, U.S. Bureau of the Census, 1973. p. 187.

levels of about 900% is possible (see Section V.A.1), a decrease of 400% (factor of 5) under uncontrolled conditions was assumed for those dryland cattle feeding states.

Particulate emissions from the beef cattle feeding industry were 20,500 metric tons in 1972, and comprised 0.11% of national emissions of total suspended particulates. The emission burdens were determined by dividing the statewide emissions due to beef cattle feedlots by the state total emissions of a pollutant as furnished by the National Emissions Data System (NEDS) plus the statewide emissions due to beef cattle feedlots. (The NEDS does not presently include beef cattle feedlots in its inventory of source types, so a truer emission burden is determined in this manner.) The emission burdens for many of the southwestern states are artificially high and misleading, also, because the NEDS does not include most open and fugitive dust sources in its compilation. This is why many western states have low emission totals due to industry, yet have background particulate levels chronically above ambient air quality standards.

Four states had particulate emissions which exceeded 1.0% of the state total suspended particulate emissions: Arizona (7.7%), New Mexico (1.5%), Colorado (1.4%), and Nebraska (1.3%). Nine other states had particulate emission burdens which exceeded 0.1% (Table 5).

Ammonia emissions from beef cattle feedlots were 3,480 metric tons in 1972. The leading states were those with dry climates and/or a large beef feeding capacity. No control measures were assumed for gaseous emissions.

C. DEFINITION OF REPRESENTATIVE SOURCE

The beef cattle feedlot representative of the industry was chosen as a worst-case example because of the available data (Appendix A). The representative feedlot is defined as one which fed and marketed 14,800 head in a lot with a capacity of 8,000 head on a square area of 111,300 m^2 (27.5 acres). The length of the sides of the feedlot is 330 m, which is taken to be the length of the line source of emissions (Appendix A). The representative feedlot is assumed to be located in a dry climate during the dry season, which simulates worst-case conditions.

The emission rate of total suspended particulates is 3.61×10^{-2} g/s-m; the ammonia emission rate is 1.36×10^{-3} g/s-m; the total amines emission rate is 5.44×10^{-5} g/s-m; and the total sulfur compound emission rate is 2.04×10^{-4} g/s-m (no estimations of uncertainty can be ascribed to these data).

The distance to the nearest neighbors is assumed to be 800 meters downwind because a feedlot of 8,000-head capacity is likely to have at least one section of land (1 square mile, or 640 acres) surrounding or adjacent to the feedlot for supplementary feed grain production and manure disposal.

D. ENVIRONMENTAL EFFECTS

1. Maximum Ground Level Concentration

The maximum time-averaged ground level concentration, $\overline{\chi}$, at the property edge of each pollutant resulting from the representative beef cattle feedlot was estimated by Gaussian plume dispersion theory. The concentration at the property edge (800 m) was taken to be the maximum ground level concentration to which a population could be exposed. The following formula was used for the calculation of $\bar{\chi}$:[23]

$$\bar{\chi} = \chi\left(\frac{t_0}{t}\right)^{0.17} = \left(\frac{t_0}{t}\right)^{0.17} \sqrt{\frac{2}{\pi}} \frac{Q_L}{u\sigma_z} \exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right] \quad (5)$$

where χ = concentration at property edge for a 3-min sampling time, g/s

t_0 = instantaneous averaging time, 3 min

t = averaging time used for ambient air quality standard, 24 hr

π = 3.14

Q_L = mass emission rate per length of a line source, g/s·m

u = average wind speed (4.47 m/s, national average)

σ_z = standard deviation in the vertical of the plume concentration distribution, m

H = effective height of emission, m

The effective height of emission was assumed to be 3.05 m (10 ft), a nominal amount for a ground level source, and the vertical dispersion coefficient, σ_z, was estimated from:[24]

$$\sigma_z = 0.113(x^{0.911}) \quad (6)$$

where x = downwind distance (800 m), and class C atmospheric stability is assumed (national average).

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[23]Turner, D. B. Workbook of Atmospheric Dispersion Estimates. U.S. Department of Health, Education, and Welfare, National Air Pollution Control Administration. Cincinnati. Public Health Service. Publication No. 999-AP-026. May 1970. 65 p.

[24]Eimutis, E. C., and M. G. Konicek. Derivations of Continuous Functions for the Lateral and Vertical Atmospheric Dispersion Coefficients. Atmospheric Environment. 6:859-863, November 1972.

2. Source Severity at Representative Feedlot

The maximum severity from beef cattle feedlots was determined for each pollutant emitted. The source severity is defined as the time-averaged maximum ground level concentration of a pollutant ($\bar{\chi}$) acting on a population divided by the hazard level of exposure for a particular pollutant (F). The hazard level, F, is defined as the primary ambient air quality standard for criteria pollutants (with the same averaging time as $\bar{\chi}$), or as a modified threshold limit value (TLV · 8/24 · 1/100) for noncriteria pollutants. The source severity equation (Equation 1, described earlier) is thus:

$$S = \frac{\bar{\chi}}{F}$$

The source severity for each pollutant emitted from a representative beef cattle feedlot is shown in Table 6. For total particulates the severity is greater than 0.1 but less than 1.0. It is emphasized that these calculations were based on the emission rates described in Appendix A and applied to a worst-case situation.

Table 6. SOURCE SEVERITY OF EMISSIONS FROM REPRESENTATIVE BEEF CATTLE FEEDLOT

Emission	Source severity
Total particulates	0.17
Ammonia	0.033
Amines	0.00057
Sulfur compounds	0.013

3. Distribution of Source Severities

Industry size and emission data were used to calculate source severities for particulate emissions from all feedlots in the dryland states of Arizona, California, Colorado, Idaho, Kansas, Nebraska, New Mexico, Oklahoma, and Texas. Figure 6 presents a plot of source severity against cumulative percent of feedlots having source severity less than or equal to the indicated value. The methodology used to generate this distribution was described in an earlier document.[25] The results indicate that, for particulate emissions, nearly 50% of all feedlots in these dryland states have a source severity less than or equal to 0.1 and 90% have a source severity less than 0.16. Particulate emissions are not recognized as a problem in states with wetter climates.

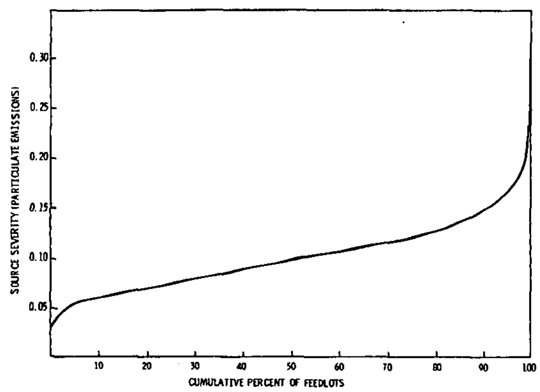

Figure 6. Beef cattle feedlots - source severity distribution

4. Affected Population

Affected population designates the average number of persons exposed to high concentrations (i.e., those for which $S > 1.0$) of a given emission from a given source. Since the source severity is less than 1.0 for each pollutant emitted from a representative beef cattle feedlot, the affected population is zero.

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[25]Eimutis, E. C., B. J. Holmes, and L. B. Mote. Source Assessment: Severity of Stationary Air Pollution Sources--A Simulation Approach. Monsanto Research Corporation. Dayton. Report No. MRC-DA-543. Environmental Protection Agency, EPA-600/2-76-032e. July 1976. 133 p.

SECTION V

CONTROL TECHNOLOGY

A. STATE OF THE ART

1. Dust Control

Currently there is no officially required air pollution dust control technology or methodology for beef cattle feedlots. Dust generated from feedlot surfaces depends upon the dryness of the area; hence, any method used to add moisture to pens is helpful in controlling dust levels. Natural phenomena such as rain or snow inhibit particulate dust emissions because, after precipitation occurs, the dust adheres to the moisture and becomes confined within the pen.

Dust control techniques for feedlots must prevent air entrainment of dust particles from the feedlot surface since it is not feasible to remove them after suspension in air. This can be effectively accomplished by maintaining sufficient moisture levels in the manure pad-feedlot surface.

Recent investigations[26] indicate that several methods can be effective in controlling feedlot dust emissions. Increasing

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[26] Elam, C. J., T. Westing, J. W. Algeo, and L. Hokit. Measurement and Control of Feedlot Particulate Matter. California Cattle Feeders Association. Bakersfield. Bulletin C. February 1971. 30 p.

cattle density has been shown to be promising with regard to particulate matter levels and cattle weight gain performance. Feed efficiency is improved and a lower cost of weight gain is found in higher density cattle lots. Soil moisture results indicate that high cattle density (6.5 to 7.5 m^2/head) increases soil moisture and this, in turn, controls dust emissions.

In dry weather, dust problems are noticed first in pens in which the moist manure pack has just been removed. Light replacement cattle produce only half as much manure moisture as slaughter-weight cattle. Animal spacing and body size control the quantity of moisture added to the feedlot surface in the form of manure and urine. The amount of moisture[27] (mm/day) generated in this manner is shown in Figure 7. A 454-kg steer at a spacing of 11.6 m^2/head (125 ft^2/head) directly produces about 0.71 m of moisture per year. This moisture, together with the water released through digestion of organic matter and precipitation, essentially offsets evaporation from a feedlot surface in a typical year in the Texas panhandle region. Whenever moisture produced by cattle or by precipitation is consistently less than the daily evaporation rate, dust emission problems will eventually follow.

High cattle density has a limiting factor, though, because the pens must be cleaned of waste more often, odor problems arise more often, and the health risks to the cattle rise.

While manure accumulations can be beneficial by storing moisture, dry and pulverized manure is a liability to dust control efforts because more moisture is required for dust

[27]Sweeten, J. M. Control of Dust from Cattle Feedlots. Texas Agricultural Extension Service. College Station. Publication No. GPE-7851. April 1974. 10 p.

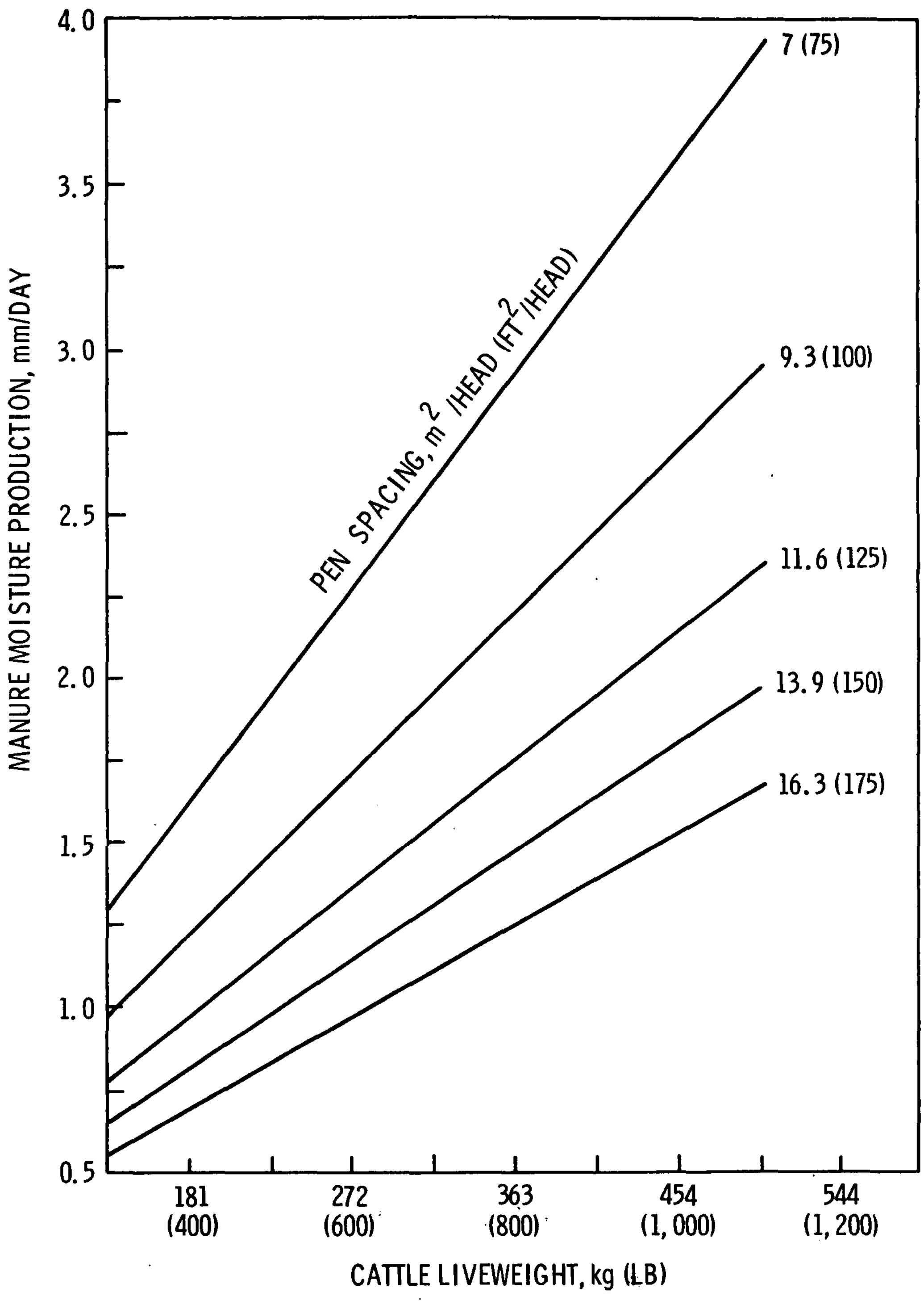


Figure 7. Amount of manure moisture produced by feedlot cattle of various sizes and at various pen spacings[27]

control than would be necessary if smaller accumulations were present. Thus, minimizing manure accumulation increases the effectiveness of dust control procedures. A maximum depth of loose manure of 20 mm to 80 mm (1 in. to 3 in.) is recommended.

The most common and effective method of dust control is application of water to the feedlot surface regardless of whether the pen is maintained with loose manure or scraped clean of manure. The rate of water application is critical in this method since such application involves a delicate balance between effective dust control and control of odors. The moisture content of the surface manure should be maintained at 25% to 40%, insofar as possible. The moisture content of the feedlot surface can be determined by the oven drying procedure.[27]

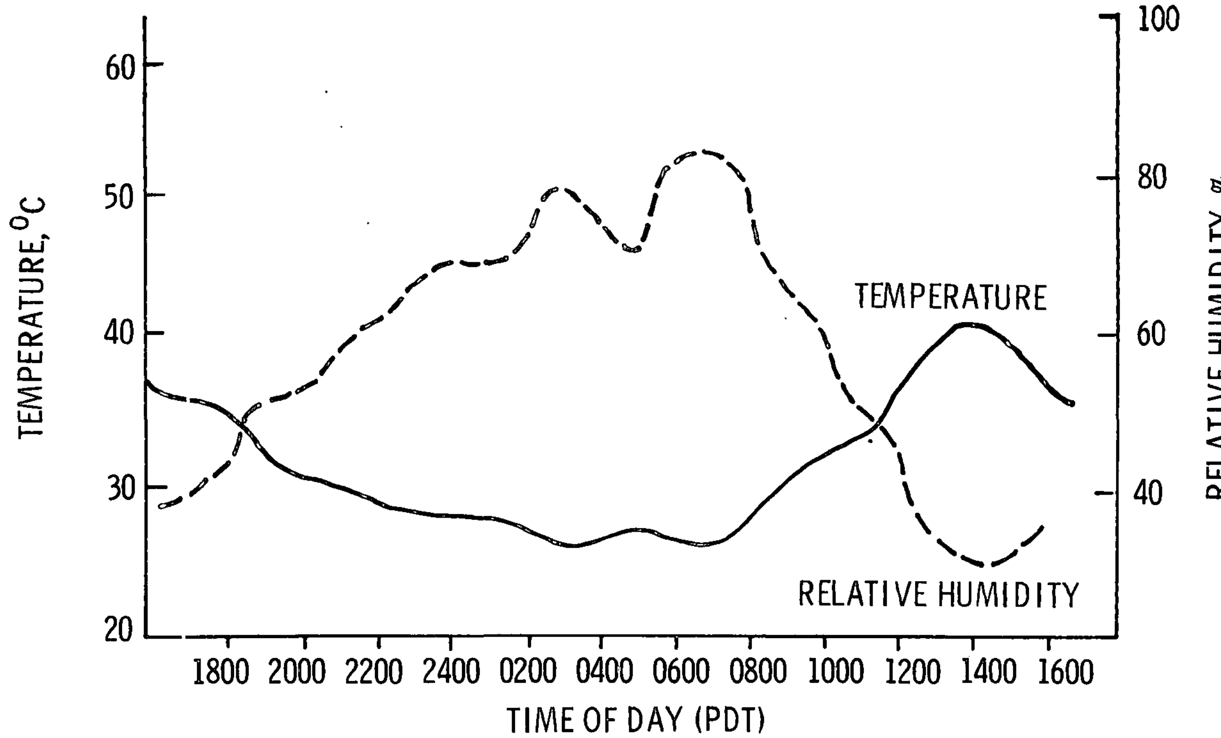
During dry weather, surface manure may contain only 7% to 10% moisture and severe dust emission problems will occur at this level. The moisture can be raised to the desirable operating range by heavy initial water application and/or reduction of pen space, followed by a daily water treatment program. The sprinkled water will provide moisture for aerobic metabolism of the manure. About 40% moisture content is required for best aerobic bacterial activity, which produces no unpleasant odor. However, care must be taken to avoid overwatering. Excessively wet spots and puddling support anaerobic decomposition which is the primary source of feedlot malodors.[27]

Water application rates should be adjusted according to weather conditions, animal size, and manure depth. Effectiveness of water treatment is enhanced by an initially high application rate such as 0.0045 cubic meters of water per square meter of area per day (1 gal/yd^2-day) until a 25% to 35% moisture level is reached.[26] Thereafter, water should be applied at 0.00225 to 0.003 cubic meter per square meter per day (0.5 to 0.75 gal/yd^2-day) as long as dry weather persists.

Research at California feedlots[26] has shown that daily watering yielded significantly better dust emission control than alternate day watering. Watering frequency has proved to be a more critical factor than depth of loose manure on the feedlot surface.

Careful consideration must be given to any sprinkler installation design so that total pen coverage can be achieved. Overhead sprinklers can be positioned to provide more complete pen coverage than can be achieved with fence-line sprinklers. If installed sprinklers are not possible, mobile systems such as trucks or carts can be as effective in controlling fugitive dust. The important criteria are that the complete area must be covered and adequate amounts of water must be applied. It is more effective to apply 0.00225 cubic meter of water per square meter of area at less frequent intervals than to apply lower measures of water more frequently.[26] If either of the two criteria is neglected, inadequate and ineffective dust control will result.

The time of day for water application can also be an important factor depending upon the specific region of the U.S. in which the feedlot is located. For example, a feedlot in the Imperial Valley in southern California exhibited the condition displayed in Figure 8. For Lots A and B, temperatures were highest and humidity lowest during the period 1100 to 1700 Pacific Daylight Time (PDT). During high temperature periods, it is desirable to maintain humidity at the lowest levels; thus water application during this



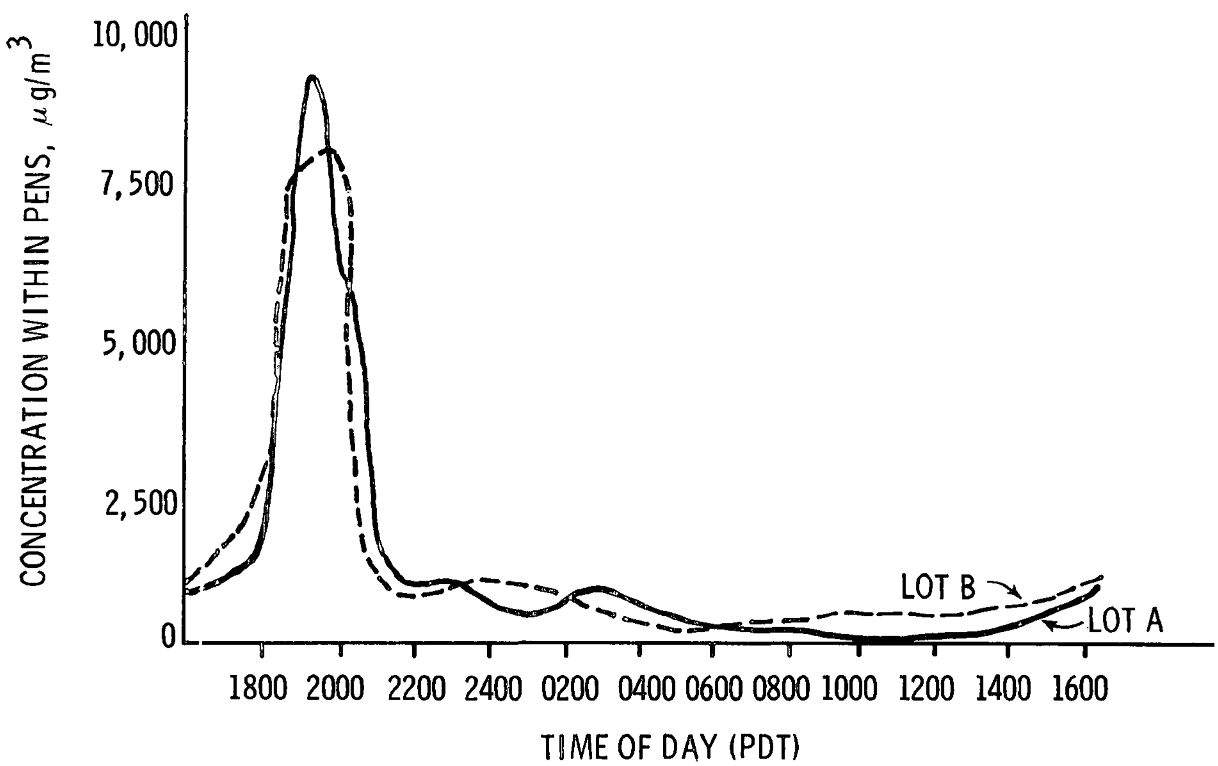


Figure 8. Temperature and relative humidity profiles, and particulate matter level, 24-hr sampling, Lots A & B[26]

period is not indicated since it would cause greater discomfort in the cattle with concomitantly lower weight gain performance. The best time to apply moisture under high temperature conditions in the low desert valleys is in the evening hours from 1800 PDT on.

Water application in the time period indicated would not only tend to eliminate animal health problems due to the temperature-humidity interaction but would also protect moisture from the excessive evaporation that occurs during heat extremes. In addition to lowering dust levels, protecting moisture from excessive evaporation would lower the ammonia emissions because gaseous emissions are highest at high evaporation periods. Under moister climate conditions the above precautions would probably not be as necessary, since ambient temperatures do not reach levels which cause cattle discomfort or hyper-respiration type interactions with humidity.[26]

The most important step in effective dust control is to attack the problem early and maintain steady control. This requires periodic inspection and/or moisture sampling of the feedlot surface to anticipate dust control requirements. Dust control systems and equipment must be restored to peak working effectiveness as the dry season approaches and must be maintained in good repair throughout the period of use.

Table 7 illustrates the particulate matter level observed after 6 days of regular water application and that observed after no water application during the next 7 days for the same Lot A in the Imperial Valley. Particulate emission readings were taken within the pen, but demonstrate what could be

Table 7. COMPARATIVE PARTICULATE MATTER LEVEL WITHIN PEN FOR LOT A AS FUNCTION OF WATER TREATMENT[26]

Treatment	Time, days	Wind velocity, km/hr	Particulate matter, $\mu g/m^3$
Daily water	6	1.3 to 2.2	2,950
No water	7	2.7 to 3.1	22,800

the effect on downwind particulate samplings. An 868% increase in particulate matter level was observed within the same lot after no water treatment for 7 days (following daily watering) as compared to that observed after daily water treatment for the previous 6 days. Such could be the effect of irregular, sporadic dust control techniques or equipment breakdown.

Permanent sprinkler systems offer the advantage of providing water to most or all of the feedlot simultaneously immediately prior to occurrence of dusty conditions so that their effectiveness is maximized. These systems, which require minimum labor for operation, can be fully automated to apply water at preselected times of the day when dust is critical. Major disadvantages of permanent sprinklers are high initial costs, frequent maintenance requirements, dependence on good weather conditions for adequate distribution uniformity, possible puddling of water in pens, and water loss due to evaporation. Poor uniformity resulting from improper design, nozzle plugging, and/or high winds leads to ineffective dust control on portions of the lot, and excessive moisture (and subsequent fly and odor production) on the remainder of the lot.[28]

[28]Dust, Fly and Odor Control Methods Practiced by Western Feeders. Texas Cattle Feeders Association. Amarillo. Special Report. June 1972. 15 p.

Mobile tank trucks have a lower initial cost than does the permanent sprinkler system, and are quite versatile. These units afford the capability of spraying water at high rates if needed, and with sufficient operator skill they can achieve equal or better watering uniformity. With properly designed nozzles, all areas of the feedlot (even corners) can be treated. Dusty "trouble spots" in a feedyard can be treated independently at times when sprinkling the entire lot would be unnecessary or unwise. Equipment "freezing" is less likely than for sprinklers. Tank trucks can be equipped to spray roads and alleys, and can also be used as fire trucks if desired. Spray patterns from mobile equipment are less affected by high winds than sprinklers, and evaporation loss is probably lower. One major disadvantage of tank trucks is high labor costs; another is the fact that the total dust control system is inoperative if a breakdown occurs, unless another truck is available.[28]

Pens with sun shades may require mobile sprinkling from both feed and cattle alleys to obtain good coverage without creating a mud problem under the shades. The shaded area is kept moist by the cattle and therefore should receive little or no water. Feed bunks should also be kept free from sprinkled water.[29]

Initial costs of stationary sprinkler systems typically range from $3 to $10 per head of feedlot capacity. Operating costs (exclusive of depreciation) of 20 cents to 40 cents per head per year may be incurred.[29]

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[29] Sweeten, J. M. Down with Dust. Feedlot Management. 1975 Planner Issue. p. 30-33.

The largest mobile units can cost up to $2 per head of feedlot capacity if purchased new. Used equipment may be available at a far lower cost, but must be outfitted with 1.85 m^3/min to 7.40 m^3/min (490 to 1950 gal/min) output pumps and multiple nozzles. A main nozzle with 30-m to 40-m maximum trajectory is required, along with one or more additional nozzles to accomplish uniform distribution over the area within 2 m to 30 m of the vehicle. Operating costs of 4 cents to 14 cents per head per month up to 50 cents per head seasonally have been reported for mobile dust control equipment.[29]

In terms of convenience, well-designed permanent sprinkler systems provide an easy means of maintaining control over feedlot dust problems since quantities can be regulated virtually by clock, and the entire feedlot can be treated quickly at the most opportune time. However, automation requires frequent, routine inspection of the performance of each sprinkler head as well as the entire system to prevent or minimize poor distribution and/or overwatering. Sprinkler heads placed inside feedpens are inconvenient from the standpoint of pen cleaning. Unlike mobile equipment, sprinkler systems can suffer damage (hidden or visible) during idle seasons which may entail unscheduled and untimely corrective action. Sprinkler systems must be designed, installed, and operated for a particular feedlot configuration. If the feedlot is expanded, pens relocated, or water supply altered appreciably, the system may not function properly.[28]

Use of mobile equipment in dust control requires more labor than a sprinkler system. However, labor and maintenance needs are probably more predictable. Management factors against the use of water trucks are the inability to gain quick control over the dust problems and the difficulty in regaining control after equipment trouble has occurred.[28] The creation of additional vehicular traffic around the pens may also pose slight problems. Mobile equipment for dust control can, however, be readily adapted to changes in feedlot configuration.

2. <u>Gas/Odor Control</u>

The lack of oxygen in bacterial decomposition of cattle manure causes feedlot odor. Odor control actions should enhance aerobic metabolism on the feedlot surface, in the runoff holding ponds, and in the manure stockpiles. Good housekeeping procedures are the simplest and least costly means for feedlot odor abatement.

Besides reducing the dust emissions, sprinkling provides moisture for aerobic biodegradation of the manure. A 25% to 40% moisture content is required for best aerobic bacterial activity and good dust control. If no wet spots are formed by sprinkling, it is possible to maintain a moisture level for both dust suppression and good aerobic conditions on the feedlot surface.[8] Any spot with excess moisture will turn anaerobic and cause malodors. To avoid odors during pen scraping, only the surface manure layer should be removed.

Odor control for the runoff holding ponds begins with removing solids from the runoff. This dilutes the nutrient concentration in the holding pond water. Odor from the holding pond can be further reduced by adding more water or using aeration equipment. Aeration of the surface of the pond will reduce the formation and subsequent transfer of odors into the air.

Intermediate storage of manure in stockpiles allows regular removal of solids regardless of the immediate readiness of land for disposal or ponds for treatment. Mounding of manure inside the pens, an intermediate step in collection, promotes drainage and provides a dry resting area for cattle during adverse weather. Further manure drying and decomposition accompanied by weight and volume reduction occur during storage. However, storage periods longer than 4 to 5 days without aeration will cause anaerobic conditions to develop, and malodors will be released upon excavation. Also, the presence of high, mounded, too-wet, encrusted manure piles, inside which the manure is preserved in a fresh state, further decreases pen space per head since cattle tend to walk around them. This will augment odor problems in these pens until the manure piles can be removed.

When stockpiling outside the pens is required, the solid manure should be piled in long narrow rows, called windrows (1.2 m to 1.8 m high). Access lanes for trucks and earth moving equipment should be left between rows. This stockpiling procedure will enable rapid control of spontaneous combustion fires and is compatible with present day composting machines. The windrows are aerated by turning every 3 to 7 days or by injecting air using underlying perforated pipe. Windrow composting requires 15 to 21 days to complete if satisfactory moisture (40% to 60%) and temperature (54°C to 77°C) can be maintained. Aerobic composting produces no offensive odors, generates enough heat to kill weed seeds, fly larvae, and most pathogens, and reduces materials volume by 10% to 45% and weight by 30% to 60%. Loss of nitrogen through volatilization may lower the fertilizer value of finished compost. Composting requires careful management, and difficulties can be expected during prolonged periods of immoderate weather.[30]

Some governmental agencies are cognizant of problems caused by odors from feedlots. Typical special provisions written into operating permits issued by the Texas Air Control Board include:[31]

- Excess moisture must be drained from pen areas to prevent ponding. Good pen drainage must be maintained at all times either by uniform slopes of 2% to 4% or by constructing permanent mounds in flat pens.
- When it becomes necessary to stockpile manure outside the pen area, the moisture content must be maintained between 10% and 30% (wet basis) in the top 6 inches of the pile or it must be successfully demonstrated that the stockpile is not a source of odors. The stockpile must be crowned with sloping sides and must be located in a well drained area to assure rapid dewatering.
- Cleaning or scraping of pens and removal of manure from stockpiles must be performed under favorable atmospheric conditions (e.g., wind direction must not be out of the southwest).
- Runoff water in the holding ponds must not become a source of obnoxious odors. It must be chemically or biologically treated or aerated, if necessary, to prevent nuisance conditions.

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[30]Sweeten, J. M., W. S. Allen, and D. L. Reddell. Solid Waste Management for Cattle Feedlots; Cattle Feeders Information. Texas Agricultural Extension Service. College Station. Publication No. L-1094. 1973. 4 p.

[31]Sweeten, J. M. Feedlot Pollution Control Guidelines. Texas Agricultural Extension Service Miscellaneous Publication No. MP-1155. College Station. July 1974. 12 p.

Research[32] has shown potassium permanganate ($KMnO_4$) to be the most economical odor control chemical agent of seven materials tested for total suppression of the release of malodorous gases from beef cattle waste slurry experiments. The quantity of $KMnO_4$ required to totally suppress emissions of sulfurous gases was estimated to be 14 g/500 g of manure (56 lb/ton). Potassium permanganate was judged to be effective in the reduction of malodors when applied at a rate of 2.24 g/m^2 (20 lb/acre) in a 1% water solution. Also considered were potassium nitrate, paraformaldehyde, hydrogen peroxide, ozene (orthodichlorobenzene), Formula 2, and a digestive deodorant.

Other research[33] recommended the following procedure which was found to be effective in a southern California feedlot treated with $KMnO_4$:

> Remove manure from yards at least 3 times/yr and scarify the ground to promote aerobic conditions.
>
> Follow scarification with spraying of a 1% solution of $KMnO_4$ so that treatments amount to 2.2 g/m^2.
>
> If excessively wet spots develop between regular sprayings, these spots should be resprayed.

This procedure was found to be effective under both summer (dry season) and winter (wet season) conditions. Also, permanganate solutions were effective for odor abatement in a variety of situations at the feedlot, e.g., odors developing in sumps and ditches were abated by $KMnO_4$ addition in either solid or solution form. No data are available on the

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[32] Ford, J. P., and W. L. Ulich. Odor Control for Confined Beef Cattle Feedlots. In Proceedings of the First Annual Symposium on Air Pollution Control in the Southwest. College Station, Texas A&M University, 1973. p. 189-204.

[33] Faith, W. L. Odor Control in Cattle Feedyards. Journal of the Air Pollution Control Association. 14:459-460, November 1964.

effect of the permanganate residues in the manure which may be later sold and/or used on farmland.

In more recent research[34] at an actual operating feedlot, nine products were each applied to one or more pens to determine their effectiveness in reducing odor release from this source. Relatively simple measurements - ammonia release rate and odor intensity - served effectively to compare odor control effort successes. Of the nine products, sodium bentonite, Odor Control Plus, and two natural zeolites were found to consistently reduce the rate of ammonia release when the treated areas were compared to untreated control areas. Odor intensity measurements confirmed the effectiveness of sodium bentonite. The pens treated with Odor Control Plus (a dried bacterial and enzyme product) had a measurably less intense odor 5 days after treatment but not 10 days after treatment. Only one of the two observers was able to distinguish the zeolite treated pens from the control. Interestingly, potassium permanganate failed the odor abatement tests. The cost of the effective materials ranged from $\$0.07/m^2$ to $\$0.15/m^2$ (\$300 to \$600 per acre) for treatment during the odor production season.

At the same feedlot[10] a water spray system was installed which creates a mist extending 6 m (20 ft) into the air along the predominantly downwind borders. Although difficult to evaluate in a highly variable natural setting, the data seemed to suggest a more rapid decrease in ammonia release rate with downwind distance when the water spray was in operation

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[34] Miner, J. R., Oregon State University, and R. C. Stroh, University of Idaho. Controlling Feedlot Surface Odor Emission Rates by Application of Commercial Products. (Paper No. 75-4566, presented at the 1975 Winter Meeting of the American Society of Agricultural Engineers. Chicago. December 15-18, 1975.) 16 p.

than at other times. This system is effective only under low wind velocities; the condition that causes greatest odor transport is an inversion with low wind velocities.

The spray system was also used to spray a dilute $KMnO_4$ solution. The first application was made to demonstrate that the practice would not damage wetted vegetation. When applied at concentrations below 74 g/m^3 (74 mg/l), no plant effects were noted. When added to the spray at 10 g/m^3 (10 mg/l), potassium permanganate seemed to further speed the odor intensity reduction with distance; however, that result must still be substantiated.

From the literature surveyed, it is obvious that particulate, gaseous and odoriferous emissions from beef cattle feeding operations can be controlled by conventional methods now available. These simple methods and procedures require an appreciable expenditure of managerial dedication and expertise as well as the monetary investment to purchase, install and maintain such systems.

B. FUTURE CONSIDERATIONS

Calcium sulfate (gypsum) showed promise as a chemical agent to increase moisture and control dust emissions.[26] It has long been used in the reclamation of alkaline soil. The mode of action of calcium sulfate involves an exchange of sodium for calcium ions which allows for greater water penetration. Increased water penetration should elevate pen moisture levels and reduce dust.

The application level of calcium sulfate tested in the literature was 0.14 kg/m^2 applied with a fertilizer spreader. However, its cost was 50% to 80% higher than that for water treatment.

Chemicals for dust control are more effective and practical in controlling dust from feed alleys, roads, and loading/unloading areas around a feedlot than from the feedlot surface itself. Other materials commonly used for roadways include waste petroleum oil, coarse gravel, and asphalt.

SECTION VI

GROWTH AND NATURE OF THE INDUSTRY

A. PRESENT TECHNOLOGY

Just after World War II the trend to confinement production of livestock began. This trend was brought about by a declining farm labor supply and the need to substitute machines that could make it possible for one operator to produce a better quality product without increasing comparative consumer costs.[35]

Within the last 15 years, commercial feedlot operations have been decreasing in number but expanding in size rapidly. Large commercial feedlots were developed in the arid climates of Arizona and California in the 1950's. In the mid 1960's, innovative cattlemen on the Great Plains developed the financial arrangements needed to duplicate these "California" feedlots nearer the grain supply. The number of total feedlots decreased by 35% between 1962 and 1972, but the number of over 1,000-head beef cattle feedlots increased 33% from 1,517 to 2,035. The number of fed cattle marketed from these over 1,000-head feedlots increased threefold.[1] Most of the cattle fed in the Northern Plains, Southwest, Mountain

[35]Hazen, T. E. Discussion. Journal of the Air Pollution Control Association. 22:771-772, October 1972.

and Pacific (Figure 9) regions are confined in feedlots with a capacity of more than 1,000 head. Between 1961 and 1972 Texas had the greatest numerical increase (over 3.7 million head) in finish cattle feeding, followed by Nebraska, Kansas, Colorado, and Iowa. Over 80% of the national increase in cattle feeding during this period occurred in these five states.

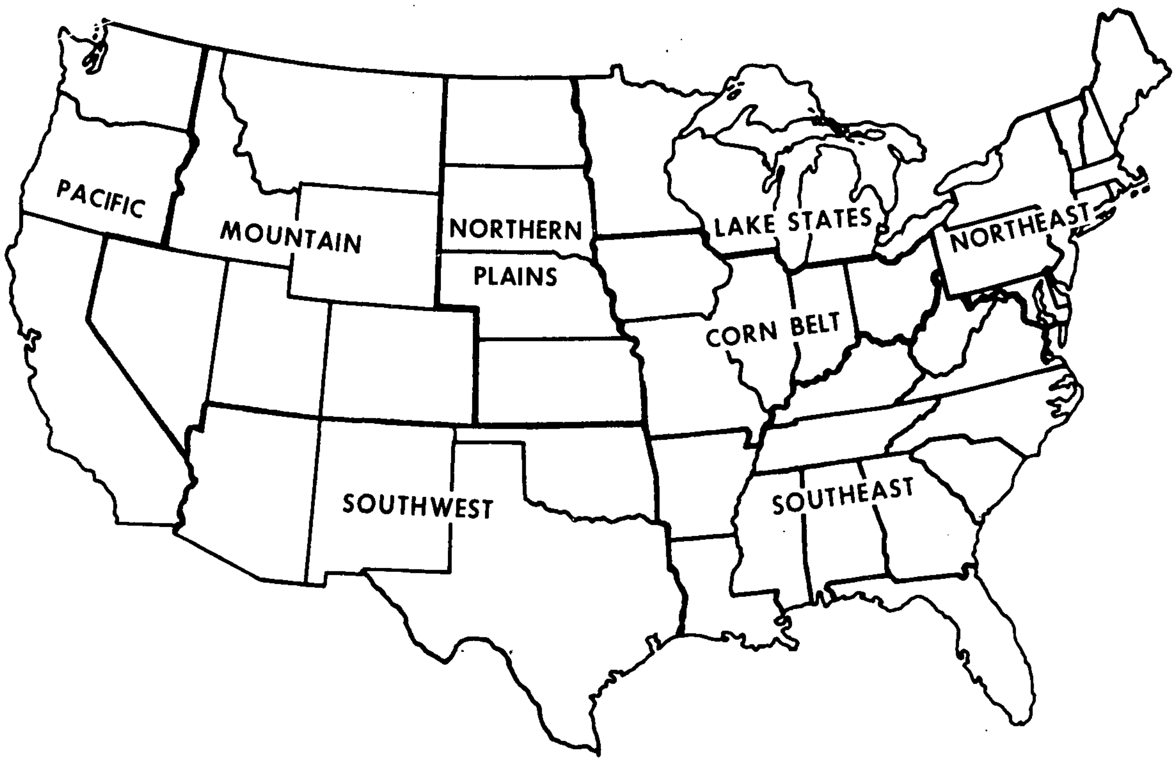
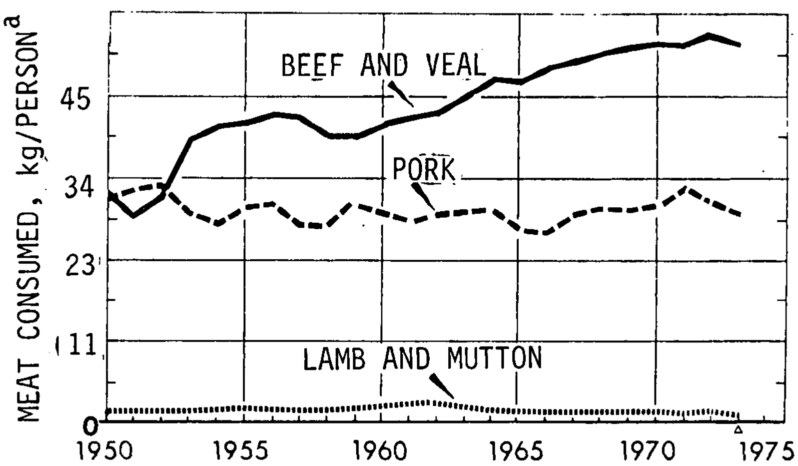


Figure 9. Cattle-raising regions

The increase in commercial confined beef feedlot operations occurred as a result of the proximity to an adequate supply of feeder cattle, the strong demand for beef, an adequate supply of competitively priced feed grains, the availability of slaughtering facilities, and a dry, stable climate. Costs for feed itself amount to two-thirds or three-fourths of the total feeding costs. Labor, fuel and utilities, and depreciation are other major components of the total feeding costs. Because of weight shrinkage and transportation expenses, most cattle are sold to packing plants within 80 km to 160 km of the feedlot location. Wet, muddy feedlots adversely affect feeding efficiency; hence, a dry climate is important in obtaining consistently efficient weight gains.

Meat consumption in the United States has been rising at a steady rate since 1950. Between 1950 and 1960, the *per capita* consumption of beef increased 34%, or 3.0%/yr. Between 1960 and 1970, the *per capita* consumption of beef increased 33%, or 2.9%/yr (Figure 10).[36] In the early 1900's, annual total meat consumption *per capita* ranged between 46 kg and 49 kg, and pork consumption, which exceeded beef consumption, amounted to about 47% of the total.[37]



[a]Carcass-weight basis (ordinate rounded to nearest kg.

Δ Forecast values.

Figure 10. Annual mean consumption per person[36]

[36]1973 Handbook of Agricultural Charts. Agricultural Handbook No. 455. Washington, U.S. Department of Agriculture, October 1973. 152 p.

[37]Menzie, E. L., W. J. Hanekamp, and G. W. Phillips. The Economics of the Cattle Feeding Industry in Arizona. The Agricultural Experiment Station, University of Arizona. Tucson. Technical Bulletin 207. October 1973. 82 p.

Following 1950, some interesting changes have occurred in the meat consumption patterns of the U.S. Total red meat consumption rose from 44.1 kg *per capita* in 1950 to 57.2 kg in 1972, an increase of 31%. In addition, beef became the major source of increases in consumption, rising from 19.3 kg to 35.2 kg, an increase of nearly 85%. Veal, lamb and mutton declined while pork consumption remained relatively stable, fluctuating between 17.7 kg and 22.3 kg *per capita*. Much of the increasing beef consumption has been associated with increasing incomes. Also, population has been rising and this has added to the total demand for meat, especially beef.[37]

The rapid increases in consumption have put stress on the beef industry to meet the growing demand. In addition to large increases in quantity, consumers have demanded a better quality product with much more service provided. Between 1962 and 1972, the amount of beef produced that was classified as choice and prime rose from 50% to 64% of the total (Figure 11). The lower grades involving utility, canner and cutter, and standard commercial beef dropped from 32% to 20%. While some of this shift was associated with changes in grading standards during this period, the major factor is considered to be pressure from consumer demand.[37]

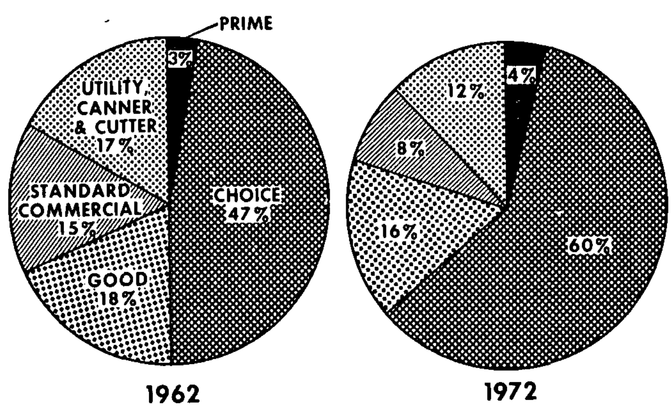


Figure 11. Beef production, by grade[36]

U.S. and world trade in meat products has been growing in recent years and indications are that the rate of growth will be increasing. The United States is a net importer of red meats. Beef and veal imports, under quota, amounted to 8.0 x 10^5 metric tons (8.8 x 10^5 tons) in 1971 or about 7% of U.S. consumption. These imports were largely of lower grade beef and did not compete directly with the fed cattle market.[37]

B. INDUSTRY PRODUCTION TRENDS

Rapid and significant changes are taking place in beef cattle production and feeding, and in slaughtering, transportation and processing operations as well. Various economic advantages have led to area specialization and long-distance transportation of inputs and products due to the strong demand for beef. These shifts and advantages have created the firmly established trend to massive confinement feeding and to ever increasing numbers of beef animals per production unit. The change to intensive production has altered the traditional complementary relationship between crop and livestock production in which the farmer fattens the calves he raises or the carload that he buys, to consume excess feed produced on the farm so that his return on that feed will be higher, and in which the wastes from the livestock are returned to the land. Cattle feeding has become an industry with huge capital requirements: purchase of most of the feed, hormones, cookers, veterinary services, computers for ration control, futures hedging, and manure handling equipment on a scale befitting the construction industry.

There has been a steady decline in the number of small (less than 1,000-head) feedlots, particularly in the Corn Belt states. The cattleman or farmer in the Corn Belt has traditionally either sold calves or fed out those raised in his own small feedlot. The finishing phase of such operations has been relatively unprofitable despite the abundance of nearby feed; consequently, more farmers are expected to discontinue their feedlot operations, emphasize the cow-calf producing enterprise, and push for heavier calves to increase returns, or grow into a larger feedlot size category.

For cattle feeding to grow in an area, it must be relatively profitable. Profitable feeding requires efficient and economical marketing and processing systems as well as an economical source of feed and efficient production. Illinois, a state with large excess supplies of feed grains, suffered a 20% decline in fed cattle marketed between 1966 and 1971 while the total U.S. enjoyed a 21% increase.[1] In Illinois, the more economical grain shipping techniques and facilities that had been developed provided added incentive to the exporting of feed in the form of grain rather than in the form of meat. Thus, a large excess feed grain supply, by itself, does not assure that cattle feeding in such an area will grow or even be maintained.

The structure of the industry has changed from that of many small feeders active seasonally to one with fewer and larger year-round feeding operations. In the 23 major feeding states for which continuous statistics have been maintained, the percentage of cattle marketed from feedlots of greater than 1,000-head capacity increased from 36% to 55% between 1962 and 1970, and rose to 65% in 1973. The shift is more marked in those states in which large-scale (16,000 head and over) feedlots have emerged.[1] The percentage of cattle placed on feed, by quarters of the year, went from a 21-16-21-42 percent distribution in 1960 to a 21-22-25-32 percent distribution in 1970.[38] This change illustrates the movement away from seasonal operations. The larger lots tend not to be seasonal at all, but rather to be full-time operations which must continually be kept nearly full in order to pay for fixed labor costs and expensive equipment.

A major factor influencing the move to larger, less seasonal cattle feeding enterprises has been the rise of custom feeding. The shift by the industry to feeding cattle on a custom basis for ranchers, cattlemen, and investors has been necessary as a means of acquiring additional capital and of spreading risks. Capital made available through custom clients reduces the large reserves needed to finance feeding operations and permits feedlots to expand and obtain economies of size. Capital required for the purchase of feeders, feed, and other operating expenses exceeds investment in plant facilities by three or four times.[37] Table 8 illustrates the percent of cattle which are fed on a custom basis for the major cattle feeding states and the distribution of clients owning the feeder cattle.

The client provides the capital for purchase of the feeder and is billed monthly by the custom feeding firm for the cost of feed and feeding services. Thus, the feedlot providing custom services provides capital only for the facilities plus feed and operating expenses on a 30-day basis. The full ownership feeder provides capital for facilities, feeder cattle, and operating expenses for the full feeding period involved. In addition to the reduction in capital requirements to finance commercial feeding operations, custom feeding spreads the risks associated with feeding. Prices

[38]Van Arsdall, R. N., and M. D. Skold. Cattle Raising in the United States. U.S. Department of Agriculture. Washington. ERS Report 235. January 1973. 88 p.

Table 8. BEEF CATTLE FED FOR OTHERS ON A CUSTOM BASIS[2]

State	Total	Percent owned by			Percent of fed cattle
		Ranchers	Packers	Others	
Arizona	685,000	21.6	7.4	71.0	77.8
California	1,380,000	32.6	7.3	60.1	76.6
Illinois	13,500	46.3	7.3	46.4	1.2
Iowa	53,000	40.5	16.3	43.2	1.7
Kansas	934,000	70.4	9.7	19.1	59.0
Nebraska	633,000	43.6	11.1	45.3	23.2
New Mexico	191,000	60.5	13.9	25.6	64.9
Oklahoma	325,000	54.8	5.6	39.6	62.5
Texas	2,310,000	37.6	25.0	37.4	82.9
Colorado	544,000	37.1	25.7	37.2	32.8

and costs are subject to major changes in relatively short periods of time. As a result, the industry can and does experience, at varying times, high profits and high losses. Since the custom feedlot owners make their returns based on charges for services provided to clients, the market risks associated with cattle feeding are transferred to their clients.[37]

Fed cattle production increased from 1.29×10^7 head in 1960 to over 2.67×10^7 head in 1972.[39] This expansion has been due primarily to the growth of cattle feeding in seven western states. Fed cattle marketings in Arizona, New Mexico, Texas, Oklahoma, Kansas, Nebraska, and Colorado soared to 1.5×10^6 head in 1972, representing 75% of the national growth in the last 10 years (Figure 12). Expansion in fed

[39] Livestock and Meat Statistics. Economic Research Service, U.S. Department of Agriculture. Washington. Bulletin No. 333. Supplement for 1962-72. June 1971. 6 p.

cattle marketings of 7.4%/yr also occurred in the northwestern states, bringing marketings for this area to over 1.1 x 10^6 head (Figure 13).

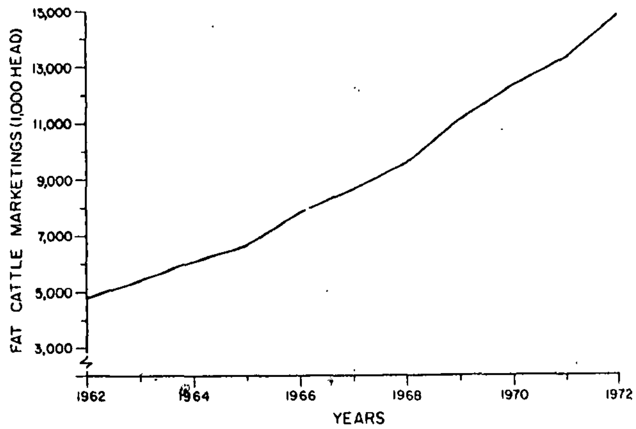


Figure 12. Fed cattle marketings of seven western states (Arizona, New Mexico, Texas, Oklahoma, Nebraska, Kansas and Colorado), 1962-1972[37]

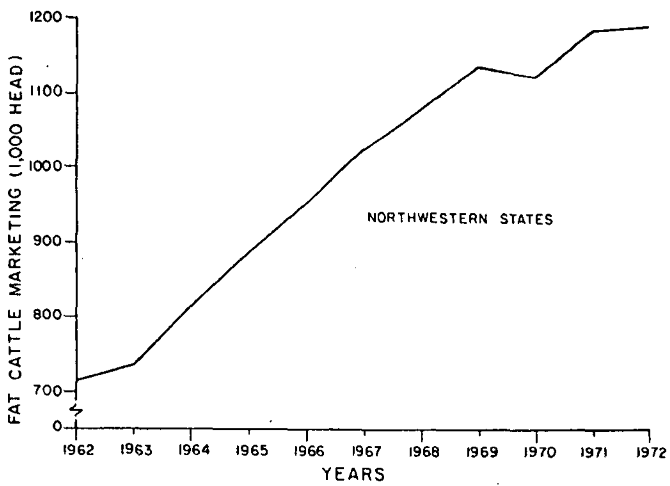


Figure 13. Fed cattle marketings in the northwestern states (Washington, Oregon, Montana, Idaho), 1962-1972[37]

The growth experienced by many western states, however, has not been shared by the cattle feeding regions of the Corn Belt. After recording a gradual growth in fed cattle marketings in the early and middle 1960's, the Corn Belt states reached a peak in 1969-1970 of 7.4 x 10^6 head. They have since declined each year to 6.4×10^6 head in 1972 (Figure 14). A drop in fed cattle marketings in Iowa was mainly responsible for the decline in output of the Corn Belt region. Numbers marketed in Iowa decreased from 4.58×10^6 head in 1970 to 3.91×10^6 head in 1972. This reduction represented over 85% of the total decline in the Corn Belt area.

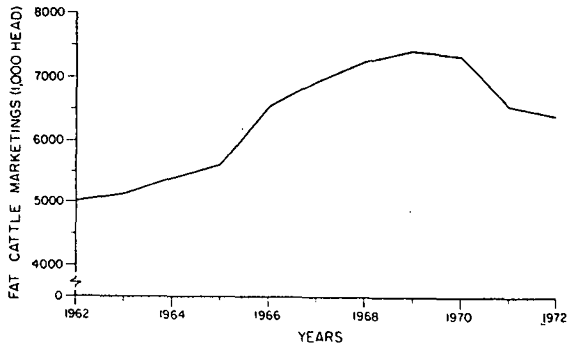


Figure 14. Fed cattle marketings in the Corn Belt states (Iowa, Indiana, Illinois, Ohio, and Missouri), 1962-1972[37]

Declines in fed cattle were also registered as early as 1965 in California, one of the most active feeding states in the country. Numbers marketed decreased from 2.28×10^6 head in 1965 to 1.97×10^6 head in 1970. However, following 1970, marketings increased slightly.

Figure 15 displays the change in fed cattle marketings in total numbers and in percentages. The top seven cattle feeding states - Texas, Nebraska, Iowa, Kansas, Colorado, California, and Illinois - comprise 75% of the U.S. production. The U.S. growth rate was 4.5%/yr from 1964 to 1973. Each of the seven leading states exhibits a different growth pattern (Tables 9 through 16) from the overall U.S. growth pattern. The percentage distribution by feedlot size shows that marketings from the small feedlots (under 1,000-head capacity) declined while very large (16,000-head and over) feedlots increased substantially until 35% of all fed cattle

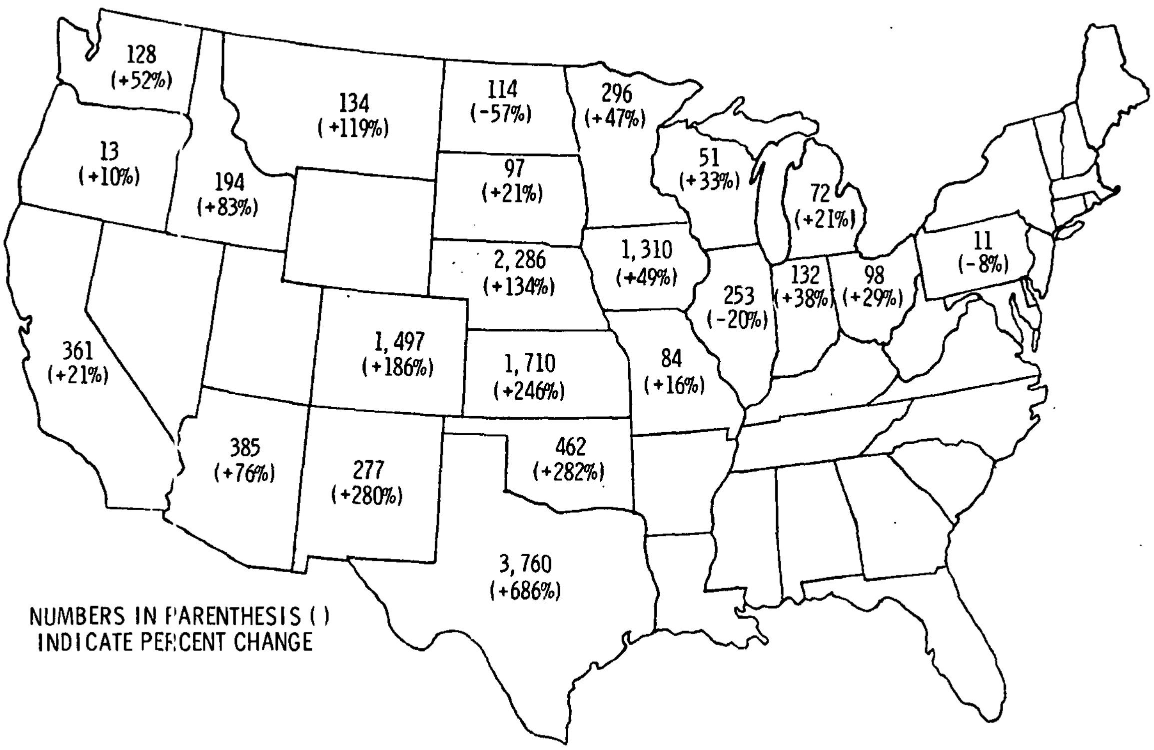


Figure 15. Change in fed cattle marketings, 1961 to 1972 (thousand head)

came from very large feedlots. The growth and distribution are shown in Figures 16 and 17 for Nebraska and Texas. Nebraska has thousands of small farmer-feeder concerns but was able to increase its fed cattle output primarily through addition of large feedlots. Texas' growth was brought about almost entirely by the springing up of a cattle feeding industry and large feedlots.

The phenomenal growth in Texas cattle feeding (18%/yr) is noteworthy. In the early 1960's, Texas was the nation's leading exporter (to other states) of feeder cattle and ranked about sixth in cattle feeding. However, Texas will not be able to supply feeder cattle to feedlots in other areas during the coming years if the recent trends continue because the state will use all its feeder cattle in its own feedlots.

Table 9. CAPACITY OF FEEDLOTS IN UNITED STATES[a] (4.5% GROWTH/YR)[1]
(percent of all marketings)

Year	Under 1,000 head	1,000 to 15,999 Head	16,000 Head and over
1962	64	28	8
1963	63	29	8
1964	59	31	10
1965	58	30	12
1966	56	31	13
1967	55	31	14
1968	54	30	16
1969	48	30	22
1970	45	31	24
1971	42	31	27
1972	38	30	32
1973	35	30	35

[a] 23 Leading states.

Table 10. CAPACITY OF FEEDLOTS IN TEXAS (18.0% GROWTH/YR)[1]
(percent of all marketings)

Year	Under 1,000 head	1,000 to 15,999 Head	16,000 Head and over
1962	14	86	0
1963	13	72	15
1964	13	69	18
1965	10	67	23
1966	12	67	21
1967	8	63	29
1968	6	50	44
1969	4	38	58
1970	3	38	59
1971	3	32	65
1972	2	24	74
1973	2	22	76

Table 11. CAPACITY OF FEEDLOTS IN NEBRASKA (4.5% GROWTH/YR)[1]
(percent of all marketings)

Year	Under 1,000 head	1,000 to 15,999 Head	16,000 Head and over
1962	38	52	0
1963	71	29	0
1964	61	39	0
1965	61	39	0
1966	56	36	8
1967	53	38	9
1968	52	40	8
1969	47	44	9
1970	45	44	11
1971	45	44	11
1972	41	46	13
1973	39	46	15

Table 12. CAPACITY OF FEEDLOTS IN IOWA (1.5% GROWTH/YR)[1]
(percent of all marketings)

Year	Under 1,000 head	1,000 to 15,999 Head	16,000 Head and over
1962	97	3	0
1963	97	3	0
1964	96	4	0
1965	96	4	0
1966	95	5	0
1967	93	7	0
1968	93	7	0
1969	91	9	0
1970	90	10	0
1971	90	10	0
1972	89	11	0
1973	87	13	0

Table 13. CAPACITY OF FEEDLOTS IN KANSAS (15.5 % GROWTH/YR)[1]
(percent of all marketings)

Year	Under 1,000 head	1,000 to 15,999 Head	16,000 Head and over
1962	68	32	0
1963	64	36	0
1964	55	45	0
1965	48	34	18
1966	46	39	15
1967	46	38	16
1968	40	42	18
1969	33	36	31
1970	26	36	38
1971	25	37	38
1972	20	39	41
1973	16	40	44

Table 14. CAPACITY OF FEEDLOTS IN COLORADO (9.5% GROWTH/YR)[1]
(percent of all marketings)

Year	Under 1,000 head	1,000 to 15,999 Head	16,000 Head and over
1962	29	71	0
1963	36	64	0
1964	33	67	0
1965	31	39	30
1966	26	44	30
1967	24	38	38
1968	23	40	37
1969	17	38	45
1970	15	42	43
1971	11	40	49
1972	8	44	48
1973	8	40	52

Table 15. CAPACITY OF FEEDLOTS IN CALIFORNIA (NO GROWTH)[1]
(percent of all marketings)

Year	Under 1,000 head	1,000 to 15,999 Head	16,000 Head and over
1962	2	64	34
1963	2	57	41
1964	2	51	47
1965	2	49	49
1966	1	48	51
1967	2	46	52
1968	1	47	52
1969	1	45	54
1970	1	42	57
1971	1	42	57
1972	–[a]	40	60
1973	–[a]	37	63

[a]Less than 0.5%.

Table 16. CAPACITY OF FEEDLOTS IN ILLINOIS (3.1% DECLINE/YR)[1]
(percent of all marketings)

Year	Under 1,000 head	1,000 to 15,999 Head	16,000 Head and over
1962	95	5	0
1963	94	6	0
1964	92	8	0
1965	91	9	0
1966	91	9	0
1967	91	9	0
1968	93	7	0
1969	93	7	0
1970	91	9	0
1971	90	10	0
1972	88	12	0
1973	89	11	0

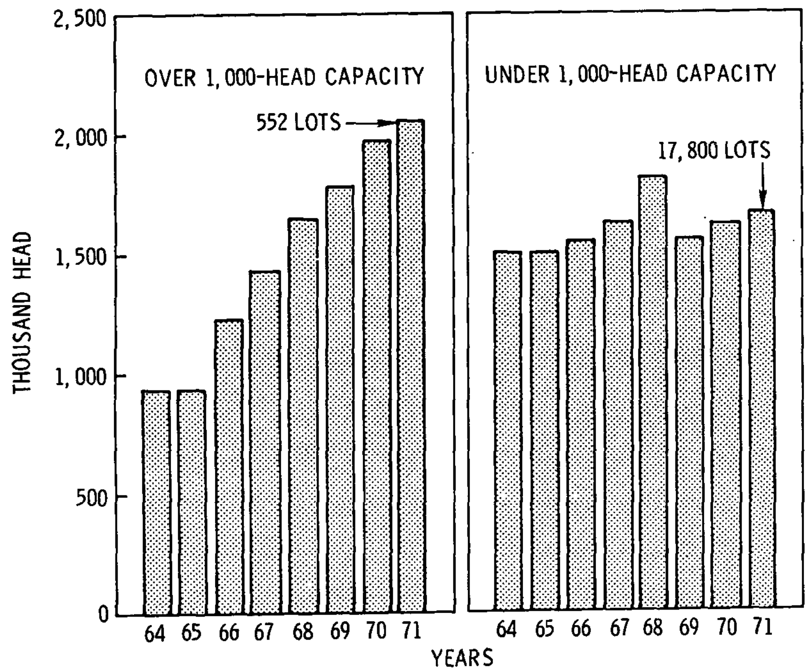


Figure 16. Fed cattle marketings by feedlot size in Nebraska [1]

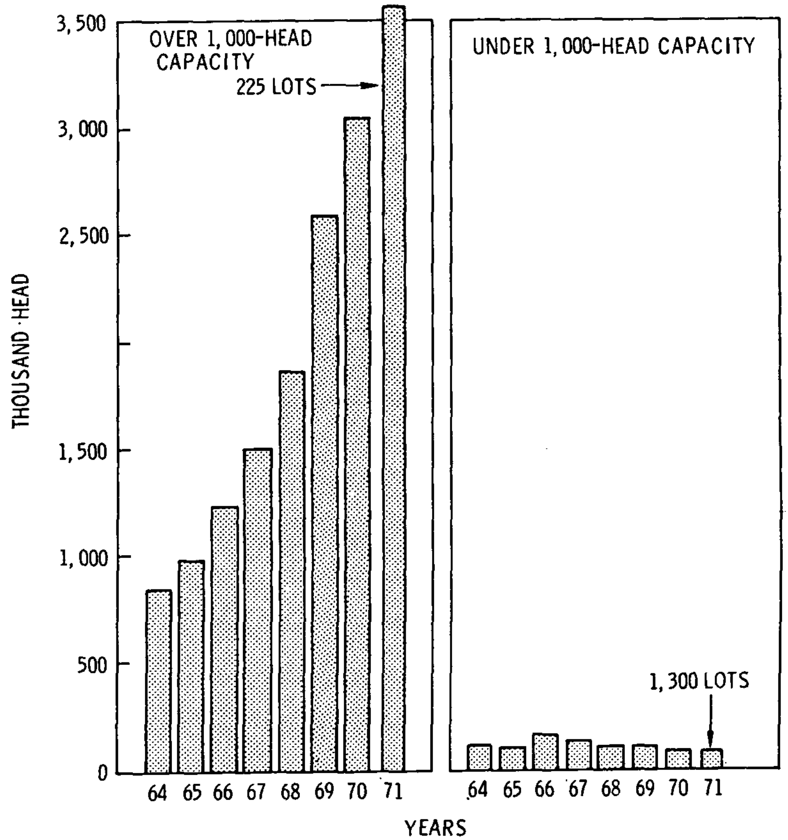


Figure 17. Fed cattle marketings by feedlot size in Texas [1]

The explosive growth in cattle feeding in the Texas high plains developed from a corresponding growth in grain sorghum production which, in turn, followed the introduction of new irrigation equipment. The new equipment could lift water economically from deep wells. Water levels have dropped due to the intensive irrigation that followed. If cotton and grain sorghum are to continue as the major crops of the Lower Texas Panhandle region, water will have to be imported. If this is not done, and Texas is to continue to grow in cattle feeding, grain will have to be imported.

Feed grain areas that do not rely on irrigation may have more long-run cattle feeding growth potential than an area dependent upon shrinking groundwater supplies. Should water for irrigation of local feed grains become too expensive in the Texas high plains, cattle feeding could continue for some time on shipped-in grains. The investment in highly efficient new feedlots and slaughter plants, the concentration of finances and skills, the ideal weather and nearby feeder cattle could continue to keep the area highly competitive even if grain had to be imported.

Major adjustments in the cattle feeding industry can be expected in the coming years. More feeding will be done by the larger lots as a continuance of past trends, and the operations will become increasingly competitive. Currently, because of an oversupply of cattle and as a result of high feed prices, commercial cattle feeding is undergoing difficult times. By the end of 1974, the cost of adding weight to a steer in the feedlot had risen to $1.32/kg (60¢/lb), versus $0.55/kg (25¢/lb) in late 1972.[40]

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[40]Lean Times for Cattlemen. Business Week. March 17, 1975. p. 94,96.

Since January 1973, the number of cattle in U.S. feedlots had dropped 34% to 9.6 x 10^6 head in spring, 1975.[40] With the higher cost of grain, cattlemen are leaving cattle to fatten in pastures longer and sending more of them directly from the pasture to the slaughterhouse. In 1973, almost 70% of all cattle slaughtered in the U.S. had been fattened in a feedlot. By 1974 that number had dropped to 60%, by mid-1975 that proportion was down to 50%, and it is not expected to rise much past 60% in 1976.[41]

The nation's largest feedlot operator is presently purchasing steers reared on pasturelands to weights of 340 kg to more than 363 kg (750 lb to 800 lb) versus 272 kg (600 lb) last year because it is cheaper to allow the animal to gain weight on grass than on grain.[42] Meanwhile, the Department of Agriculture has increased its involvement in improving the technology of forage production and harvesting.[42]

Increased demand from other countries for U.S. assistance to feed the world will affect the cattle feeding industry. Since most of the grainstuff that cattle consume is not adaptable for human consumption, world food demand will change the priority for the types and uses of grains which are raised in the U.S. Consequently, with cattle feed in shorter supply the production of meat products will be reduced.

The challenge posed by synthetic products has significantly affected various agricultural products. In fibers, leather and dairy products, for example, the levels of substitution have grown rapidly. In foods, however, synthetics have played a limited role to date.

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[41]Bullish Times for the Nation's Cattlemen. Business Week. March 15, 1976. p. 46, 48.

[42]Using Less Grain to Fatten Cattle. Business Week. December 14, 1975. p. 72, 74, 75.

For beef products, the competition will likely come from soybean product substitutes rather than synthetics, at least for the near future. Increasing worldwide needs for protein sources and the preference for beef products have helped spur the search for acceptable substitutes. The relatively lower cost of vegetable protein has provided the incentive for the development of vegetable substitutes for meat products.

A USDA study[43] estimates that up to 1980, various factors will prevent meat "analogs" from becoming competitive for direct consumer sale. Institutional usage will grow and there will be increased use as processed meat extenders, with amounts ranging from 10% to 15% of the total product. Three levels of use were projected. With use at a low level, it was estimated that nearly 2 x 10^6 cattle would be replaced and about 4% of the total production of beef for 1980 would come from soy substitutes. The high level estimate would replace over 4 x 10^6 head and provide 8.5% of the total beef supply. The level of use will depend on beef supplies and prices, technological advancements and public attitudes toward the substitute products.

New developments in either cattle feeding or handling of beef could cause further shifts in the scale and location of feeding. These are not expected to seriously affect the trends being developed and the projections for larger feedlot growth in the near future. Consumer demand should continue to be strong; this will tax the capacity of competitive elements of the industry in all areas.

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[43] Synthetics and Substitutes for Agricultural Products: Projections for 1980. Economic Research Service, U.S. Department of Agriculture. Washington. Marketing Research Report No. 947. March 1972. 18 p.

Surprisingly, U.S. demand for beef has remained high during the cattle industry's present cost-price squeeze, despite concurrent growing pressure on consumer purchasing power. Annual beef consumption increased about 6% in 1974 to 52.5 kg *per capita* and it is expected to rise to 55.3 kg *per capita* in 1975.[40] That compares to an average annual consumption increase of about 3% *per capita* between 1960 and 1970.

The growth factor for the beef cattle feeding industry from 1972 to 1978 is anticipated to be 2.0%/yr, even with the disastrous years of 1973 and 1974. The ratio of emissions to production is assumed to be constant; consequently, the ratio of 1978 production to 1972 production will be 1.13 or an overall increase of 13%. This will manifest itself in a 13% increase in emissions over this period.

SECTION VII

APPENDIXES

A. Data Treatment for Emissions and Source Severity Calculations

B. Health Hazard Potential Attributable to Odorous Emissions

C. Results form Presurvey Air Samples Taken at Two Texas Cattle Feedlots

D. Raw Data

APPENDIX A

DATA TREATMENT FOR EMISSIONS AND SOURCE SEVERITY CALCULATIONS

Emissions originate from several points and mix in the atmosphere surrounding the feedlot. Particulates are generated from dry pen surfaces by wind and cattle movement. Vehicular traffic along alleyways between the pens also contributes to particulate generation. Ammonia is generated by manure decomposition and evaporation from the pen surfaces, by urine breakdown to urea to ammonia evaporation, and by desorption from runoff ponds, basins, and lagoons. Odors are evolved from the same sources as ammonia and from spilled feed decomposition and manure-pad/pen-surface scraping operations. In addition, odoriferous compounds may be adsorbed onto particulate matter or the dust may contain a fraction comprised of manure dust.

1. PARTICULATES

Particulate matter levels have been measured and reported in research sponsored by the California Cattle Feeders Association (CCFA). In one study,[26] control technology experiments were conducted. Particulate levels were reported as total particulates for 10 feedlots and particle size distribution was not determined. Measurements were conducted using a Staplex high-volume air sampler, which was placed inside the pens. The average particulate level for 24-hr sampling of the 10 lots was 14,200 $\mu g/m^3$ with a range from 1,946 $\mu g/m^3$ to 35,537 $\mu g/m^3$ and an estimated population of 11,814 $\mu g/m^3$. These data were of little value for the current source assessment study since much of the particulate matter inside dusty pens will settle out rapidly, although the amount that will settle is unknown. In addition, no data exist on wind speed and its correlation with dust levels, atmospheric stability class, feedlot location, size, number of cattle, and particulate levels leaving or outside the feedlot. This study showed that particulate levels in the pens vary throughout the day; the critical period of dust production at the feedlots studied occurred in the early evening, when the cattle commence playful activities.

In the second CCFA study,[5] feedlot air, water, and soils were analyzed. Twenty-five member feedlots were sampled upwind and downwind with Staplex high-volume air samplers, and atmospheric concentrations were reported as shown in Table A-1. These data are useful in that a mean level can be calculated and a standard deviation derived. However, the limitations of these data are numerous: (1) all feedlots were sampled during California's dry season; no data exist for the remainder of the year or for other parts of the U.S.; (2) the distances of the samplers downwind are not reported; (3) the atmospheric conditions (i.e., wind speed, wind shift, stability class) of the sampling period are not defined; (4) no information is provided regarding the use or absence of emission control techniques in the feedlots sampled; and, (5) feedlot size, number of cattle on feed, and cattle density in pens are not reported. Correlations with geographic, topographic, or meteorological parameters are not possible based on the data reported for particulate air pollution from feedlots. However, this literature data can be used to estimate the order of magnitude of ambient concentrations that can be expected.

In order to estimate the emission rate from the downwind concentration data of Table A-1, several assumptions were made and a dispersion model was utilized. The most appropriate dispersion model for this application is the continuous line source, shown in Figure A-1. As the wind moves across the feedlot it picks up the dust generated by cattle

Table A-1. PARTICULATE MATTER FROM 25 CALIFORNIA FEEDLOTS[5]

Area	Feedlot number	Particulate matter, $\mu g/m^3$			
		Downwind	Upwind	Downwind minus upwind	Upwind as percent downwind
Los Angeles	19	527.9	74.6	453.3	14.1
	25	1,176.9	199.0	977.9	16.9
	avg	852.5		715.5	
Desert	4	521.5	103.2	418.3	19.8
	8	1,304.3	269.5	1,034.8	20.7
	9	163.8	55.2	108.6	33.7
	12	586.1	237.7	348.4	40.6
	13	959.5	425.0	534.5	44.0
	15	1,115.2	155.4	959.8	13.9
	17	949.7	233.7	716.0	24.6
	20	99.9	46.2	53.7	46.3
	avg	712.6		521.8	
Central Valley	2	1,260.4	214.0	1,046.4	16.9
	3	551.0	171.2	379.8	31.1
	5	1,356.0	271.3	1,184.7	20.0
	6	827.9	167.6	660.3	20.2
	7	1,235.1	374.8	860.3	30.3
	10	1,598.9	331.1	1,267.8	20.7
	14	1,163.6	460.0	703.6	39.5
	22	347.7	79.2	268.5	22.8
	23	1,217.2	56.2	1,161.0	4.6
	24	473.4	197.3	276.1	41.6
	avg	1,003.1		780.9	
Central Coast	1	445.6	166.2	279.4	37.3
	11	351.7	0	0	0
	16	1,449.6	319.8	1,129.8	22.0
	26	345.3	129.1	216.2	37.4
	avg	648.3		542.0	
North Coast	18	860.0	199.4	660.6	23.1
Overall average		835.6		654.2	

and carries it to the apparent place of emission - the edge of the feedlot. The downwind sampler thus "sees" a continuously emitting line source.

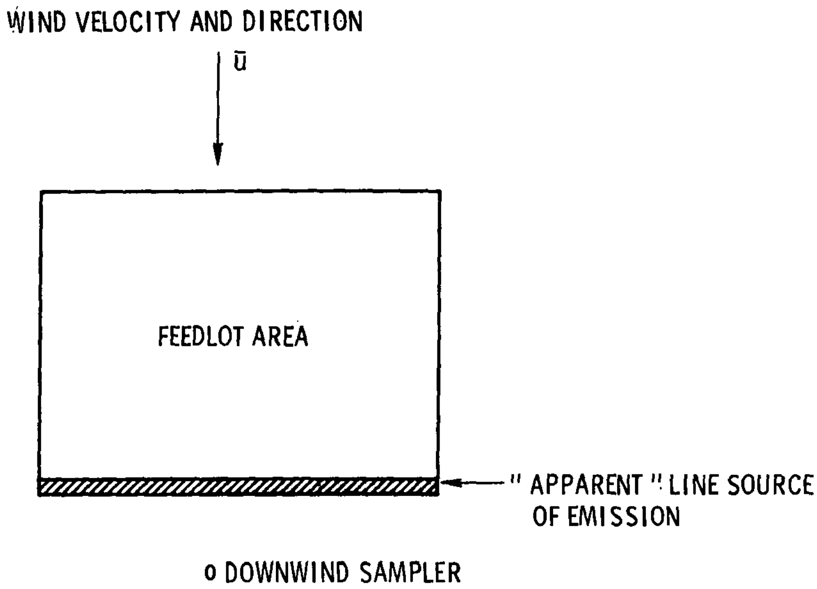

Figure A-1. Representation of the continuous line source dispersion model

The following equation was used to calculate the emission rate:[23]

$$\chi = \frac{2\, Q_L}{\sqrt{2\pi}\ \sigma_z u} \exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right] \qquad \text{(A-1)}$$

or

$$Q_L = \frac{1}{2}\, \chi\, \sqrt{2\pi}\ \sigma_z u \exp\left[\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right] \qquad \text{(A-2)}$$

where χ = concentration at downwind distance X, g/m^3

Q_L = emission rate per length of a line source, g/s·m

u = average wind speed, m/s

H = effective height of emission, m

σ_z = standard deviation in the vertical of the plume concentration distribution, m

π = 3.14

The value of σ_z and the use of the above dispersion equation are representative for a sampling time of about 10 minutes. Since the data were taken from a 24-hr sampling period, it was necessary to correct the reported concentration values to a 10-min averaging time. The appropriate equation for this correction is:[23]

$$\chi_k = \chi_s \left(\frac{t_s}{t_k}\right)^{0.17} \qquad \text{(A-3)}$$

where χ_s = concentration for actual sampling time
χ_k = concentration for 10-min sampling time
t_k = 10 min
t_s = actual sampling time, min

The corrected concentrations for inclusion in the dispersion model are shown in Table A-2.

Since data were lacking as to atmospheric conditions and distance downwind from the feedlots sampled, the following assumptions were made for each feedlot:

Downwind distance (x)	= 50 m
Wind speed (u)	= 4.47 m/s (national average)
Stability class	= C (national avarage)
Height of emission (H)	= 3.05 m (10 ft)
Vertical coefficient (σ_z)	= $0.113\left(x^{0.911}\right)$ = 4.0 m

The calculated emission rate per length is shown in Table A-2 for each feedlot.

The mean particulate emission rate for the 25 feedlots is 0.0361 g/s-m. In order to estimate the emission rate in grams per second instead of grams per second per meter, the length of the line source was estimated. Figure A-2 displays

Table A-2. CALCULATION DATA FOR CALIFORNIA FEEDLOT EMISSION RATE PER LENGTH OF A LINE SOURCE

Feedlot number	χ (measured), $\mu g/m^3$	χ (corrected), $\mu g/m^3$	Q_L g/s-m
19	453.3	1,056.2	0.0256
25	977.9	2,278.5	0.0553
4	418.3	974.6	0.0237
8	1,034.8	2,411.1	0.0585
9	108.6	253.0	0.0061
12	348.4	811.8	0.0197
13	534.5	1,245.4	0.0302
15	959.8	2,236.3	0.0543
17	716.0	1,668.3	0.0405
20	53.7	125.1	0.0030
2	1,046.4	2,438.1	0.0592
3	379.8	884.9	0.0215
5	1,184.7	2,760.4	0.0670
6	660.3	1,538.5	0.0373
7	860.3	2,004.5	0.0487
10	1,267.8	2,954.0	0.0717
14	703.6	639.4	0.0398
22	268.5	625.6	0.0152
23	1,161.0	2,705.1	0.0657
24	276.1	643.3	0.0156
1	279.4	651.0	0.0158
11	263.7	614.4	0.0149
16	1,129.8	2,632.4	0.0639
26	216.2	503.7	0.0122
18	660.6	1,539.2	0.0373
			$\bar{Q}_L$ = ±0.0361

the size distribution of California feedlot capacities; from this an average-sized feedlot of 8,000-head capacity was chosen. Typical cattle stocking rates for eastern portions of Nebraska, Kansas, South Dakota, and for Illinois, Minnesota, Iowa, and other Corn Belt cattle feeding states is about 10 acres per 1,000 head of cattle, or 436 ft^2/head. For California, Arizona, New Mexico, Texas, Colorado and other dryland feeding areas, however, the stocking rates

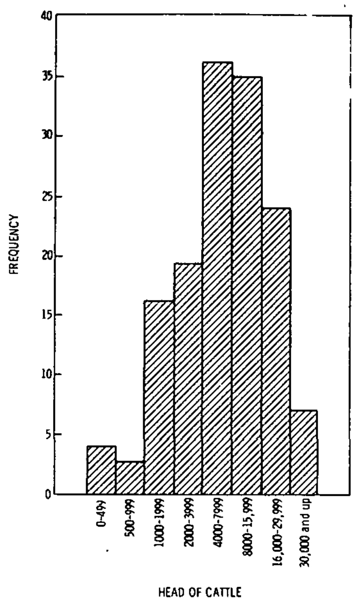

Figure A-2. California feedlot size distribution[1]

average 150 to 175 ft^2/head including alleys and feed pens, or 3.44 acres per 1,000 head of cattle.[44] Hence, an area of 27.5 acres was assumed as an average-sized California feedlot. Assuming the area to be square, the length of its sides is 330 m. This was taken to be the length of the line source of emissions as depicted in Figure A-1. Thus, the emission rate from an average-sized California feedlot during the dry season is (0.036 g/s-m) x (330 m), or 11.9 g/s. On an area basis, the particulate emission rate is 36.7 $\mu g/s\text{-}m^2$ (0.15 g/s-acre).

2. AMMONIA

The method for determining the extent of air pollution from ammonia volatilized from feedlot surfaces is much better

[44]Personal communication. Dr. J. M. Sweeten, Extension Agricultural Engineer, Texas Agricultural Extension Service, Texas A&M University System. College Station. April 1976.

defined than that for particulates. The nitrogen, N, content of manure, as ammonia, can be lost by volatilization and widely dispersed. This N is effectively lost to the atmosphere, and decreases the fertilizer value of manure. Animals ingest N that has been taken up by crops in an inorganic form and converted to organic N in the plant. During digestion enzymatically labile organic N compounds are formed. Following excretion enzymatic reaction with these labile compounds releases ammonia which is subject to volatilization. Inherently, animal production with volatile losses of ammonia from manure allows a potentially significant "leak" or mass flow of N from the agricultural N cycle. Ammonia volatilization decreases the amount of N that could be recycled back to a crop where the N originated. Ammonia loss by volatilization occurs in addition to other avenues of loss including leaching and runoff from manure in feedlots. However, volatile losses of ammonia are considered more significant in total flow of N than those other pathways because of the rapid dynamics of the volatilization process. Estimates show that as high as 50% of N in manure is lost by ammonia volatilization.[45]

Two studies[46,47] reported the rates at which ammonia was absorbed directly from the air by nearby water surfaces under different conditions of temperature and climate at various distances and directions from feedlots. Dilute sulfuric acid

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[45]Lauer, D. A. Limitations of Animal Waste Replacement for Inorganic Fertilizers. In: Energy, Agriculture and Waste Management - Proceedings of the 1975 Cornell Agricultural Waste Management Conference, Jewell, W. J. (ed.). Ann Arbor, Ann Arbor Science Publishers, Inc., 1975. p. 409-432.

[46]Hutchinson, G. L., and F. G. Viets. Nitrogen Enrichment of Surface Water by Absorption of Ammonia Volatilized from Cattle Feedlots. Science. 166:514-515, October 1969.

[47]Luebs, R. E., K. R. Davis, and A. E. Laag. Diurnal Fluctuation and Movement of Atmospheric Ammonia and Related Gases from Dairies. Journal of Environmental Quality. 3(3):265-269, 1974.

traps were utilized to increase the water's ammonia retention capacity and minimize biological transformation of the ammonia. Dilute sulfuric acid absorbs ammonia at approximately twice the rate of demineralized water.

In one study,[46] it was found that surface lake water could absorb from 0.9 g/m^2 to 7.3 g/m^2 (8 lb/acre to 65 lb/acre) of nitrogen as ammonia per year throughout the year, even when both the feedlot and the lake were covered with ice and snow. Wide fluctuations in weekly absorption rates noted at the testing sites were due to the moisture status of the feedlots. Absorption peaks coincided with the time when the feedlots were undergoing rapid drying, and low points paralleled periods of precipitation or low evaporation. The researchers reported that 3.4 g/m^2 (30 lb/acre) is sufficient to eutrophy a lake averaging 6 m (20 ft) in depth to two or three times the concentration needed for algal blooms. Growth of algae in a lake is dependent upon an adequate supply of approximately 16 different factors (temperature, light, carbon dioxide, and many mineral nutrients). In many lakes the supply of nitrogen and phosphorus appears limiting. Approximately 0.01 ppm of phosphorus and 0.5 ppm of nitrogen must be present in water for algal growth.

In another study,[3] it was found that cattle urine, when added to laboratory soil columns, volatilized as ammonia. When urine was added every 2 days to an initially wet soil, 20% to 25% of the added nitrogen was lost as ammonia and ~65% was converted to nitrate. When urine was added every 4 days to initially dry soil, essentially all of the water evaporated between urine additions, and 85% to 90% of the added nitrogen was lost as ammonia.

Actual downwind atmospheric concentrations were reported by researchers who used air samplers and dilute H_2SO_4 to monitor ammonia levels around large and small dairies in southern California.[47] Local concentrations were discovered which ranged from 20 to 40 times the distillable nitrogen (80% to 95% ammonia) concentration that was present in an urban area 11 km upwind from the large dairy area. Atmospheric concentrations of 36, 38, 45, and 66 $\mu g/m^3$ were reported (subtracting upwind from downwind) at a distance of 0.8 km from the dairy area. The acid trap findings used in that study confirmed the work described earlier.[46] The report also indicated that if large surface bodies of water absorb and retain ammonia at the rates observed in areas where cattle distribution and weather conditions were similar to those studied, such waters would soon have higher ammonia concentrations than that recommended for public consumption or industrial use.

Excellent data on ammonia volatilization rates from a cattle feedlot were given in a study[34] on commercial odor abatement product efficacy. Comparisons between treated pens and untreated (control) pens of daily average ammonia release rates were presented. In all, 56 data points for untreated pens under varying temperature and humidity conditions were given.

In the study, the rate of ammonia evolution was used as a measure of odor production since anaerobic conditions favor production of ammonia as well as other odoriferous compounds. To quantify the rate of ammonia release, a sampling box was placed on the feedlot surface. The box covered a square area of 0.37 m^2 with a plywood deck 0.3 m from the bottom. A diaphragm pump was used to pull air from beneath the deck through an absorption tube containing 10 ml of dilute sulfuric acid. The acid solution absorbed the ammonia from the pumped air. Replacement air entered the space beneath the deck through a tube which terminated in a can of crushed charcoal. Thus, only ammonia-free air entered the chamber beneath the deck.

The ammonia concentration of the absorbing solution was measured by nesslerization. Knowing the area covered by the sampling box, the sampling time, the absorbing solution volume, and the ammonia concentration of the absorbing solution, the ammonia nitrogen release rate was calculated in mg per m^2-hr. The 56 data points ranged from 1.3 mg/m^2-hr to 51 mg/m^2-hr, with a mean value of 14.5 mg/m^2-hr. For a 27.5 acre feedlot, the total emission rate is 0.45 g/s, and the line source emission rate is 1.36 mg/m-s.

3. AMINES

Researchers have indicated that amines volatilized from cattle feedlot surfaces comprise about 2% to 6% of the mass emitted relative to ammonia.[17] Air samples taken at two feedlots (Appendix C) indicated no amines present at a level of 10% relative to the ammonia detected. Based on literature data, it was assumed that emissions of amines were 4% relative to ammonia emissions; thus, the emission rate of all amines from an average-sized California feedlot is 0.04 x 0.45 g/s, or 0.018 g/s. No estimation of uncertainty was possible.

All of the amines which have been identified in atmospheres surrounding cattle feedlots were presented in Table 4. Other amines have different TLV's and, since the relative concentrations of the amines were not known, a composite TLV could not be calculated. Instead, a mean TLV for all amines was assumed by averaging those amines for which TLV's have been established; thus, from Table 4, the TLV for amines from cattle feedlots is 35.7 mg/m^3, or 0.036 g/m^3.

4. SULFIDES AND MERCAPTANS

Air samples taken at two cattle feedlots (Appendix C) indicated that total sulfur compounds constituted 4% to 25% relative to ammonia concentrations. A simple average of these two values, or 15%, was assumed as an estimate of the emission rate of sulfur compounds from feedlots, 0.068 g/s. No determination of uncertainty was attempted. Again, a mean TLV was assumed for total sulfur compounds based on values presented in Table 4, which resulted in a TLV of 5.8 mg/m^3, or 0.006 g/m^3.

APPENDIX B

HEALTH HAZARD POTENTIAL ATTRIBUTABLE TO ODOROUS EMISSIONS

Odor has always been associated with cattle feedlot operations. Owners and operators of feedlots usually become insensitive to the odor or find it unobjectionable. However, neighbors, especially those downwind, often object to the odor. Complaints which arise are sometimes translated into legal action which has forced changes in operation or removal of feedlots. Reactions to odor are notoriously subjective.

It is generally accepted that odor production at a feedlot is the result of anaerobic (oxygen-less, bacterial) digestion of the cattle wastes on the feedlot surface. Aerobic (oxygen-consuming, bacterial) digestion products are, in theory, almost entirely CO_2 and H_2O. Anaerobic digestion of organic matter produces gaseous products which are typically ∿60% CH_4, ∿35% CO_2, and the remainder an odoriferous mixture of H_2, N_2, NH_3, CO, O_2, H_2O, sulfides, alcohols, aldehydes, and volatile amines.

From the above list, it is logical to concentrate on those compounds which are known to be strong odorants: the amines (generally low molecular weight compounds); sulfur compounds; low molecular weight organic acids; and low molecular weight organic aldehydes. Several researchers[7,17-20] have identified compounds in the atmosphere above cattle feedlots. These compounds were listed earlier in Table 4 along with their TLV's and odor thresholds (if known).

A common observation regarding feedlot odors is that odors downwind from a feedlot are not of the same quality (i.e., "smell different") as those immediately outside a feedlot.

The detection in feedlot air of the nitrogen heterocyclic compounds indole and skatole (3-methyl indole) is useful. Indole reportedly has a powerful, harsh α-naphthylamine odor in large concentrations and a jasmine odor upon dilution. Skatole has been called "the odorous principle of faeces" because of its powerful disagreeable odor, which is present even upon great dilution.[48] Skatole's odor threshold is the lowest in Table 4 (7.5×10^{-8} ppm). Both indole and skatole are very tenacious odorants which cling to clothing and other articles and persist for long periods. Skatole has been found to be present in concentrations approximately 18 times higher than indole.[48] Skatole is evidently responsible for the strong fecal note in feedlot malodor and probably is in part responsible for the tenacious character of animal waste odor.

A persistence factor has been defined as a relative measure of the time that odorous substances will remain olfactorily perceptible.[16] The persistence factor, P, is defined as:

$$P = \frac{p_0}{p} \exp\left[\frac{1}{2}\left(\frac{T}{T_0}\right)\frac{M_0}{M}\right] \qquad \text{(B-1)}$$

where p = vapor pressure of gaseous compound, torr
M = molecular weight of gaseous compound
T = air temperature, °K

The subscript $_0$ refers to water vapor as a standard under the following conditions:

$T_0 = 15°C = 288°K$; $p_0 = 12.7$ torr; $M_0 = 18$

[48]Burnett, W. E. Determination of Malodors by Gas Chromatographic and Organoleptic Techniques. Environmental Science and Technology. 3:744-749, August 1969.

Water vapor at these standard conditions has a persistence factor of 1.0. Higher persistence factors would indicate a more persistent compound. Lower P values would indicate lesser persistence and thus less chance of transport and perception downwind. Using the above equation, the persistence factors of four odorous compounds emitted from feedlots are compared below. Note that trimethylamine, which has a low odor threshold, is included. The persistence factors shown in Table B-1 refer to 68°F (293°K).

Table B-1. PERSISTENCE OF ODOROUS SUBSTANCES

Odorous gas	Persistence factor, P	Odor threshold, ppm
Ammonia	0.0035	46.8
Hydrogen sulfide	0.0012	0.0047
Trimethylamine	0.0092	0.00021
Skatole	9.1	0.000000075

Table B-1 demonstrates that ammonia, hydrogen sulfide, and trimethylamine have approximately the same level of persistence; however, skatole is much more persistent. Hence, skatole is a good compound for use in assessing the health effects which might result from downwind exposure to feedlot odors.

The question to be addressed here is: What is the hazard potential of skatole and can it be considered as a hazardous material emitted from cattle feedlots? No TLV has been established for skatole, but the LDLo[a] for 3-methyl indole

[a] LDLo = lethal dose low; the lowest dose of a substance, other than LD_{50}, introduced by any route other than inhalation, over any given period of time and reported to have caused death in man, or the lowest single dose introduced in one or more divided portions and reported to have caused death in animals.

(skatole) is 1,000 mg/kg applied subcutaneously on frogs.[49] The human respiration rate can be estimated as 0.01 m^3/min and the assumption can be made that subcutaneous application on frogs is equal to human inhalation. This assumption may be off by a factor of 10, but not much more than that (based on comparison with other chemical substances where the TLV is known). The irritation of the epithelium is markedly similar in either the subcutaneous tissue or the primary and secondary lobules in the lung. Hence, irritation will be equated to toxicity in this case.

Next, it is assumed that the LDLo dosage may be equated to a concentration by assuming that the maximum retention of the chemical substance will be 1 year. This assumption is out of proportion but will compensate for any error associated with the first assumption. Then, for a 70-kg person, the hazardous concentration is calculated by:

$$\frac{(1{,}000\ \text{mg/kg})(70\ \text{kg})}{(0.01\ \text{m}^3/\text{min})(60\ \text{min/hr})(24\ \text{hr/day})(365.25\ \text{day/yr})} = 13.3\ \text{mg/m}^3$$

Thus, the hazardous concentration for a 70-kg person would be 13 mg/m^3 on a continuous dosage basis. Applying a further safety factor of 100, the hazard potential concentration would be 130 μg/m^3. This value is about six orders of magnitude above the odor threshold (0.0004 ng/m^3) for skatole and probably three or more orders of magnitude above the highest concentration around a cattle feedlot. Therefore, skatole is not apt to exist in high enough concentrations to be a hazard to public health, even though it may cause a severe odor nuisance.

[49]The Toxic Substances List, 1974 Edition. U.S. Department of Health, Education, and Welfare. Rockville, Maryland. HEW Publication No. (NIOSH) 74-134. June 1974. 904 p.

APPENDIX C

RESULTS FROM PRESURVEY AIR SAMPLES TAKEN AT TWO TEXAS CATTLE FEEDLOTS

Air samples were taken earlier within the confines of two beef cattle feedlots located in the high plains region of Texas in order to identify the gases emanating from the feedlot surface. These results were to be used to prioritize the compounds to be sampled, should field sampling have occurred.

Fiber glass filters impregnated with sulfuric acid and mounted in a cassette were used for the collection of ammonia and amines. In addition, the following four types of porous polymer packings in Porapak Q stainless steel sampling tubes were treated for the collection of different classes of gases:

Packing	Material to be treated
Chromosorb 101	Acidic materials
Chromosorb 104	Sulfides and mercaptans
Chromosorb 103	Low molecular weight amines
Tenax-GC	Basic materials (ammonia)

Bendix Unico personal samplers were utilized as pumps. Sampling flow rates through the filters were approximately 2.5 to 3.0 liters/min for 10-min durations. Flow rates through the polymer tubes ranged from 1.3 to 3.1 liters/min for the same duration. The sampling apparatus is shown in Figure C-1.

1. AMMONIA AND AMINES

The fiber glass filters impregnated with H_2SO_4 were desorbed with a 20% aqueous solution of NaOH and were collected for analysis in water cooled externally with ice. From this water solution, ammonia analyses were performed using an ion specific electrode and the addition method. The following results were obtained:

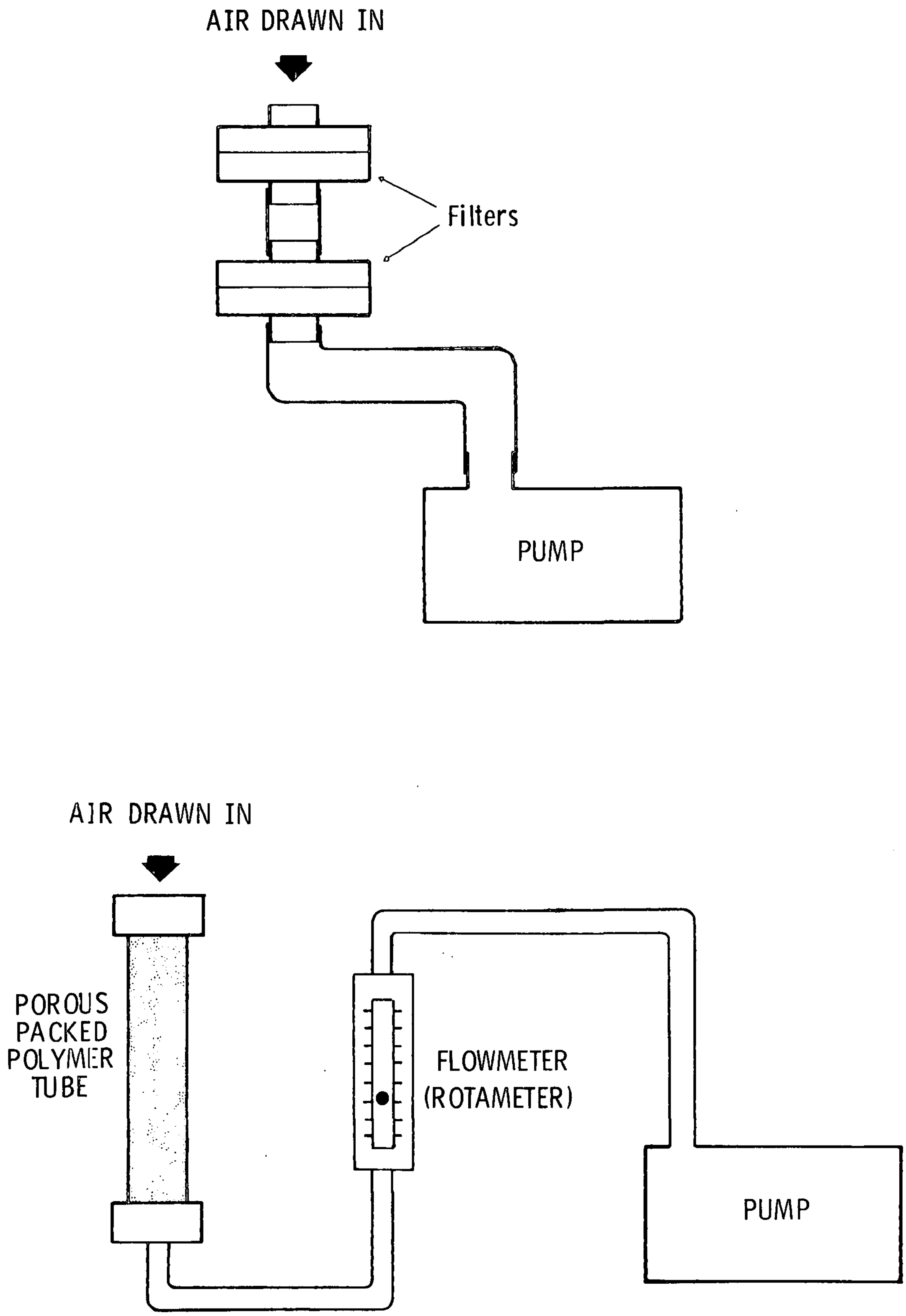

Figure C-1. Preliminary sampling setup

Feedlot	Quantity of ammonia collected, μg	Calculated ammonia level, μg/m^3
A	2.6	104
B	3.0	120

From this water solution, an amine analysis was performed using a gas chromatograph (F&M 810) equipped with a flame ionization detector and a column composed of 4 ft x 1/4 in. Teflon-GP 4% Carbowax plus 0.8% KOH on Carbopack B. No amines were detected at the 8×10^{-5} g/filter level (10 μg/m^3).

A Chromosorb 103 packed porous polymer tube was used to collect air samples of low molecular weight amines. Polymer decomposition fouled results with these samples.

Tenax-GC packed porous polymer tubes were also used for basic material collection. Several weak GC-FID peaks were obtained and tentatively identified based on comparison with standard mixtures of primary and secondary amines. The low intensity of these peaks precluded the use of a gas chromatograph-mass spectrometer system for component identification. The gas chromatograph operational parameters were:

- Program from 50°C to 200°C after 8-min port injection
- Port injection 190°C to 210°C
- N_2 flow 20 mm on rotometer using the stop flow method
- Chart speed Lo-1 or 4 in./min

Desorption was accomplished by insertion into the injection port and the following materials were observed:

Feedlot	Material identified
A	n-Propylamine
B	n-Ethylamine Dimethylamine n-Propylamine n-Butylamine n-Hexylamine

The collection and desorption efficiencies for the polymer tubes have not been established; consequently, a rough quantitative determination could not be made.

2. CARBOXYLIC ACIDS

Chromosorb 101 packed porous polymer was used for air sampling. No materials were detected at the lower limit of detection, 1 x 10^{-7} g (or 4 $\mu g/m^3$).

3. SULFIDES AND MERCAPTANS

Chromosorb 104 packing was used and the following materials were noted. No single species were identified because their concentrations were too small.

Feedlot	Quantity of total sulfides collected, μg	Calculated quantities and materials observed
A	0.64	27.5 $\mu g/m^3$ total sulfides; n-propyl mercaptan identified, others not identified
B	0.12	5 $\mu g/m^3$ total sulfides

APPENDIX D

RAW DATA

1. AMMONIA-AMINE ANALYSES ON FEEDLOT ATMOSPHERES

a. Summary of Sample Collecting Systems and Analyses

Two types of sampling systems were used: (a) fiber-glass filters impregnated with sulfuric acid[50] and (b) short (4 to 6 in.) tubes (approximately 1/4-in. Pyrex) packed with Chromosorb 103 and Tenax GC.[51]

The ammonia and amines were desorbed from the sulfuric acid impregnated filters with 20% aqueous solution of NaOH and were collected for analysis in water cooled externally with ice. (See Reference 50 for desorption apparatus.)

Ammonia analyses were performed by using an ion specific electrode and the addition method. Measurements for amines were made with a gas chromatograph (F&M 810) equipped with a flame ionization detector and column composed of 4' x 1/4" Teflon-GP 4% Carborwax 20M + 0.8% KOH on Carbopack B.

b. H_2SO_4-Impregnated Filters

No amines were detected in the desorbates (H_2O solutions) from the sulfuric acid impregnated filters. The detection limit for the individual amines with the GC-FID system is approximately 2×10^{-5} g/ml or 8×10^{-5} g/filter.

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[50]Okita, T. Filter Method for the Determination of Trace Quantities of Amines, Mercaptans, and Organic Sulphides in the Atmosphere. Atmospheric Environment, 4:93-102, 1970.

[51]Mieure, J. P., and M. W. Dietrich. Determination of Trace Organics in Air and Water. J. Chromatog. Science, 11:559-570, 1973.

The ammonia results are as follows:

Filter	Quantity of ammonia collected, μg
No. 34 amines - H_2SO_4	2.6
No. 36 amines - H_2SO_4	3.0

c. Porous Polymer Tubes

The GC-FID patterns obtained with the Chromosorb 103 porous polymer were too complicated by polymer decomposition to be useful.

Several weak GC-FID peaks were obtained from the Tenax-GC packed tubes. The low intensity of these peaks precluded use of our current GC-mass spectrometer system for component identification. Tentative peak assignments were made based on GC retention data, as determined by comparison with standard mixtures of primary and secondary amines.

The gas chromatographic operational parameters are as follows:

Instrument:	F&M 810
Program:	From 50°C to 200°C, after 8 min post inject.
Injection port:	190°C to 210°C
N_2 flow:	20 mm on rotometer - stop flow method
Chart speed:	Lo-1 or 4 in./min
Column:	4' x 1/4" Teflon-GP4% Carbowax 20M + 0.8% KOH on Carbopack B, Lot B 4302

Desorption from the porous polymers was accomplished by inserting the tube containing the polymer into the injection part of the chromatograph.[51]

The gas chromatographic measurements are as follows:

Porous polymer tube	Retention time, min	Peak height, mm	Tentative assignment	Estimated quantity of amine, µm
Tenax GC No. 19	7.5	7	Possibly n-ethyl amine	2.7
	11.7	34	Unknown (Dimethyl amine??)	13[a]
	14.1	4	Possibly n-propyl amine	1.5
	18.9	3	Possibly n-butyl amine	1.2
	26.9	55	Possibly n-hexyl amine	21
Tenax GC No. 20	13.1	54	-[b]	21[a]

[a] Calculated as propyl amine equivalent.

[b] Retention time short of n-propyl amine.

L. Metcalfe
J. E. Strobel
J. V. Pustinger

Addendum:

The collection and desorption efficiencies have not been established. Methyl and ethyl amines probably would not have been retained on the porous polymers.

J.V.P.

Project No: 6912-48-9(5)
Date: 18 November 1974

2. ANALYSIS OF PRODUCTS COLLECTED FROM BEEF CATTLE FEEDLOTS - MERCAPTANS, SULFIDES

Porous polymer tube number	Peak height, mm	Retention time, min	Tentative assignment	Estimated quantity,[a] g
No. 17	70	4.0	Unknown	2.1×10^{-7}
	105	7.9	n-propyl mercaptan (?)	3.1×10^{-7}
	48	11.8	Unknown	1.4×10^{-7}
No. 23	5	5.6	??	0.2×10^{-7}
	10	10.3	??	0.4×10^{-7}
	15	17.5	??	0.6×10^{-7}

[a]Calculated based on n-propyl mercaptan equivalents.

Remarks:

Broad peaks were obtained from tube No. 23, whereas much sharper peaks were observed in the pattern for effluent from No. 17. Tubes contained Chromosorb 104. No positive component identification can be made based on GC retention data alone.

Project No. 6912-48 ANALYST: L. Metcalfe
Date: 4 December 1974 GROUP LEADER: J. V. Pustinger

3. ANALYSIS OF POROUS POLYMER TUBES No. 13 and No. 21 - CARBOXYLIC ACIDS FROM FEEDLOT SAMPLING

We were unable to make a positive identification of compounds desorbed from the Chromosorb 101 polymers. The low levels of the atmospheric contaminants required the use of high sensitivity settings with the FID-GC systems which empahsized the background from the polymer. Although some weak peaks were observed, all of these appear due to components being emitted from the polymer itself.

Comparison of retention times for a standard mixture of carboxylic acids - propionic acid, butyric acid, valeric acid, caproic acid, and heptanoic acid - show no evidence for the presence of these materials at the 1×10^{-7} g level.

L. Metcalfe
J. E. Strobel
J. V. Pustinger

Project Number: 6912-48-9(5)
Date: 19 November 1974

SECTION VIII

GLOSSARY OF TERMS

ATMOSPHERIC STABILITY CLASS - An alphebetic designation for dispersion categories used to describe the turbulent structure of the atmosphere.

CONFIDENCE LEVEL - The probability that a random variable lies within a specified range given a known distribution of that variable.

CONFIDENCE LIMITS - Upper and lower boundaries of values within which a random variable will occur with a given probability.

CRITERIA POLLUTANTS - Pollutants for which ambient air quality standards have been defined.

ELEVATED SOURCES - Sources with a point of emission above ground level.

EMISSION BURDEN - Ratio of emissions from a source to the total emissions per state or nation.

FED CATTLE - Cattle which have been finish fed with grain concentrates in a confined space prior to slaughter.

FEEDER CATTLE - Cattle which have been range or pasture grazed prior to entering a feedlot.

HAZARD FACTOR - Toxicity of a pollutant corrected for a 24-hr exposure with a safety factor of 100.

NESSLERIZATION - Method of detection of ammonia using a solution of $KI-HgI_2$ in H_2O and KOH, called Nessler's reagent.

NONCRITERIA POLLUTANTS - Pollutants for which ambient air quality standards have not been established.

NUCLEPORE - A polycarbonate filter medium.

OPEN SOURCES - Fugitive sources which do not have a definable point of emission such as a stack or vent.

THORNTHWAITE'S P-E INDEX - A relationship expressing the amount of precipitation and the mean temperature in a given region.

SECTION IX

CONVERSION FACTORS AND METRIC PREFIXES[52]

CONVERSION FACTORS

To convert from	to	Multiply by
degree Celsius (°C)	degree Fahrenheit	$t_{°F} = 1.8\ t_{°C} + 32$
degree Kelvin (°K)	degree Celsius	$t_{°C} = t_{°K} - 273.15$
kilogram (kg)	pound-mass (lb mass avoirdupois)	2.204
kilometer^2 (km^2)	acre	2.470×10^2
meter (m)	foot	3.281
meter (m)	inch	3.937×10^1
meter^2 (m^2)	acre	2.470×10^{-4}
meter^2 (m^2)	yard^2	1.196
meter^3 (m^3)	gallon (U.S. liquid)	2.642×10^2
meter^3 (m^3)	inch^3	6.102×10^4
metric ton	pound	2.205×10^3
paschal (Pa)	pound-force/inch^2 (psi)	1.450×10^{-4}
paschal (Pa)	torr (mm Hg, 0°C)	7.501×10^{-3}

PREFIXES

Prefix	Symbol	Multiplication Factor	Example
kilo	k	10^3	1 kg = 1×10^3 grams
milli	m	10^{-3}	1 mm = 1×10^{-3} meter
micro	μ	10^{-6}	1 μg = 1×10^{-6} gram
nano	n	10^{-9}	1 nm = 1×10^{-9} meter

[52]Metric Practice Guide. American Society for Testing and Materials. Philadelphia. ASTM Designation: E-380-74. November 1974. 34 p.

SECTION X

REFERENCES

1. Number of Cattle Feedlots and Fed Cattle Marketed -- By Size of Feedlot Capacity, by States. Crop Reporting Board. Statistical Research Service, U.S. Department of Agriculture. Washington. 1962 up to 1973.

2. Census of Agriculture, 1969. Volume V, Special Reports. Part 9, Cattle, Hogs, Sheep, Goats. Washington, U.S. Bureau of the Census, 1973. 667 p.

3. Stewart, B. A. Volatilization and Nitrification of Nitrogen from Urine Under Simulated Cattle Feedlot Conditions. Environmental Science and Technology. 4:579-582, July 1970.

4. Taiganides, E. P., and T. E. Hazen. Properties of Farm Animal Excreta. Transactions, American Society of Agricultural Engineers. 9:374-376, 1966.

5. Elam, C. J., J. W. Algeo, T. Westing, and A. Martinez. Feedlot Air, Water and Soil Analysis. California Cattle Feeders Association. Bakersfield. Bulletin D. June 1972. 75 p.

6. Thornthwaite, C. W. Climates of North America According to a New Classification. Geographical Review. 21:633-655, 1931.

7. Narayan, R. S. Identification and Control of Cattle Feedlot Odors. Texas Technological University. Lubbock. M.S. Thesis. 1971. 41 p.

8. Paine, M. D. Feedlot Odor. In: Great Plains Beef Cattle Feeding Handbook. Cooperative Extension Service - Great Plains States, 1972. 2 p.

9. Elliott, L. F., G. E. Schuman, and F. G. Viets, Jr. Volatilization of Nitrogen-Containing Compounds from Beef Cattle Areas. Soil Science Society of America Proceedings. 35:752-755, 1971.

10. Miner, J. R. Evaluation of Alternative Approaches to Control of Odors from Animal Feedlots. Idaho Research Foundation, Inc. Moscow. Grant No. ESR 74-23211, National Science Foundation. December 1975. 83 p.

11. Personal communication. Dr. R. M. Bethea, Department of Chemical Engineering, Texas Technological University. Lubbock. November 1974.

12. Personal communication. Dr. J. M. Sweeten, Extension Agricultural Engineer, Texas Agricultural Extension Service, Texas A&M University System. College Station. October 1974.

13. Census of Agriculture, 1969. Volume V, Special Reports. Part 15, Graphic Summary. Washington, U.S. Bureau of the Census, 1973. 145 p.

14. TLV's® Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes for 1975. American Conference of Governmental Industrial Hygienists. Cincinnati, 1975. 97 p.

15. Leonardos, G., D. Kendall, and N. Barnard. Odor Threshold Determinations of 53 Odorant Chemicals. Journal of the Air Pollution Control Association. 19:91-95, February 1969.

16. Summer, W. Methods of Air Deodorization. New York, Elsevier Publishing Co. 1963. p. 46-47.

17. Mosier, A. R., C. E. Andre, and F. G. Viets, Jr. Identification of Aliphatic Amines Volatilized from Cattle Feedyard. Environmental Science and Technology. 7:642-644, July 1973.

18. Stephens, E. R. Identification of Odors from Cattle Feedlots. California Agriculture. 25:10-11, January 1971.

19. White, R. K., Ohio State University, and J. R. Ogilvie, McGill University. Developments in the Control of Air Pollution Problems Associated with Livestock Production. (Paper No. 73-103, presented at the 66th Annual Meeting of the Air Pollution Control Association. Chicago. June 24-28, 1973.) 21 p.

20. Elliott, L. F., and T. A. Travis. Detection of Carbonyl Sulfide and Other Gases Emanating from Beef Cattle Manure. Soil Science Society of America Proceedings. 37(5):700-702, September-October 1973.

21. Cowherd, C. C., C. M. Guenther, and D. D. Wallace. Emissions Inventory of Agricultural Tilling, Unpaved Roads and Airstrips, and Construction Sites. Midwest Research Institute. Kansas City. U.S. Environmental Protection Agency, EPA-450/3-74-085 (PB 238 919). November 1974. 41 p.

22. Statistical Abstract of the United States: 1973. (94th Edition). Washington, U.S. Bureau of the Census, 1973. p. 187.

23. Turner, D. B. Workbook of Atmospheric Dispersion Estimates. U.S. Department of Health, Education, and Welfare, National Air Pollution Control Administration. Cincinnati. Public Health Service. Publication No. 999-AP-026. May 1970. 65 p.

24. Eimutis, E. C., and M. G. Konicek. Derivations of Continuous Functions for the Lateral and Vertical Atmospheric Dispersion Coefficients. Atmospheric Environment. 6:859-863, November 1972.

25. Eimutis, E. C., B. J. Holmes, and L. B. Mote. Source Assessment: Severity of Stationary Air Pollution Sources--A Simulation Approach. Monsanto Research Corporation. Dayton. MRC-DA-543. U.S. Environmental Protection Agency, EPA-600/2-76-032e. July 1976. 133 p.

26. Elam, C. J., T. Westing, J. W. Algeo, and L. Hokit. Measurement and Control of Feedlot Particulate Matter. California Cattle Feeders Association. Bakersfield. Bulletin C. February 1971. 30 p.

27. Sweeten, J. M. Control of Dust from Cattle Feedlots. Texas Agricultural Extension Service. College Station. Publication No. GPE-7851. April 1974. 10 p.

28. Dust, Fly and Odor Control Methods Practiced by Western Feeders. Texas Cattle Feeders Association. Amarillo. Special Report. June 1972. 15 p.

29. Sweeten, J. M. Down with Dust. Feedlot Management. 1975 Planner Issue. p. 30-33.

30. Sweeten, J. M., W. S. Allen, and D. L. Reddell. Solid Waste Management for Cattle Feedlots; Cattle Feeders Information. Texas Agricultural Extension Service. College Station. Publication No. L-1094. 1973. 4 p.

31. Sweeten, J. M. Feedlot Pollution Control Guidelines. Texas Agricultural Extension Service Miscellaneous Publication No. MP-1155. College Station. July 1974. 12 p.

32. Ford, J. P., and W. L. Ulich. Odor Control for Confined Beef Cattle Feedlots. In Proceedings of the First Annual Symposium on Air Pollution Control in the Southwest. College Station, Texas A&M University, 1973. p. 189-204.

33. Faith, W. L. Odor Control in Cattle Feedyards. Journal of the Air Pollution Control Association. 14:459-460, November 1964.

34. Miner, J. R., Oregon State University and R. C. Stroh, University of Idaho. Controlling Feedlot Surface Odor Emission Rates by Application of Commercial Products. (Paper No. 75-4566, presented at the 1975 Winter Meeting of the American Society of Agricultural Engineers. Chicago. December 15-18, 1975.) 16 p.

35. Hazen, T. E. Discussion. Journal of the Air Pollution Control Association. 22:771-772, October 1972.

36. 1973 Handbook of Agricultural Charts. Agricultural Handbook No. 455. Washington, U.S. Department of Agriculture, October 1973. 152 p.

37. Menzie, E. L., W. J. Hanekamp, and G. W. Phillips. The Economics of the Cattle Feeding Industry in Arizona. The Agricultural Experiment Station, University of Arizona. Tucson. Technical Bulletin 207. October 1973. 82 p.

38. Van Arsdall, R. N., and M. D. Skold. Cattle Raising in the United States. U.S. Department of Agriculture. Washington. ERS Report 235. January 1973. 88 p.

39. Livestock and Meat Statistics. Economic Research Service, U.S. Department of Agriculture. Washington. Bulletin No. 333. Supplement for 1962-72. June 1971. 6 p.

40. Lean Times for Cattlemen. Business Week. March 17, 1975. p. 94, 96.

41. Bullish Times for the Nation's Cattlemen. Business Week. March 15, 1976. p. 46, 48.

42. Using Less Grain to Fatten Cattle. Business Week. December 14, 1975. p. 72, 74, 75.

43. Synthetics and Substitutes for Agricultural Products: Projections for 1980. Economic Research Service, U.S. Department of Agriculture. Washington. Marketing Research Report No. 947. March 1972. 18 p.

44. Personal communication. Dr. J. M. Sweeten, Extension Agricultural Engineer, Texas Agricultural Extension Service, Texas A&M University System. College Station. April 1976.

45. Lauer, D. A. Limitations of Animal Waste Replacement for Inorganic Fertilizers. In: Energy, Agriculture and Waste Management - Proceedings of the 1975 Cornell Agricultural Waste Management Conference, Jewell, W. J. (ed.). Ann Arbor, Ann Arbor Science Publishers, Inc., 1975. p. 409-432.

46. Hutchinson, G. L., and F. G. Viets. Nitrogen Enrichment of Surface Water by Absorption of Ammonia Volatilized from Cattle Feedlots. Science. 166:514-515, October 1969.

47. Luebs, R. E., K. R. Davis, and A. E. Laag. Diurnal Fluctuation and Movement of Atmospheric Ammonia and Related Gases from Dairies. Journal of Environmental Quality. 3(3):265-269, 1974.

48. Burnett, W. E. Determination of Malodors by Gas Chromatographic and Organoleptic Techniques. Environmental Science and Technology. 3:744-749, August 1969.

49. The Toxic Substances List, 1974 Edition. U.S. Department of Health, Education, and Welfare. Rockville, Maryland. HEW Publication No. (NIOSH) 74-134. June 1974. 904 p.

50. Okita, T. Filter Method for the Determination of Trace Quantities of Amines, Mercaptans, and Organic Sulphides in the Atmosphere. Atmospheric Environment, 4:93-102, 1970.

51. Mieure, J. P., and M. W. Dietrich. Determination of Trace Organics in Air and Water. J. Chromatog. Science, 11:559-570, 1973.

52. Metric Practice Guide. American Society for Testing and Materials. Philadelphia. ASTM Designation: E 380-74. November 1974. 34 p.

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16. ABSTRACT The report describes a study of atmospheric emissions of fugitive dusts and volatile products from beef cattle feedlots. Total particulate emissions are affected by feedlot area, cattle density in pens, wind speed, and the regional precipitation-evaporation index. The predominant volatile product, ammonia, constitutes 70% to 90% of the total gaseous emissions. Emissions from the beef cattle feeding industry constitute 0.35% of the national emissions of total particulates. Eight states have emissions of total dust which exceed 1.0% of the state total particulate emissions burden. Source severity for total particulate is 0.069 (+ or - 0.017); for ammonia, 0.88 (+ or - 0.42); and for sulfide and mercaptan gas, 0.395 (+ or - 0.19), with all errors stated at the 95% confidence level. (Source severity is defined as the ratio of the maximum ground level concentration of an emission to the ambient air quality standard for criteria pollutants or to a hazard potential for noncriteria pollutants.)

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution	Air Pollution Control	13B
Feeders	Stationary Sources	
Beef Cattle	Feedlots	06C, 02E
Dust	Source Assessment	11G
Gases	Particulate	07D
Ammonia	Sulfides	07B
Thiols	Source Severity	07C

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