10B.2 IMPACT OF LIVESTOCK OPERATIONS ON AIR QUALITY

Jerry L. Hatfield*, Richard L. Pfeiffer, and John H. Prueger
USDA-Agricultural Research Service, Ames, Iowa

1. INTRODUCTION

Air quality impacts from livestock operations have become an environmental, ecological, and sociological problem. Emissions for gases and particulates from livestock operations are considered to be environmental impacts that must be controlled. Within livestock operations there are three sources of emissions, production buildings, manure storage and handling sites, and manure application sites. Each of these components of livestock production produce a different mixture of gases and dispersion patterns. It will be critical for both scientists and livestock producers to understand these issues in order to develop a better understanding of how to manage the air quality impacts of livestock operations.

2. AIR QUALITY COMPONENTS

Emissions from livestock systems consist of ammonia, methane, nitrous oxide, hydrogen sulfide, volatile organic compounds (VOC's), and particulates. These gases and particulates are not present in the same concentration nor do they travel across the atmosphere in the same way. Odor is an extremely subjective term because the detection and measurement is dependent upon human olfactory responses and the variation among humans in their response to different compounds is large. In this discussion we will concentrate on the generation, emission, and dispersion of specific gases and particulates. Volatile organic compounds are comprised of a wide range of organic compounds and consist of indoles, phenols, acids, disulfides, and cresols. Zahn et al. (1997) found that there were 24 different VOC's prevalent in swine production systems and the concentration of these VOC's varied with different manure handling systems. It has been commonly reported that there are over 160 different VOC's that are detected in livestock manure systems; however, these concentrations are often extremely low and variable.

Formation of the different gaseous components depends upon the biology of the system. Ammonia formation is a result of either hydrolysis of urea, deamination of amino acids, or fermentation of nitrogenous compounds. hydrogen sulfide is produced from either sulfur- or sulfate-reducing bacteria. Volatile organic compounds are caused by anaerobic digestion of manure or digestive processes. Methane and nitrous oxide are caused by bacterial processes linked with methanogenesis or denitrification. Particulates that are formed within production buildings are associated with dust from feed, animal dandruff, or conversion of ammonia, nitrous oxide or sulfur oxides into particles. It is important to realize that the formation processes for the different compounds associated with air quality and livestock originate from different sources. Buildings and manure storage and handling sites are the primary areas of formation with no air quality constituents formed during manure application.

3. ATMOSPHERIC CONCENTRATIONS

Concentrations of the different components vary with livestock species, production building, and manure storage system. Ammonia concentrations are the highest in poultry and dairy barns followed by swine production and then beef feedlots. Concentrations adjacent to poultry or dairy barns often exceed 50 ppm which exceeds the exposure limit for ammonia. Within swine production units concentrations exceeding 20 ppm are not uncommon. Although, concentrations are an important factor when these values are coupled with the air flow rates the ammonia load into the atmosphere from livestock becomes a critical factor. Zahn et al. (2001) estimated that ammonia emissions from a lagoon manure system were 233 kg NH_3 site^{-1} day^{-1} which would generate 85,045 kg NH_3 from a site per year. In contrast from this same system the methane generated per year was 170,090 kg CH_4 but only 256 kg H_2S and 1,240 kg VOC's (Zahn et al., 2001). These values

**Corresponding author address:* Jerry L. Hatfield, USDA-ARS, National Soil Tilth Laboratory, 2150 Pammel Drive, Ames, IA 50011; email : hatfield@nstl.gov.

will change with production unit and there have been several studies conducted on ammonia emissions from livestock but relatively little on the other gases. One primary concern with these values is that they are collected for very short periods of time during the year and extrapolated to complete year. Observations adjacent to production buildings exhibit large variations among days due to changes in the animal size, meteorological conditions, and management of the building.

Observations adjacent to a swine production building during a period in which manure was being removed from the building produced a large variation in ammonia concentrations throughout and among days. Ammonia concentrations reported in the literature also show large variations that are due to variations among production buildings and management of those buildings.

Hydrogen sulfide concentrations vary among units and because the threshold for human detection is so low, small amounts in the air can cause a negative human reaction. There is not a strong correlation between emission of one gas and other gases. For example, high concentrations of ammonia are not linked with high values of other gases. Managing a livestock facility to reduce one gas may not cure all air quality problems. The generation processes are both biological and chemical which causes the temporal variations in the emissions of different gases to change in response to a number of factors.

Particulate measurements in livestock facilities also show large variations. Both 2.5 and 10 µm sized particulates are of interest because of the human health impacts. There have been few measurements of either $PM_{2.5}$ or PM_{10} around livestock facilities. Estimates from beef feedlots of PM_{10} exceed 34,000 Mg PM_{10} yr^{-1} ; however, there is concern about the assumptions used to generate the emission factors for particulate matter in feedlots. Observations from central Iowa on PM_{10} from swine buildings showed an increase above ambient levels but not above air quality standards. Estimates of total particulate loadings from swine production are nearly 1.6 kg pig^{-1} yr^{-1} and if one assumes most current production units have an animal population of 4,500 then the total annual loading into the atmosphere of 7,355 kg. Particulate emissions from livestock production units can be quite large.

4. DISPERSION OF EMISSIONS

Air quality impacts from animal production facilities are dependent upon the dispersion of gases and particulates. Livestock facilities are located in a variety of microclimates and create their own microclimate because of the effect of the arrangement of the buildings and manure storage on wind flow and temperature. Observations of the microclimate around a lagoon manure storage system for an entire year revealed that the direction of wind across the building and the development of the adjacent crop field were primary factors in determining how gases were dispersed from the lagoon surface (Hatfield et al., 2000). One of the major challenges on dispersion from manure storage systems are constructed in a manner that disturbs the air flow patterns. Many of the current micrometeorological models are not sufficiently robust to address this problem.

Application of the RIMPUF model for dispersion from production buildings showed that plumes downwind of the site are affected by small variations in topography (Hatfield et al., 2000). Efforts will have to be directed toward developing improved dispersion models that can address the complex microclimate and the biologically-induced variation in the source term for the various gases. Air quality impacts of livestock operations present a challenge and opportunity to biometeorologists for these next several years.

5. REFERENCES

Hatfield, J.L., J.H. Prueger, R.M. Cionco, T.J., Sauer, R.L. Pfeiffer, L.E. Hipps, and J.A. Zahn, 2000: Air flow and microclimate around earthen manure storage units. Proc. Air Pollution from Agricultural Operations. ASAE., St. Joseph, MI. pp. 124-131.

Zahn, J.A., J.L. Hatfield, Y.S. Do, A.A. DiSpirito, D.A. Laird, and R.L. Pfeiffer. 1997: Characterization of volatile organic emissions and wastes from swine production facility. *J. Environ. Qual.,* **26**, 1687-1696.

Zahn, J.A., J.L. Hatfield, D.A. Laird, T.T. Hart, Y.S. Do, and A.A. DiSpirito, 2001: Functional classification of swine manure management systems based on effluent and gas emission characteristics. *J. Environ. Qual*. **30**, 635-647.