Evaluation of Zeolite for Control of Odorants Emissions from Simulated Poultry Manure Storage

L. S. Cai[1,2], J. A. Koziel[1], Y. Liang[1,3], Anh Thu Nguyen[1], and H. W. Xin[1]

[1]Department of Agricultural and Biosystems Engineering, Iowa State University, Ames, Iowa
[2]Department of Chemistry, Wuhan University, Wuhan, PR China
[3]Current address: USDA-ARS, Pendleton, Oregon

Abstract

Poultry feeding operations are associated with aerial emissions of ammonia (NH_3), volatile organic compounds (VOCs), and odor, and the magnitude of emissions is influenced by manure management practices. As a manure treatment additive, zeolites have been shown to have the potential to control NH_3. Because of their properties it is also expected that zeolites could effectively adsorb VOCs and odor. In this controlled laboratory study involving simulated poultry manure storage, the effectiveness of zeolite in controlling odor and VOCs was evaluated. In the first 2 trials zeolite was topically applied on fresh poultry manure from egg layers at the rates of 0, 2.5%, 5% or 10% (by weight). In the third trial, zeolite was applied in layers over fresh manure. Headspace samples from the emission vessels were collected with solid phase microextraction (SPME) and analyzed on a multidimensional-gas chromatograph-mass spectrometer-olfactometry (MDGC-MS-O) system for identification and prioritization of poultry manure odorants (Figure 1). Acetic acid, butanoic acid, isovaleric acid, indole and skatole were consistently controlled, with the reduction rate being proportional to the zeolite application rate. Dimethyl trisulfide and phenol were consistently generated, and with a few exceptions, the rate of generation was proportional to the application rate. Average reduction of the total odor was 67% (±12%) and 51% (±26%) for the two topical applications, respectively, while no significant reduction of VOCs and odor was found for the layered application.
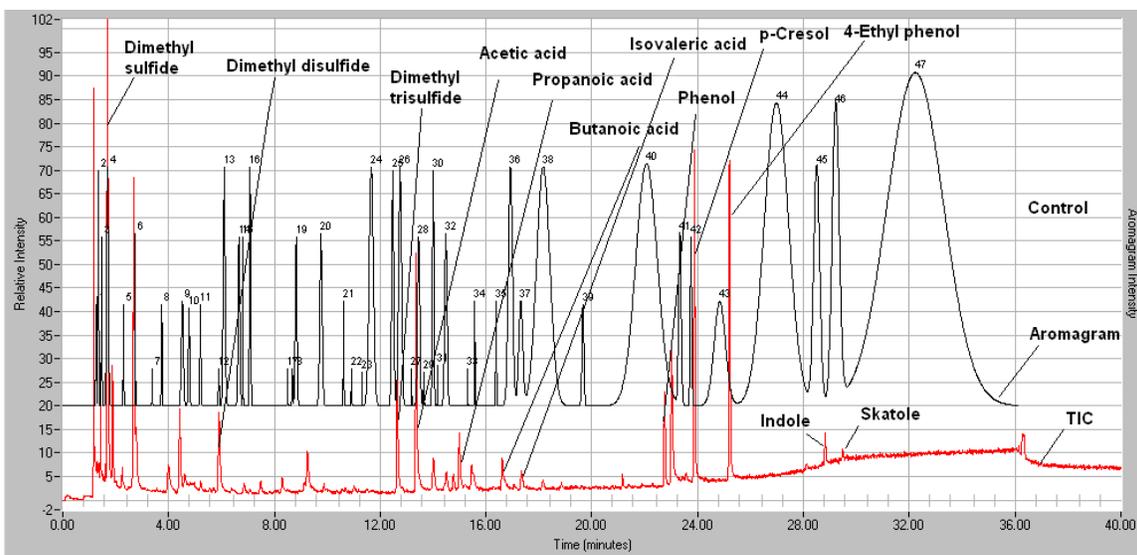
Part A
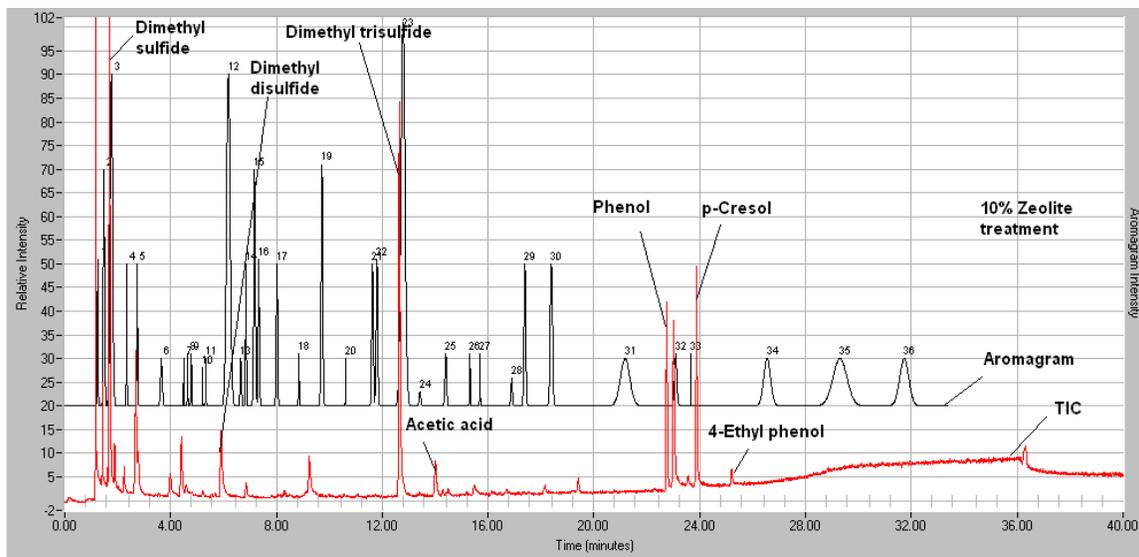
Part B

Figure 1. Comparison of total ion chromatogram (TIC) (lower, red line) and aromagram (upper, black line) of VOCs emitted from poultry manure between control and 10% zeolite treatment (Part A) and control (Part B). Air samples were collected using Carboxen/PDMS 85 μm SPME fiber and 10 min sampling time. Numbers signify odor/aroma events.

Correlation of Meteorological Data to Nitrogen Mass Balance of Broiler Production as Influenced by Litter Age

J. B. Carey and C. D. Coufal

Department of Poultry Science, Texas A&M University, College Station, TX

Abstract

Emission of nitrogen (ammonia) from commercial broiler facilities has become a topic of increased concern, debate and research efforts worldwide. Most studies to date have been performed in commercial facilities by measuring ammonia concentrations and ventilation rates, resulting in large variation and uncertainty in reported results. Recent studies by our laboratory have employed the mass balance technique to quantify nitrogen loss from pens of commercial broilers raised under simulated commercial conditions on recycled litter. Eighteen consecutive flocks were reared to 42 days of age with an average ending body weight of 2.2 kg. All birds and feeds were obtained from a commercial broiler integrator. Correlation coefficients were determined for nitrogen loss and meteorological data. Nitrogen loss was significantly correlated to average temperature when all flocks were considered. Correlations were further determined in sub groups of the flocks (flock 1-5 vs flocks 6-18). Nitrogen loss was not correlated with average temperature during flocks 1-5 but was significantly correlated during flocks 6-18. Thus litter age has an impact on nitrogen loss. Relative humidity was not significantly correlated to nitrogen loss. These results suggest that older litter may not result in greater ammonia loss during cooler weather. In summary, this study demonstrated that seasonality is an important factor affecting nitrogen volatilization from broiler facilities.

Introduction

The main factors that influence the volatilization of ammonia (NH_3) from poultry manure have been identified as pH, temperature, and moisture content (listed in decreasing order of importance) (Elliott and Collins, 1982). The process of NH_3 release from the breakdown of uric acid in poultry manure is catalyzed by enzymes produced by microorganisms (reviewed by Nahm, 2003), and microorganism growth and proliferation are sensitive to temperature and moisture content (water activity). As a result, the factors of temperature and moisture will greatly influence the formation of NH_3 in broiler litter under commercial conditions.

Ambient climatic conditions outside a broiler house will inevitably influence temperature and moisture conditions within the house as a result of necessary ventilation. The purpose of this report is to compare N loss data obtained from the N mass balance study presented in Coufal et al. (2006) with meteorological data corresponding to the grow-out period of each flock. In this manner, the influence of ambient temperature and moisture (humidity) on N retention in litter materials and N lost to the environment will be accessed.

Materials and Methods

Nitrogen mass balance data for 18 consecutive flocks of broilers reared on the same recycled litter was presented in Coufal et al. (2006). Easterwood Airport in College Station, Texas is located approximately 0.8 km from the Texas A&M University Poultry Research Center where the nitrogen mass balance study was performed. Meteorological data for each day during the grow-out period of each flock was obtained from the National Climatic Data Center website for College Station, TX (NCDC, 2005). Data for daily average dry bulb and dew point temperature were averaged over the 40 to 42-d grow-out period for each flock. Daily average dry bulb temperature and daily average dew point temperature were used to calculate daily average relative humidity (RH). Daily RH was then averaged for all days in each flock. Pearson correlation coefficients (r) between meteorological variables, N partitioned into litter, cake, all litter materials, and N lost to the environment were determined using the CORR procedure of SAS[1]. Correlations

---

[1]SAS for Windows, Version 8.01, SAS Institute, Cary NC

were considered significant at P<0.05. Correlations were determined considering all 18 flocks and considering flocks 1 to 5 separate from flocks 6 to 18 to investigate the effect of litter age.

Results

Pearson correlation coefficients between meteorological data, N partitioned into litter, cake, all litter materials, and N lost to the environment considering all 18 flocks are presented in Table 1. All litter N and N loss were significantly correlated to average dry bulb and dew point temperatures. Relative humidity was not significantly correlated to any N balance variables. This can be attributed to the fact that no consistent pattern of variation among flocks was observed for RH, while N balance variables did vary among the flocks. Although no data on RH levels inside the broiler house were collected, it can be assumed that RH levels within the house will usually be elevated. This would be especially true in the hot weather conditions when the evaporative cooling system was used to cool the air entering the house. In cold weather, RH levels would also be expected to be elevated within the house as ventilation rates are reduced to retain heat in the house. Therefore, high RH would promote NH_3 formation year-round and would not be expected to contribute to the observed variations in N loss.

TABLE 1. Pearson correlation coefficients (r) between meteorological data, nitrogen partitioned into litter materials, and nitrogen lost to the environment in flocks 1 to 18[1]

	All Litter N[2]	N Loss
Ave. Temp.[3]	-0.75 (<0.001)	0.69 (0.002)
Dew Point[4]	-0.79 (<0.001)	0.73 (0.001)
Relative Humidity	-0.18 (0.483)	0.23 (0.353)

[1] Numbers in parentheses are P-values for test of significant correlation between corresponding variables
[2] All Litter N = litter N + cake N
[3] Ave. Temp. = average daily dry bulb temperature
[4] Dew Point = average daily dew point temperature

When r values were calculated for flocks 1 to 5, no significant correlations were determined between any temperature variables and N mass balance variables (Table 2). All litter N and N loss were also not significantly correlated in flocks 1 to 5. In flocks 6 to 18, strong, significant correlations were observed between all temperature variables and all litter N and N loss (Table 2). All litter N was negatively correlated with temperature while N loss was positively correlated with temperature. Therefore, as temperature increases, the amount of N inputs partitioned into the litter materials decreases. Conversely, as temperature increases, the amount of N inputs lost to the environment also increases. Such results would be expected since it has been previously shown that NH_3 volatilization increases with temperature (Elliott and Collins, 1982; Carr et al., 1990). The correlation between average daily temperature and N loss in flocks 6 to 18 was r = 0.85. The differences in r between the analysis for flocks 1 to 5 and 6 to 18 indicate that litter age is an important factor influencing N retention in the litter and, therefore, N loss. This fact demonstrates that with newer litter temperature has little or no influence on N loss compared to older litter. RH and N loss were not significantly correlated in any of the analyses.

The results of this analysis demonstrate that the factors of temperature and litter age can have significant impacts on N loss from broiler facilities. It can be concluded that temperature has more influence on N partitioning than moisture (humidity) since ambient RH levels did not vary by a seasonal pattern in this study and were not found to be correlated with N loss. Therefore, litter age and ambient climatic

conditions (season) are important factors to consider when quantifying and estimating nitrogen emissions from broiler housing.

TABLE 2. Effect of litter age on Pearson correlation coefficients (r) between meteorological data, nitrogen partitioned into litter materials, and nitrogen lost to the environment[1]

	Flocks 1 to 5		Flocks 6 to 18	
	All Litter N[2]	N Loss	All Litter N	N Loss
Ave. Temp.[3]	-0.33 (0.591)	-0.25 (0.682)	-0.87 (<0.001)	0.85 (<0.001)
Dew Point[4]	-0.27 (0.660)	-0.32 (0.599)	-0.90 (<0.001)	0.88 (<0.001)
Relative Humidity	0.62 (0.263)	-0.79 (0.115)	-0.18 (0.550)	0.23 (0.459)

[1] Numbers in parentheses are P-values for test of significant correlation between corresponding variables
[2] All Litter N = litter N + cake N
[3] Ave. Temp. = average daily dry bulb temperature
[4] Dew Point = average daily wet bulb temperature

Acknowledgements

References

Carey, J. B., R. P. Burgess, R. A. Russo, C. Chavez, T. P. Niemeyer and C. D. Coufal. 2000. Field evaluation of litter conditions in tunnel ventilated broiler houses at the end of the production cycle. Pages 340-343 in *Proceedings of 2000 National Poultry Waste Management Symposium*, Ocean City, MD.

Carr, L. E., F. W. Wheaton, and L. W. Douglass. 1990. Empirical models to determine ammonia concentrations from broiler chicken litter. *Trans. ASAE* 33:1337-1342.

Coufal, C. D., C. Chavez, P. R. Niemeyer, and J. B. Carey. 2006. Nitrogen emissions from broilers measured by mass balance over eighteen consecutive flocks. *Poult. Sci.*85:384-391.

Elliott, H. A. and N. E. Collins. 1982. Factors affecting ammonia release in broiler houses. *Trans. ASAE* 25(2):413-424.

Moore, P. A., Jr., T. C. Daniel, D. R. Edwards, and D. M. Miller. 1996. Evaluation of chemical amendments to reduce ammonia volatilization from poultry litter. *Poult. Sci.* 75:315-320.

Nahm, K. H. 2003. Evaluation of the nitrogen content in poultry manure. *World's Poult. Sci. J.* 59:77-88.

National Climatic Data Center (NCDC). 2005. Meteorological data for College Station, TX. http://cdo.ncdc.noaa.gov/ulcd/ULCD. Accessed June 2005.

Singh, A., J. R. Bicudo, A. L. Tinoco, I. F. Tinoco, R. S. Gates, K. D. Casey, and A. J. Pescatore. 2004. Characterization of nutrients in built-up broiler litter using trench and random walk sampling methods. *J. Appl. Poult. Res.* 13:426-432.

Elemental Compositions of PM$_{2.5}$ in Ambient Air Downwind of Agricultural Operations in California's San Joaquin Valley

O. F. Carvacho, L. L. Ashbaugh, and R. G. Flocchini

Crocker Nuclear Laboratory, University of California, One Shields Ave.,
Davis, California 95616 USA

Abstract

Fugitive dust emissions from soil are thought to constitute a large fraction of the PM$_{10}$ and PM$_{2.5}$ inventory in California's San Joaquin Valley (SJV) and other western air basins. The major sources of these emissions are paved and unpaved roads, construction sites, windblown dust, and agricultural activities.

PM$_{2.5}$ is considered to be among the most harmful of all air pollutants. When inhaled these particles evade natural defenses of the respiratory system and lodge deep in the lungs causing serious health problems. According to Dr. M. Waalkes of the National Cancer Institute, some heavy metals have the tendency to donate electrons and to form basic oxide. Biologically, many metals are essential to living systems and are involved in a variety of cellular, physiological, and structural functions. But at high doses, many metals become toxic. The route of exposure may affect the dose and the site where the metal concentrates, and thus the observed toxic effect.

In California's San Joaquin Valley, California agricultural operations are highly complex and potentially significant sources of PM$_{2.5}$, especially during late summer and fall.

We collected PM$_{2.5}$ samples using traditional upwind-downwind ambient sampling arrays in a variety of locations in the San Joaquin Valley. We analyzed them for elemental content using Proton Induced X-Ray Emission (PIXE), Proton Elastic Scattering Analysis (PESA) and X-Ray Fluorescence (XRF) analysis

Introduction

Soil particles become resuspended into the atmosphere of California's San Joaquin Valley during agricultural operations in the fall months and by a variety of other activities, such as construction or travel on paved and unpaved roads, during much of the year. In prior studies, we have documented the relationship between the amount of PM$_{2.5}$ generated by a soil (PM$_{2.5}$ Index) and its texture as measured by the amount of sand, silt, and clay in the soil. In this study, we document the elemental composition of a variety of soil textures. For this study we collected ambient PM$_{2.5}$ samples downwind of typical agricultural operations that caused soil dust to be resuspended into the atmosphere. The operations included disking, bed formation, and land planing.

Method

All field measurements were made under actual field conditions. A combination of upwind/downwind source isolation and vertical profiling was used to quantify PM$_{2.5}$ concentrations. The aerosol mass concentrations were calculated using the gravimetric method. The elemental composition in the filters (22 elements) was determined using three analytical methods to characterize the elemental composition of the aerosol deposits on the Teflon membrane filters: PIXE (Proton Induced X-ray Emission) analyzing elements from Na to Mn, XRF (X-Ray Fluorescence) from Fe to Pb, and PESA (Proton Elastic Scattering Analysis) for hydrogen.

PIXE and PESA technique were conducted using a 4.5 MeV proton beam produced by the 76" Cyclotron at the Crocker Nuclear Laboratory at the University of California, Davis. A schematic of the PIXE/PESA system is shown in Figure 1.

The X-Ray Fluorescence system uses a General Electric grounded molybdenum anode diffraction type X-ray tube. The x-rays produced by the tube are collimated and directed onto an aerosol sample. The sample

deposit absorbs the Mo X-ray energy and re-emits the energy as x-rays characteristic to the elements present on the sample. A schematic of the X-Ray Fluorescence system is shown in Figure 2.
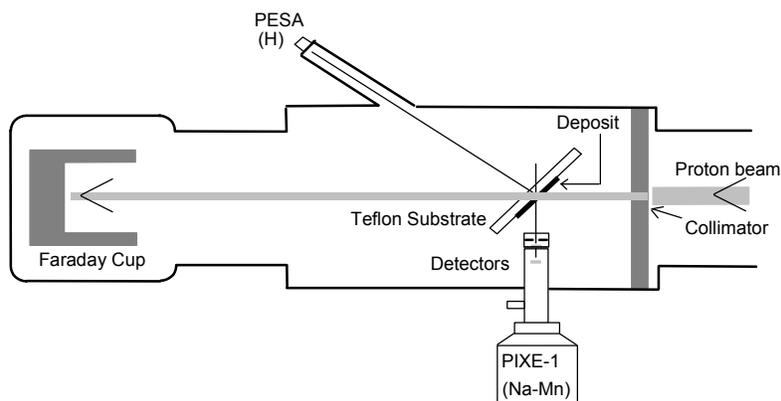

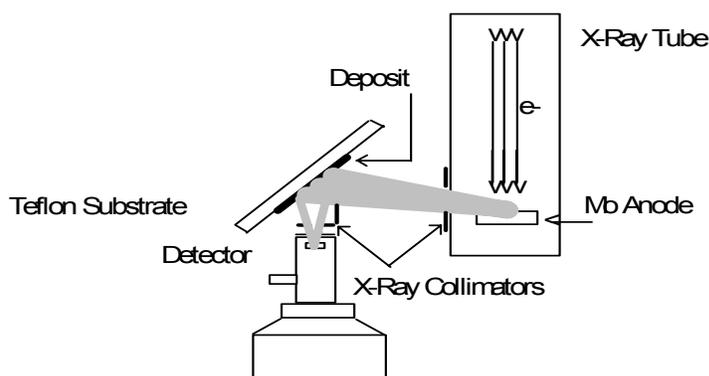**Figure 1. PIXE and PESA Filter Analysis**

Figure 2. XRF Analysis System

Composite Variables

A soil parameter was calculated using the IMPROVE formula by adding the concentrations of five soil elements weighted by their typical oxide form in sediments as follows:

$$\text{SOIL} = 2.20*[\text{Al}] + 2.49*[\text{Si}] + 1.63* [\text{Ca}] + 2.42* [\text{Fe}] + 1.94* [\text{Ti}]$$

The hydrogen concentration is useful as an estimate of organic mass. Sulfur was used to calculate the sulfate aerosol components which assumed to be ammonium sulfate, fallowing the IMPROVE formulas (Eldred et.al., 1987 and 1989)

$$\text{Organic (by H)} = 13.75 * (\text{H} – 0.25* [\text{S}]$$

$$\text{SO}_4^{=} = 4.125 * [\text{S}]$$

Results

The $PM_{2.5}$ mass concentrations measured for different soil textures downwind of agricultural operations varied between 31.9 and 238.7 μg/m³. Figure 3 shows the composition of the $PM_{2.5}$ collected from these samples. For all soil types examined, mineral soil accounts for 49.5% to 64.5%. Organic matter varied between 25.5% and 43.9% of the mass of all soil types, with sulfate, metals, and other elements accounting for the rest of the mass. The inset graph in Figure 3 shows the soil elements Al, Si, Ca, Fe, and Ti as a fraction of their total for the ambient samples.
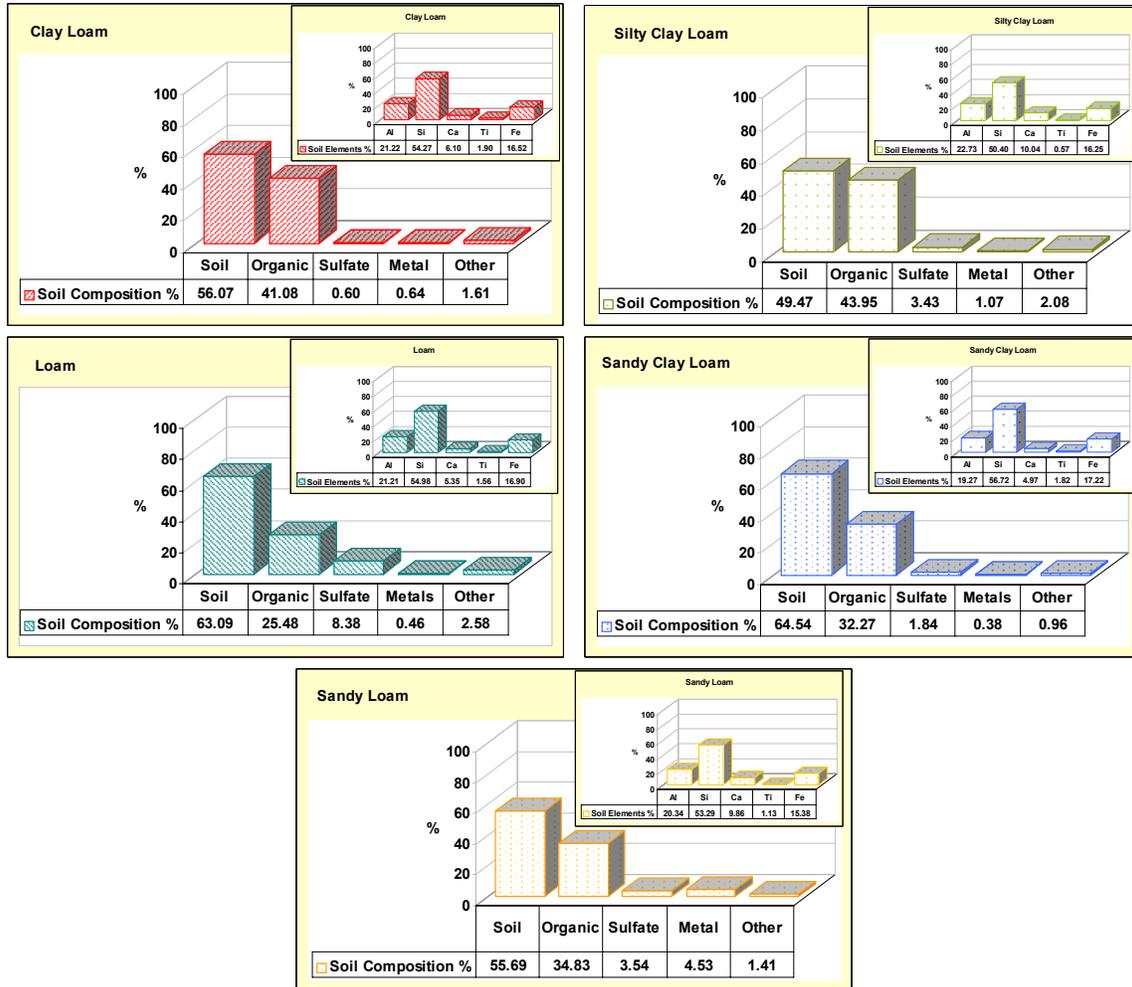
Figure 3. Composition of PM$_{2.5}$ soil dust from ambient samples. The insert shows the elemental signature of the five soil elements used to calculate the SOIL parameter.

Figure 4 shows the fractional concentrations of heavy metals (to their total). The concentrations of Cl, V, Cr, Mn, Cu and Zn vary according the soil type, but are detectable at 10 times the detection limit. Metals such as Ni, Hg, Pb, Br, As and Se are detectable, but are near the minimum detection limit. All are hazardous to human health and were detected in the PM$_{2.5}$ samples.

Conclusions

The composition of PM$_{2.5}$ dust raised from agricultural operations is quite similar across different soil types, being mostly mineral soil and organic matter. The split between mineral soil and organic matter varies slightly. Loam has a higher mineral soil and lower organic content, while silty clay loam is more evenly split. Other soil types lie between these two. The signature of the soil elements Al, Si, Ca, Ti, and Fe is very similar across all soil types, but the heavy metals signature is different for different soil types. Metals may be a natural component of the soil or they may arise from other sources in the San Joaquin Valley.
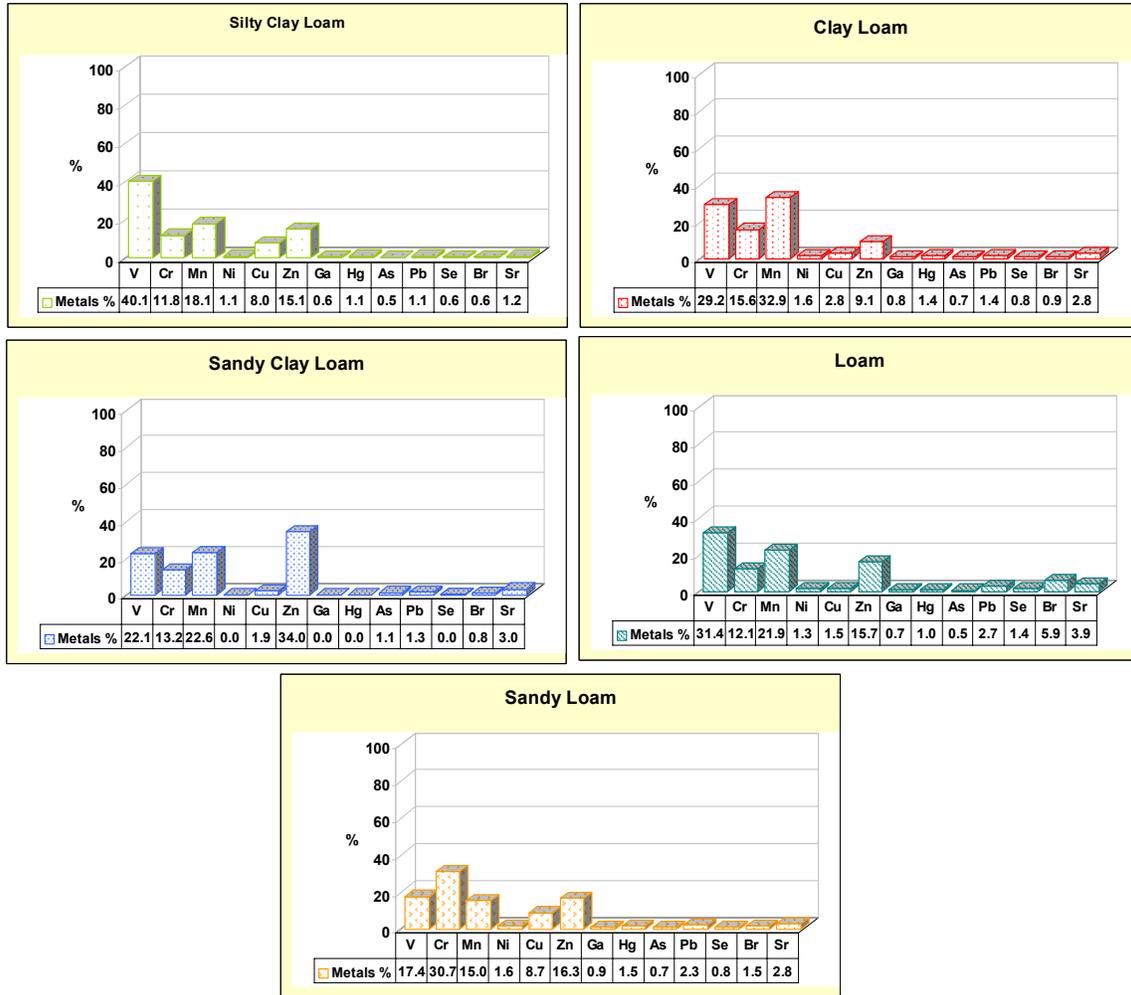
Silty Clay Loam

Metals %	V	Cr	Mn	Ni	Cu	Zn	Ga	Hg	As	Pb	Se	Br	Sr
	40.1	11.8	18.1	1.1	8.0	15.1	0.6	1.1	0.5	1.1	0.6	0.6	1.2

Clay Loam

Metals %	V	Cr	Mn	Ni	Cu	Zn	Ga	Hg	As	Pb	Se	Br	Sr
	29.2	15.6	32.9	1.6	2.8	9.1	0.8	1.4	0.7	1.4	0.8	0.9	2.8

Sandy Clay Loam

Metals %	V	Cr	Mn	Ni	Cu	Zn	Ga	Hg	As	Pb	Se	Br	Sr
	22.1	13.2	22.6	0.0	1.9	34.0	0.0	0.0	1.1	1.3	0.0	0.8	3.0

Loam

Metals %	V	Cr	Mn	Ni	Cu	Zn	Ga	Hg	As	Pb	Se	Br	Sr
	31.4	12.1	21.9	1.3	1.5	15.7	0.7	1.0	0.5	2.7	1.4	5.9	3.9

Sandy Loam

Metals %	V	Cr	Mn	Ni	Cu	Zn	Ga	Hg	As	Pb	Se	Br	Sr
	17.4	30.7	15.0	1.6	8.7	16.3	0.9	1.5	0.7	2.3	0.8	1.5	2.8

Figure 4. The signature of metals hazardous to human health for different soil types.

References

Cahill, A. T., A.R. Eldred, D. Shadon, J.P. Feeney, H.B. Kusco, Y. Matsuda. 1984. Complete Elemental Analysis of Aerosol PIXE, FAST, LIMP and Mass. *Nuclear Instruments and Method in Physics Research* B3 291-295.

Carvacho, O.F., L.L. Ashbaugh, M.S. Brown, R.G., Flocchini. 2001. Relationship Between San Joaquin Valley Soil Texture and PM_{10} Emission Potential Using the UC Davis Resuspension Test Chamber. *Transactions of the ASAE*, 44(6): 1603-1608.

Eldred, R.A., T.A. Cahill, P.J. Feeney. 1987. Particulate Monitoring at US National Park using PIXE. *Nuclear Instruments and Method in Physics Research* B22 289-295.

Eldred, R.A., T.A. Cahill, L.K. Wilkinson, P.J. Feeney. 1989. Particulate Characterization at Remote Sites Across the US: First year results of the NPS/IMPROVE Network. *Air Waste Management Assoc. 82nd Annual Meeting& Exhibition*, Anaheim, California June 25 – 30. Paper 89-151.3

Holmen, B.A., et al. 2001. Lidar-Assisted Measurement of PM_{10} Emissions from Agricultural Tilling in California's San Joaquin Valley – Part II: Emission Factors. *Atmospheric Environment* 35:3265-3277.

Comparison of Measured Estimates of Annual Ammonia Emissions from Poultry Production Facilities with Mass Balance Modeling Approaches

K.D. Casey[1], R.S. Gates[2], A.J. Pescatore[3], H.Xin[4], Y. Liang[5], E.F. Wheeler[6]

[1]Texas Agricultural Experiment Station, Texas A&M University System, Amarillo, Texas
[2]Biosystems and Agricultural Engineering, University of Kentucky, Lexington Kentucky
[3]Animal and Food Sciences, University of Kentucky, Lexington Kentucky
[4]Agricultural and Biosystems Engineering, Iowa State University, Ames, Iowa
[5]USDA-ARS, Adams, Oregon
[6]Agricultural and Biological Engineering, The Pennsylvania State University, State College, Pennsylvania

Abstract

Aerial ammonia is the predominant gaseous pollutant from poultry production facilities, resulting from microbial decomposition of uric acid in bird feces. These emissions are an important environmental issue as these emissions contribute to increased nitrogen deposition in land and aquatic environments, and as a precursor to atmospheric, fine particulates. Ammonia emissions have been monitored from broiler and egg laying production facilities over twelve to fifteen month periods in Kentucky, Pennsylvania, Iowa, Indiana, and North Carolina in recent years as part of USDA competitive grant funded projects. A report by the National Research Council (2003) found there was a need for the development of process based models with mass balance constraints of emissions. Undertaking a nitrogen balance on four, high-rise layer houses in Iowa, Liang et al (2005) showed that the residual error between nitrogen input and nitrogen outputs was less than 6% for any of the houses. In a study of a broiler house in Tennessee, Burns et al (2003) was able to able to obtain an estimate of ammonia emissions by mass balance modeling that was within 3% of the measured ammonia emission.

Estimates of manure production and characteristics are often used evaluating farm nutrient balances and determining the adequacy of land application areas. Sources of these estimates include published values by the American Society of Agricultural and Biological Engineers (ASABE), Midwest Plan Service (MWPS) and Natural Resources Conservation service (NRCS). The ASAE Standard D384.2 (2005) provides estimates of typical manure characteristics based on a mass balance modeling approach. Applegate et al. (2003) list a series of potential inaccuracies in this approach including that it is based on average diet formulations, limited nutrient retention values, assumptions and generalizations. Angel et al. (2003) compared the ASABE mass balance approach with the results of a biological mass balance on a mass balance broiler experiment and found that the ASABE model overestimated excretion of dry matter, nitrogen and phosphorus. A more flexible approach was used by McGahan (2002) in developing a worksheet based mass balance for broiler farms that allows customization of the diet nutrient composition, flock characteristics and uses carcass nutrient estimates rather than nutrient retention factors.

The study described in this paper was conducted at a site with four mechanically ventilated houses in central Kentucky. Each house was 12.2 m ×152.5 m. Houses were built in 1997. Each house had a 0.67-m opening along the full length of both sidewalls covered by a single layer curtain for emergency ventilation. There was an insulated ceiling in all houses. Ventilation fans included 8, 1.22-m diameter fans and 6, 0.92-m diameter fans in each house. Box inlets were located along both sidewalls and were automatically controlled based on static pressure differences. The ventilation system was controlled by individual thermostats and timers. Air temperature data were collected using a sensor positioned in the brooding area. The central half of the houses was used for brooding. All houses reused litter between flocks and performed one annual cleanout, with decaking between flocks. Broiler litter was characterized at the end of each flock. The brooding area of two of the houses was treated with poultry litter treatment, a chemical product (sodium hydrogen sulfate, $NaHSO_4$) that is applied to the litter prior to each flock to reduce the pH of litter. The number and type of birds placed alternated between 25,000 females placed at 13.44 birds/m^2 and grown for 54 days and 20,000 males placed at 10.75 birds/m^2 and grown for 64 days. The houses were

divided into 3 zones, nonbrooding (north end, 632 m^2), brooding (center, 706 m^2) and nonbrooding (south end, 520 m^2). The 8, 1.22-m diameter fans for tunnel ventilation were located in the south end.

For the data collected and reported here, ammonia emission rate (ER) was obtained from Portable Measuring Units (PMU) developed for the project. The PMU used two electro-chemical NH$_3$ sensors and an infrared CO$_2$ sensor. To avoid measurement errors caused by electro-chemical sensor saturation from continuous exposure to NH$_3$-laden air, cycles of 14 min purging with fresh outside air and 6 min sampling of exhaust air stream were used. This purging-sampling cycle resulted in 20 min measurement intervals. Complete details of the PMU are given in other references and not repeated here (Xin et al., 2002; Liang et al., 2005; Gates et al., 2005). One PMU was installed in each broiler house. The PMU was located near and monitored near the primary minimum ventilation timer fan used for cold weather ventilation. A second PMU was located on the first of the tunnel ventilation fans during warmer conditions when the house is likely to transition into tunnel ventilation mode. PMUs typically collected data at each house for about 48 h however, for one monitoring period, data collection exceeded 72 h. The interval between collection periods at a site was typically two or three weeks. A 'day' of data collection was nominally from noon of one day to noon of the following day.

Each house contained 14 exhaust ventilation fans. Each fan's ventilation capacity was determined with a Fan Assessment Numeration System (FANS) unit. The FANS incorporates an array of five propeller anemometers to perform a real-time traverse of the air flow entering fans of up to 1.37 m diameter. Details of the FANS unit's design and performance specifications are provided elsewhere (Gates et al., 2004; Wheeler et al., 2002). The FANS unit was used to evaluate each fan in all four of the broiler houses on this site. Fan on-off time was monitored using fan motor loggers. Average static pressure difference over the fan on-time interval was used to determine fan ventilation rate, using fan curves developed for each fan as determined from the FANS testing.

Based on the regression equations developed for each flock at this site during the monitoring period emission (Wheeler et al., 2004) and the methodology developed by Gates et al. (2005a) for assessing broiler house emissions, the ammonia emissions from the four houses at the KY-B site were calculated for the five flock period between cleanouts. The cumulative ammonia emission over the period was 23,484 kg, while the cumulative emission over time is presented in Figure 1.
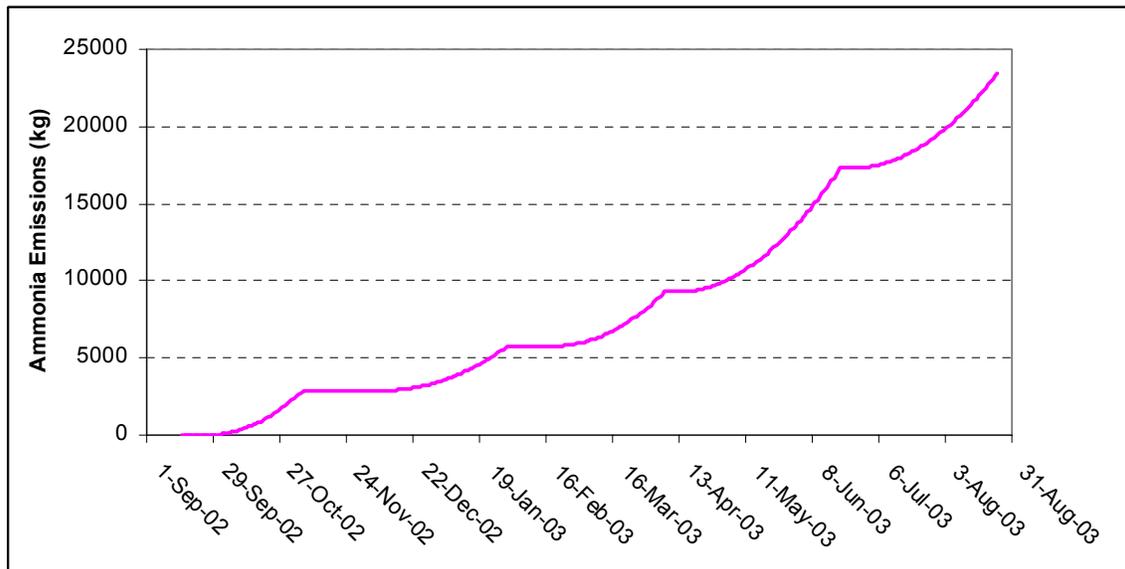

Figure 1. Cumulative ammonia emissions from Site KY-B with 4 broiler houses over 5 flocks in 1 annual cycle between litter clean-outs.

The litter in the brooding and non-brooding sections of the houses was separately sampled at the conclusion of each flock using the random walk method (Singh et al., 2004). A single composite sample was analyzed

from each house section. Analyses included moisture content, pH, total ammoniacal nitrogen (TAN), total nitrogen (TN) and total phosphorus (TP).

A mass balance was constructed based on integrator records for numbers and weights of birds placed and removed, feed analysis and feed consumed, and farmer records of mortalities, sawdust placed and litter removed. The completed mass balance is shown as Table 1.

Category	Nitrogen (kg)
Birds In	514
Feed In	78034
Sawdust In	218
Total In	78765
Birds Out	35938
Mortalities	494
Litter Removed	18824
Ammonia Emitted	19340
Total Out	74593

The error in closure of mass balance is 5.6%, with nitrogen inputs exceeding measured nitrogen outputs by 4172 kg over the period of five flocks. Ammonia emission represents 24.6% of the total nitrogen input into the system or 24.7% of the non-bird nitrogen inputs into the system. Potential sources of error in the mass balance included assumptions on carcass analysis and determination of mass of litter removed. Potential losses that were not measured or accounted for include nitrogen loss in particulate emissions, as nitrous oxide and other gaseous nitrogen forms. Based on the total suspended particulate (TSP) emission factor determined by Lacey et al. (2003), and assuming that particulate nitrogen content is the same as the litter, the nitrogen loss as particulates would have been approximately 750 kg. Given the nature of the experiment, conducted on a commercial broiler production site, obtaining a mass balance closure with less than 6% error is deemed successful, thus supporting the ammonia emission estimates derived in the project.

References

Angel, R., T. Applegate, S. Bastyr. 2003. Comparison of Two methods for Estimating Broiler Manure Nutrient Excretion: Biological Mass Balance Versus Model Based on Mass Balance Approach. Proceedings of the International Symposium for Animal, Agricultural, and Food Processing Wastes IX. ASAE. St. Joseph, MI. 303–309.

Applegate,T., L. Potturi, R. Angel. 2003. Model for Estimating Poultry Manure Nutrient Excretion: A Mass Balance Approach. Proceedings of the International Symposium for Animal, Agricultural, and Food Processing Wastes IX. ASAE. St. Joseph, MI. 296–302.

ASAE Standards. 2005. D384.2 Manure Production and Characteristics. St. Joseph, Mich.: ASAE.

Burns, R.T., Armstrong, K.A., Walker, F.R., Richards, C.J. and Raman, D.R. 2003. Ammonia emissions from a broiler production facility in the United States. In *Proceedings of International Symposium on Gaseous and Odor Emissions from Animal Production Facilities*. Horsens, Denmark, CIGR. pp. 88-95.

Casey, K.D., R.S. Gates, A. Singh, A.J. Pescatore, E.F. Wheeler, H. Xin, and Y. Liang. 2005. The Effect of Litter Management on Ammonia Emissions from U.S. Broiler Chicken Houses. In *Proceedings of A&WMA's 98th Annual Conference & Exhibition: Exploring Innovative Solutions. Minneapolis, MN, June, 21-24, 2005*. CD-ROM, Pittsburgh, Penn.: A&WMA.

Gates, R.S., K.D. Casey, A.J. Pescatore, E.F. Wheeler and H. Xin. 2005a. Assessing Annual U.S. Broiler Chicken House Emissions. In *Proceedings of A&WMA's 97th Annual Conference & Exhibition: Exploring Innovative Solutions. Minneapolis, MN, June, 21-24, 2005*. CD-ROM, Pittsburgh, Penn.: A&WMA.

Gates, R.S., H. Xin, K.D. Casey, Y. Liang, and E.F. Wheeler. 2005b. A method for measuring ammonia emissions from poultry houses. *Journal of Applied Poultry Research*. 14(3): 622-634.

Gates, R.S., K.D. Casey, H. Xin, E.F. Wheeler, J.D. Simmons. 2004. Fan Assessment Numeration System (FANS) Design and Calibration Specifications. *Transaction of the ASAE*. 47(5): 1709-1715.

Liang, Y., H. Xin, E.F. Wheeler, R.S. Gates, J.S. Zajaczkowski, P. Topper, H. Li and K.D. Casey. 2005. Ammonia emissions from U.S. poultry houses: laying hens. *Transactions of the ASAE* 48(5): 1927-1941.

McGahan, E.J. 2002. BroilerBal: A Nutrient Balance Model for Broiler Farms. Ver. 1.2. Toowoomba, Australia. Feedlot Services Australia Pty Ltd.

National Research Council. 2003. *Air Emissions from Animal Feeding Operations: Current Knowledge, Future Needs*. National Academy Press, Washington, DC. ISBN: 0-309-08705-8; www.national-academies.org.

Singh, A., J.R. Bicudo, A.L. Tinoco, I.F. Tinoco, R.S. Gates, K.D. Casey, A.J. Pescatore. 2004. Characterization of nutrients in built-up broiler litter using trench and random walk sampling methods. *Journal of Applied Poultry Research*. 13(3): 426-432.

Wheeler, E.F., K.D. Casey, R.S. Gates, J.L. Zajaczkowski, P.A. Topper, H. Xin, Y. Liang and D. Brown. 2004. Seasonal Ammonia Emission Variation Among Twelve U.S. Broiler Houses. ASAE Paper No. 044105. St. Joseph, Mich.: ASAE.

Wheeler, E. F., R. S. Gates, H. Xin, J. Smith Zajaczkowski, P.A. Topper and K. D. Casey. 2002. Field Estimation of Ventilation Capacity Using FANS. ASAE Paper No. 024125. St. Joseph, Mich.: ASAE.

Xin, H.; Tanaka, A.; Wang, T.; Gates, R.S.; Wheeler, E.F.; Casey, K.D.; Heber, A.J.; Ni, J.; Lim, T. A portable system for continuous ammonia measurement in the field; ASAE Paper 024168; American Society of Agricultural Engineers: St. Joseph, MI. 2002.

Carbon Dioxide and Nitrous Oxide Fluxes in Organic, No Till and Conventional Till Cropping Systems

Michel Cavigelli[1], John White[2], Larry Sikora[2], Greg McCarty[3], Peter Groffman[4]

[1]US Department of Agriculture, ARS-SASL, Beltsville, MD 20705, USA;
[2]US Department of Agriculture, ARS-BARC-EMBUL, Beltsville, MD 20705, USA;
[3]US Department of Agriculture, ARS-BARC-HRSL, Beltsville, MD 20705, USA;
[4]Institute of Ecosystem Studies, Millbrook, NY 12545, USA.

Abstract

The potential roles of organic and conventional cropping systems in mitigating current increases in atmospheric concentrations of carbon dioxide (CO_2) and nitrous oxide (N_2O) remain unclear. As part of a long-term study to evaluate the sustainability of organic and conventional cropping systems, we measured soil fluxes of CO_2 and N_2O in organic, no till and chisel till cropping systems. We measured gas fluxes on 24 and 27 dates in three field replicates in the corn phase of the three corn-soybean-wheat/legume crop rotations in 2004 and 2005, respectively. Cumulative CO_2 flux was greater in the organic (12.88 g CO_2 m^{-1} h^{-1}) than in the no till (8.62 g CO_2 m^{-1} h^{-1}) and chisel till (10.38 g CO_2 m^{-1} h^{-1}) systems in 2004. Differences among systems were due mostly to large CO_2 fluxes in spring in the organic system, especially following moldboard plow incorporation of a hairy vetch cover crop and disk incorporation of poultry litter. Rotary hoeing and cultivation in the organic system did not appear to have an effect on CO_2 flux, probably because readily available soil and vetch C had already been released in response to prior field operations. Soils in the no till system responded differently to changes in soil moisture than did soils in the organic system. Maximum CO_2 flux occurred at 20.0% VWC (~38.4% water filled pore space (WFPS)) in the organic system and at 27.6% VWC (~52.5% WFPS) in the no till system. These differences might be due to lower soil porosity and greater dissolved organic carbon in the organic compared to the no till system. Carbon inputs into the organic system were also greater than in the other two systems. Full assessment of net C balance will be conducted at the end of the 10th year of cropping, in 2006. We measured CO_2 flux using both static and dynamic methods on 17 dates in 2004 in the no till and organic systems. While both methods described the same overall patterns of CO_2 flux over time, the dynamic chambers gave almost consistently higher readings than the static chambers [static method = 0.458(dynamic method) + 0.128; r^2=0.71]. A fan, which might disrupt the boundary layer between the soil and the atmosphere, may have resulted in higher measured fluxes using the dynamic method. Results from CO_2 flux measurements for 2005 and N_2O data for both years are being analyzed and will also be presented.

Characterization of Skatole-Producing Microbial Populations in Enriched Swine Lagoon Slurry

K.L. Cook and J.H. Loughrin

United States Department of Agriculture, Agricultural Research Service
Bowling Green, Kentucky

Abstract

Skatole is a potent odorant in animal waste produced by anaerobic degradation of L-tryptophan. Little is known of the biochemistry involved in skatole production, the phylogeny of skatole-producing microorganisms or the conditions that favor their growth. These deficiencies hamper attempts to reduce skatole production. Our goals were to enrich for skatole-producers in swine waste and evaluate the microbial community structure. We supplemented swine lagoon slurry with 100 μM L-tryptophan, indole pyruvic acid (IPA) or IAA. Control treatments received no additional substrate. GC-MS was used to measure indole and skatole production in the slurries. Very little indole (0.9 ± 0.02 μM) or skatole (1.8 ± 0.07 μM) was produced in the control over the course of the 14 day experiment. The final concentration of skatole was 50.4 ± 1.6 μM, 61.6 ± 1.1 μM and 68.4 ± 24.8 μM in the L-tryptophan, IPA, and IAA supplemented treatments, respectively. DGGE analysis was performed on DNA extracts from samples taken on days 0, 7 and 14 to evaluate changes in the microbial populations over time. The average number of bands or operational taxonomic units (OTU's) for samples from unsupplemented swine lagoon slurry taken on days 7 and 14 was lower than for any of the other treatments. OTU's increased in all supplemented treatments, with the greatest differences seen in samples supplemented with IPA or IAA. Future studies will evaluate phylogenetic differences in diluted populations having high skatole concentrations. Knowledge concerning the organisms producing this odorant should provide information vital to controlling microbes responsible for its production.

Introduction

In recent years, malodorous emissions from concentrated animal feeding operations (CAFOs) have been the source of complaints from rural neighbors and are receiving greater attention from regulatory agencies. Indole and 3-methylindole (skatole) are potent volatile compounds that are known to be responsible for some of the most offensive odors emitted from livestock wastes. These compounds are produced by anaerobic degradation of L-tryptophan in the intestine and in animal waste storage systems. The types and concentrations of the two products of tryptophan degradation depends on the maintenance of a low oxidation-reduction potential in the system, the availability of the amino acid (usually depending on diet), and the production of intermediate metabolites (Yokoyama & Carlson, 1979).

Indole is the most prevalent metabolite of tryptophan degradation, it is produced by a wide-range of bacterial species and much is known about its production and biochemical regulation (Deslandes *et al.,* 2001; Yokoyama & Carlson, 1979). However, skatole is the more powerful odorant, it has a low threshold for detection, it is responsible for boar taint in swine and acts as a pneumotoxin in cattle, goats, horses, rabbits, mice and rats, and may cause tissue damage in humans as well (Diaz *et al.,* 1999). Although skatole producers from two bacterial genera, *Lactobacillus* sp. and *Clostridium* sp., have been isolated from the intestines of livestock, very little is known about the microorganisms or the biochemical pathways leading to its production (Mackie *et al.,* 1998; Zhu, 2000).

Research has shown that the addition of intermediate indolic or aromatic compounds increases formation of skatole (Honeyfield & Carlson, 1990; Yokoyama & Carlson, 1979). Isolates produce skatole either directly or by decarboxylating indole-3-acetic acid (IAA) (Jensen *et al.,* 1995; Yokoyama & Carlson, 1981). In this study, the production of skatole from mixed microbial populations present in swine lagoon slurry was evaluated following supplementation with 100 μM of either tryptophan, indole acetic acid (IAA) or indole pyruvic acid (IPA) and incubating for 14 days in anaerobic conditions with un-enriched slurry serving as a

control. The impact of these enrichments on the bacterial population was evaluated using denaturing gradient, gel electrophoresis (DGGE).

Materials and Methods

Sampling

Samples were collected from a swine waste lagoon in Bowling Green, Ky using a 2 L bucket attached to a pole. Water was collected below the lagoon surface, and strained through a double layer of cheesecloth under an atmosphere consisting of 95% CO_2, 5% H_2 in an anaerobic hood (Thermo Electron Corp., Waltham, MA). One hundred mL of filtered slurry was added to 125 mL serum bottles (I-Chem, Rockwood, TN) and supplemented with 100 µM of IAA, IPA, or tryptophan. Control samples received no supplemental substrate. One mL samples were removed from each vial for gas chromatographic analysis and one mL samples were taken for microbial community analysis on days 1, 2, 7 and 14. Each treatment was performed on triplicate samples.

Indole and Skatole Analyses

Twister® stir bars (10 by 3.2 mm- Gerstel USA, Baltimore MD) with a 1 mm PDMS coating were preconditioned for 1 hr at 250 ºC under a stream of high purity N_2. One mL samples from the vials were placed in 2 mL autosampler vials along with the stir bars/extractors, the vials closed, and the samples extracted from 1 h at 500 rpm at room temperature. Afterwards, the Twisters were removed from the vials, rinsed with deionized water, blotted dry, and placed in 17.8 cm mm long by 4 mm i.d. thermal desorption tubes (Supelco Inc.) and desorbed in a model

TDSA thermal desorption system (Gerstel USA). The stir bars were desorbed using an initial temperature of 25 ˚C with a delay time of 0.25 min. and then heated at 60 ˚C min^{-1} to 225 ˚C with a final time of 3 min. Desorbed volatiles were transferred by a heated transfer line maintained at 240 ˚C to a glass wool-packed injection liner maintained at -50 ˚C with liquid CO_2. Retained compounds were then transferred with a 20:1 split ratio to a 30 m by 0.25 mm Rtx-35 MS column (35% diphenyl-65% polydimethylsiloxane-Restek Corp., Bellefonte PA) with a film thickness of 0.25 µm by heating the injector at 10˚C min-1 to 300 ˚C with a final time of 3 min.

GC-MS was performed on a Varian Saturn 200 ion trap interfaced to a Varian model 3800 gas chromatograph (Varian Associates, Palo Alto, CA). GC operating conditions were: He carrier constant flow rate of 1 mL min^{-1}, column oven 55 ºC for 1 min, then programmed at 7 ºC min^{-1} to 100 ºC, and hence at 15 ºC min^{-1} to 295 ºC and held for 10 min, transfer line temperature 300 ˚C. The mass spectrometer was run in electron ionization mode with an emission current of 10 µamperes using a scan time of 0.35 sec per scan and a scan range of 45 to 225 amu.

DNA extraction from spiked lagoon samples

DNA was extracted from slurry (1.0 mL) using the Ultra Clean™ Soil DNA Isolation kit (MoBio Laboratories, Solana Beach, CA). Prior to extraction, samples were pelleted by centrifugation at 14,000 X g for 10 min. The pellet was then extracted according to manufacturers instructions, except bead tubes were placed in a Fast Prep FP120 (Q-BIOgene, Irvine, CA) for 30 s at a speed of 5.5 m/s instead of vortexing.

DGGE analysis of microbial populations

Total bacterial community DNA was amplified using the primers and DGGE conditions listed in Table 1. All PCR amplifications were performed in a PTC-200 DNA thermal cycler (MJ Research, Las Vegas, NV) as follows: initial denaturation at 94°C for 5 min, 10 cycles of touchdown PCR (94°C for 30 s, 61°C annealing for 30 s with an 0.5°C decrease/cycle, and extension at 72°C for 45 s), followed by 25 cycles at 94°C for 30 s, 60°C 30 s, and 72°C for 45 s, and a final extension step at 72 °C for 5 min. Sequences were amplified from 2 µl of extracted slurry template DNA using Ready-To-Go-PCR Beads (Amersham Pharmacia, Piscataway, NJ), with 800 nM each primer. Negative controls, containing all the components except DNA templates, were included in parallel. After PCR, 5 µl aliquots were subjected to agarose gel electrophoresis with 1.5% (wt/vol) agarose gels. Aliquots (20 µl) were resolved on polyacrylamide gels (37.5:1) containing a gradient of denaturants (100% denaturants consisting of 40% [vol/vol] formamide and

7 M urea) as indicated in Table 1. All the DGGE gels were run at 60°C and 82V for 15 hr, with a DCode Universal Mutation Detection system (Bio-Rad Laboratories, Hercules, Calif.). The DGGE gels were stained with Sybr Gold (Molecular Probes, Eugene, OR) according to the manufacturer's specifications, and the images were captured using a Foto Analyst Investigator Series Image Analysis System (Fotodyne, Hartland, WI).

Table 1. PCR and DGGE conditions used for visualization of swine lagoon slurry populations

Primer	Sequence (5' to 3')	Target Region[a]	Amplicon Length (bp)	DGGE Conditions[b]	Reference
-341f[c]	CCT ACG GGA GGC AGC AG	V3-V5	586	6.5%, 30-60%, 80V	Casamayor et al., 2000
907r	CCG TCA ATT CCT TTG AGT TT				

[a]Variable region within the *rrs* gene targeted by the primer set
[b]DGGE conditions=gel percentage, gradient range, voltage
[c]Primers with 40-bp GC clamp on the 5' end
GC clamp = CGC CCG CCG CGC CCC GCG CCC GTC CCG CCG CCC CCG CCC G

Results and Discussion

Metabolism of L-tryptophan, IPA and IAA in Mixed Community Swine Lagoon Slurry

Swine lagoon slurry either received no supplement or was supplemented with 100 µM L-tryptophan, IPA or IAA. Very little indole (0.9 ± 0.02 µM) or skatole (1.8 ± 0.07 µM) was produced in the control over the course of the 14 day experiment (Fig. 1). There was a 72 hour lag in production of both indole and skatole in all treatments. Indole was produced at significant concentrations only in the L-tryptophan supplemented treatments. Indole concentrations peaked on day 7 (18.5 ± 1.6 µM) and then decreased slightly by the end of the experiment (13.0 ± 1.2 µM). Skatole was produced to a greater extent in the slurries. Even in the L-tryptophan supplemented treatments, skatole production was almost 4 times greater than indole production (Fig. 1). Skatole production continued to increase over the course of the 14 day experiment. The final concentration of skatole was 50.4 ± 1.6 µM, 61.6 ± 1.1 µM and 68.4 ± 24.8 µM in the L-tryptophan, IPA, and IAA supplemented treatments, respectively (Fig. 1).

IAA supplemented treatments produced the greatest concentration of skatole. Yokoyama and Carlson (Yokoyama & Carlson, 1979) found that in the rumen skatole was produced by conversion of L-tryptophan to IAA followed by decarboxylation of IAA to form skatole. Jensen et al. (1995) found that pig fecal slurry populations also convert L-tryptophan to skatole by decarboxylation of IAA. In our experiments, we found that swine lagoon populations preferentially convert L-tryptophan to skatole rather than indole, presumably by a series of decarboxylation reactions with IAA as an intermediate.

IPA supplemented treatments also produced large amounts of skatole. In contrast to L-tryptophan supplemented slurries, however, the levels of indole were not noticeably different from those of control slurries. These results agree with those of Chung et al (1975), who found that intestinal anaerobe isolates formed IAA through indolepyruvic acid, following formation of IPA via transamination of L-tryptophan with α-ketoglutarate. However, the low level of indole produced was unexpected since IPA is the major intermediate in tryptophan degradation to indole. In the swine lagoon slurries used in this study, addition of IPA obviously drove the reaction toward skatole production.
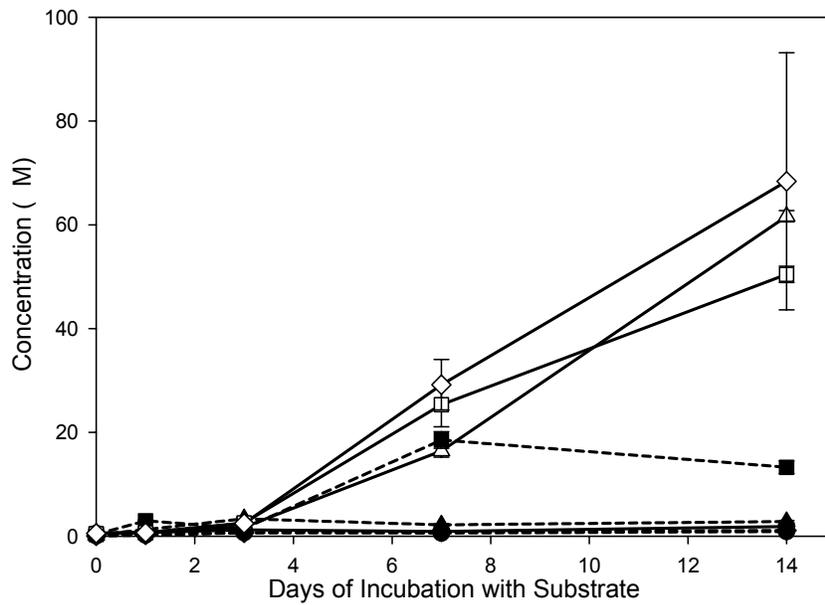
Figure 1. Plot of the concentration (µM) of Skatole (solid lines, open symbols) or Indole (dashed lines, solid symbols) for samples incubated without substrate (○) or with 100 µM IPA (△), 100 µM Tryptophan (□), or 100 µM IAA (◇) over the course of 14 days. Average and standard deviation of triplicate samples taken on days 0, 1, 3, 7 and 14.
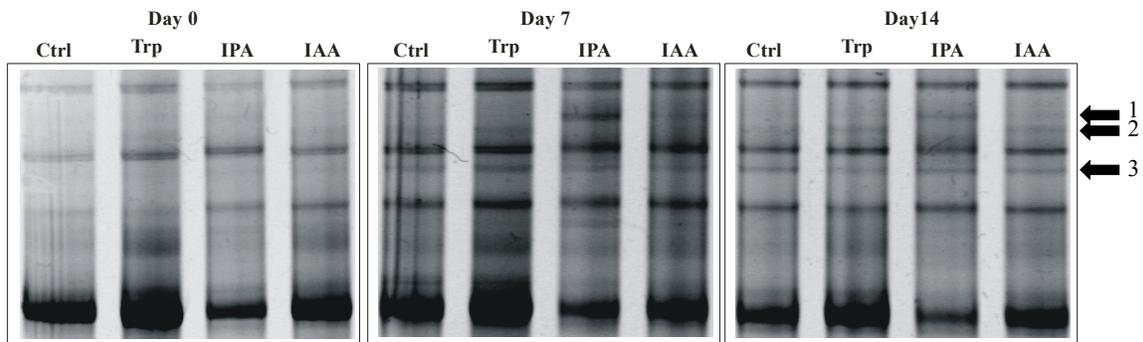

Figure 2. Negative image of Sybr Gold®-stained DGGE gels containing PCR-amplified 16S rDNA sequences from swine lagoon slurry samples. Arrows with numbers indicate bands that appeared after 7 days incubation with 100 µM substrate. Ctrl=control; Trp=Tryptophan; IPA=Indole pyruvic acid; IAA=Indole Acetic acid.

Analysis of Microbial Populations

DGGE analysis was performed on DNA extracts from samples taken on days 0, 7 and 14 using primers designed to target members of the *Bacteria* (Fig. 2). The average number of bands or operational taxonomic units (OTU's) for samples from un-supplemented swine lagoon slurry taken on days 7 and 14 was lower than for any of the other treatments. The IPA treatment had the most pronounced difference with one strong band (Fig. 2) appearing at day 7 and remaining through the end of the experiment. Similarly, the IAA treatments had an increase in the number of OTUs in both day 7 and day 14 samples (Fig. 2). Overall, patterns were very similar for all treatments with the four most intense bands present in all treatments. Using DGGE, populations that represent less than 1% of the total population are not likely to be detected (Casamayor *et al.,* 2000; Muyzer *et al.,* 1993). Therefore, the fact that the population profiles for spiked

IPA and IAA samples did change, suggests that there were significant changes in the microbial community. Preliminary data suggests that the major populations in these samples are *Bacteroides* sp. and *Clostridia* sp. (data not shown). Although species from both of these groups are common fecal commensals, species from both genera have been shown to produce IAA (obviously an important precursor to skatole formation) (Deslandes *et al.,* 2001) and species of *Clostridia* are among only a few known producers of skatole. Future work will focus on excision and sequencing of key bands from the DGGE profiles to obtain fundamental new information regarding species that are producing skatole in swine lagoon slurry.

Conclusions

In swine lagoon slurries, skatole production was enhanced by supplementation with the reaction intermediates, IAA and IPA. There was a 72 hour lag in skatole production in all treatments. This lag phase correlated with a visible shift in the DGGE profile of the microbial population in skatole-producing treatments. These results suggest that skatole production in swine lagoon systems depends on the presence and possibly on the concentration of at least three intermediate compounds: tryptophan, IPA and IAA. Shifts in the microbial population which occurred concomitant to skatole production may correlate to the build-up of populations necessary for production of essential intermediates and/or the skatole producing populations themselves. Future research will focus on phylogenetic characterization of the microbial population in skatole-producing communities. A better understanding of the populations that are instrumental in skatole-production should aid in uncovering methods for abating its formation in animal waste storage systems.

References

Casamayor E. O., Schafer H., Baneras L., Pedros-Alio C. & Muyzer G. 2000. Identification of and spatio-temporal differences between microbial assemblages from two neighboring sulfurous lakes: comparison by microscopy and denaturing gradient gel electrophoresis. *Appl. Environ. Microbiol.* 66: 499-508.

Chung K.-T., Anderson G. M. & Fulk G. E. 1975. Formation of indoleacetic acid by intestinal anaerobes. *J. Bac.* 124: 573-575.

Deslandes B., Gariepy C. & Houde A. 2001. Review of microbiological and biochemical effects of skatole on animal production. *Livestock Prodn. Sci.* 71: 193-200.

Diaz G. J., Skorodos K. W., Yost G. S. & Squired E. J. 1999. Identification of phase I metabolites of 3-methylindole produced by pit liver microsomes. *Drug Metab. Dispos.* 10: 1150-1156.

Honeyfield D. C. & Carlson J. R. 1990. Effect of indoleacetic acid and related indoles on *Lactobacillus* sp. strain 11201 growth, indoleacetic acid catabolism, and 3-methylindole formation. *Appl. Environ. Microbiol.* 56: 1373-1377.

Jensen M. T., Cox R. P. & Jensen B. B. 1995. 3-Methylindole (Skatole) and indole production by mixed populations of pig fecal bacteria. *Appl. Environ. Microbiol.* 61: 3180-3184.

Mackie R. I., Stroot P. G. & Varel V. H. 1998. Biochemical identification and biological origin of key odor components in livestock waste. *Journal of Animal Science* 76: 1331-1342.

Muyzer G., DeWaal E. C. & Uitterlinden A. G. 1993. Profiling of complex microbial populations by denaturing gradient gel electrophoresis analysis of polymerase chain reaction-amplified genes coding for 16S rRNA. *Appl. Environ. Microbiol.* 59: 695-700.

Yokoyama M. T. & Carlson J. R. 1979. Microbial metabolites of tryptophan in the intestinal tract with special reference to skatole. *American J. Clin. Nut.* 32: 173-178.

Yokoyama M. T. & Carlson J. R. 1981. Production of skatole and *para*-cresol by a rumen *Lactobacillus* sp. *Appl. Environ. Microbiol.* 41: 71-76.

Zhu J. 2000. A review of microbiology in swine manure odor control. *Agriculture, Ecosystems and Environment* 78: 93-106.

Agriculture Air Emissions and Impacts in and Near the Umatilla Indian Reservation

John L. Cox*, Rico Cruz, Barbara Harper, Tom Bailor, Stuart Harris, Ted Repasky, and Rod Skeen

Department of Science & Engineering, Confederated Tribes of the Umatilla Indian Reservation, P.O. Box 638 Pendleton, OR 97801 USA
*To whom correspondence should be addressed.

Introduction

The Confederated Tribes of the Umatilla Indian Reservation (CTUIR) is one of over 550 federally recognized Indian Tribes. The Confederation is made up of the Cayuse, Walla Walla and Umatilla Tribes with a total enrollment of about 2600 members. Their current reservation, the Umatilla Indian Reservation (UIR) is located in Umatilla County in Northeaster Oregon and consists of about 175,000 acres. In addition, members of the CTUIR are assured access to public lands for performing traditional practices within the millions of acres of land it ceded to the U.S. government in the Treaty of 1855. These practices include hunting, fishing, berry picking, gracing stock, gathering of medicines and other materials, and religious ceremonies. As with many of the Native American Tribes, the UIR is in a rural setting where agriculture, forestry and silvaculture are commonly found in and near the reservation and often the backbone of the economy (Table 1). The impact of agriculture, silviculture, and forestry on these natural resources and the freedom to practice a traditional life style without risk to human health from environmental contamination in the air and that spread (5) by the air has become alarming to indigenous peoples on many of the federally recognized tribes in the United States. The air emissions from agriculture, silviculture and forestry have until recently been largely outside the regulatory envelope of the Clean Air Act. Consequently little quantitative information is available regarding the types and amount of air emissions associated with these natural resource extraction businesses and their transport and fate in the ecosystem. These issues are identified and discussed from a tribal wisdom viewpoint of "natural relationships" - a viewpoint that air is an essential natural resource, just as food, water and energy; that all living things breathe air and are connected and interdependent; that the health and well being of the whole depends on each member and visa versa. Understanding and subscribing to this model of natural relationships is a corner stone of Traditional Native American wisdom, embodied in respecting and protecting "mother earth".

Table 1. 2004 Ag Statistics for Umatilla Co. and Umatilla Indian Reservation (1,2)

	Population	Total Acres	Harvested Acres Grain	Gross Grain Sales, $1000	Gross Farm Sales, $1000
Umatilla Co.	73,436	2,057,600	313,700	69,161	235,271
UIR	3,200	175,000	30,000	NA	NA
Oregon State	3,421,400	61,600,000	1,044,780	212,518	3,799,031

Natural Relationships Model

Traditional tribal wisdom teaches that all things, animate and inanimate, are connected and dependent upon one another, and that balance is important for health and well being. It is just this natural relationships model that is used by many Tribal communities in making policy decisions regarding their natural resources. The model demands a holistic assessment of salient factors before drawing conclusions and taking action. With respect to the subject we here are concerned with the footprint left by the anthropogenic sources of air emissions from the practice of agriculture and forestry.

In theory a mass balance as shown in equation 1 can be used to inventory and account for the flow and removal of individual and total emissions from agriculture and other practices to the air shed, where M_f is the mass released to the air shed, M_l is the mass leaving the air shed, M_r is the mass reacted in the air shed and M_a is the mass accumulated in the air shed. The amount of air pollutant in the air shed at any point, M_a, in time can be used to determine various risks to human health and the environment through various exposure, uptake and distribution mechanisms. While rather straight forward in principle, the approach suffers from incomplete and inaccurate data upon which to make the computations.

$$M_f - M_l - M_r = M_a \qquad (1)$$

The mass balance can be used in conjunction with the emission factor method, equation 2, to estimate the emission of individual pollutants, where E is the mass of a particular analyte emitted, A is the rate of its emission (mass/time), E_f is the emission factor, (1-ER/100) adjusts emission for emission control devices where ER is the efficiency of the device. Emission factors (E_f) have been compiled and regularly updated by EPA (3) for many different sources and types of air pollutants including those regulated under the NESHAP portion of the Clean Air Act, carbon monoxide, oxides of nitrogen, oxides of sulfur, and particulate matter.

$$E = A * E_f * (1\text{-}ER/100) \qquad (2)$$

Inventorying Sources of Air Emissions

There are a number of sources of information from which to build the inventory. County, state and federal agencies are a good source of statistical information as are local USDA/State Agriculture Experimental Stations. The information shown in Table 2 has been sequestered from these sources (1,2) and used in conjunction with the emission factor method to estimate the emissions from wheat production on the UIR.

There are approximately 60,000 acres of land on the UIR designated for crop production and the primary (> 95% est.) crop is non-irrigated wheat. The traditional practice of raising this crop is to have half of the land in production at any time allowing the other half to remain fallow for soil rejuvenation, so that there is about 30,000 acres in production a year. The principle activities associated with cropping wheat are listed in Table 2 along with the air emissions associated with each of the various activities in this agriculture production cycle using equation 2 and available emission factors (3).

Table 2. 2004 Estimated Air Emissions (lbs) Associated with Wheat Production on the UIR

Activity	PM-10	PM-2.5	CO	NOx	SOx	HC/VOC	NH3	HAP
plowing	101	11	113	432	11	20		
planting	51	6	57	216	5	10		
fetilizing	51	6	57	216	5	10	50,715	
pesticide/herbidice	101	11	113	432	11	16,406		16,406
harvesting	91	11	113	432	11	20		
field burning	303,072	287,232	3,537,072	123,024	24,816	286,176	70,224	
wind blown dust	600,000	60,000						
grain elevator	10,264	1,026						
transport to market	NA	NA	NA	NA	NA	NA		
Total, lbs	913,732	348,303	3,537,524	124,752	24,858	302,643	120,939	16,406

HAP, hazardous air pollutant the active ingredient in pesticide/herbicide. HC/VOC, hydrocarbon/volatile organic carbon.

Substantial quantities of otherwise regulated air pollutants are seen to be released to the air and since some of the activities listed occur in a short period of time, e.g., field burning, spraying, and fertilizing, local air quality impacts can be potentially significant. There is little regulatory control of these area sources, even though they exceed significant emission rates listed in Table 3 for point sources under the Clean Air Act.

Table 3. Significant Emissions Rates of Air Pollutants

Pollutant	Emission Rate (ton/yr)
CO	100
NOx	40
PM-10	15
VOC	40
SOx	40

Identifying, Quantifying, and Remediating Impacts

Further analysis is required to determine the impacts of agriculture and forestry practices on health and well being. The emissions inventory has shown the potential for large quantities of regulated air emissions from just one of the many different agriculture and forestry practices. Others may have as large emissions.

Monitoring data is needed to substantiate emissions estimates and determine concentrations from which human exposure and other impacts can be assessed. The emission inventory can be used in conjunction with the monitoring data to assess trans-boundary contributions to air quality on the UIR as well. The geography and weather patterns of the UIR are conducive to holding pollutants in the air-shed, providing the potential for the air pollution from a number of large upwind industrial sources to collect and react with those generated locally. Some regulatory relief is on the way to the CTUIR in the form of the Federal Air Rules for Indian Reservations that were recently promulgated by EPA (4). These rules will provide regulatory authority for Native American Tribes in the states of Oregon, Washington and Idaho.

Conclusions

Using a model of natural relationships we are directed to consider all the impacts. Such an approach makes us more responsible and protective of our environment and natural resources. This precursory holistic look at the impact of an agriculture practice has shown it to be a significant contributor to air pollution on the UIR. Those people and the ecosystems closest to the sources will generally feel the greatest impact. Further analysis and study will be required to quantify those impacts. Other agriculture and forestry practices may also be impacting air quality and other natural resources essential to the CTUIR's well being. These impacts may be larger than heretofore recognized.

The implication of these results are that the cost of products from agriculture and forestry to are much greater than currently accounted for in the product price, and further that better technology and methodologies are needed and regulations implemented to mitigate this situation, including public outreach and education. The people living in rural agriculture areas may well be bearing a disproportionate share of the hidden costs of agriculture and forestry.

References

2004 Oregon County and State Agriculture Estimates. Special Report 790-04/Revised March 2005. Oregon State Extension Service. Eesc.oregonstate.edu/agcomwebfile/EdMat/SR790-04.pdf

USDA, National Agricultural Statistics Service.

epa.gov/ttn/chief/ap42/index.html

40 CFR Parts 9 and 49, Federal Register, Vol. 70, No. 67, April 8, 2005.

Cox, J. and J. Wolf, eds., "Air Emissions from the Hanford Site: A Holistic Viewpoint, Symposium Proceedings, 2003, Confederated Tribes of the Umatilla Indian Reservation.

Identifying and Addressing Social Constraints Involved With the Use of Prescribed Fire in Forest Ecosystems of the Ouachita and Ozark Regions in Arkansas

Janean H. Creighton[1], Hal O. Liechty, Rebecca Montgomery, Matthew Pelkki and Tamara Walkingstick[2]

[1]Arkansas Forest Resources Center, University of Arkansas
[2]University of Arkansas, Division of Agriculture, Cooperative Extension Service
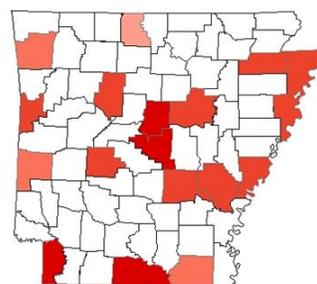
Abstract

Fire is a key ecological feature of forest ecosystems in the Southern United States and Arkansas. Stanturf et al. 2002 indicated that "other than land clearing for urban development, no disturbance is more common in southern forests than fire". Fire as a result of natural and/or historical anthropogenic sources has undoubtedly shaped the composition and structure of current forests in Arkansas. Historically, fires from natural sources as well as Native Americans and Euro-American settlers have favored the establishment of fire adapted forest ecosystems in Arkansas. Fire was extensively used in land clearing for agricultural crops, to increase visibility, as well as to increase forage production for game and/or domesticated animals by Native Americans and early Euro-American settlers (Stanturf et al. 2002). Fire return intervals or the length of time between successive fires within the Boston Mountains of Arkansas have been estimated to be between 4.6-16 years prior to European settlement (1680-1820), 2.0-3.1 years during Euro-American settlement (1821-1880), and 1.4 -5.0 years during the region's developmental (1881-1920) period (Guyette and Spetich 2002). Following the establishment of the Ouachita and Ozark National Forests as well as the passage of the Clarke-McNary Act of 1924, which provided federal funding to states for fire suppression, the use of fire decreased in the northern and western portions of Arkansas. Guyette and Spetich (2002) reported that fire return intervals increased from less than a decade to in excess of four or more decades following 1920. With the suppression of fire, the forests of the Ouachita and Ozark mountains have again changed. Spetich (2004) indicated that the removal of fire from ecosystems in northern Arkansas has reduced the regeneration and establishment of oaks and thereby favoring non-fire adapted species. Removal of fire which maintained open shortleaf pine stands with abundant diverse forb/grass communities in the Ouachita Mountains has favored closed canopy stands with dense hardwood understories (Wilson et al. 1995). Changes such as these have negatively impacted populations of a number of animals that depended on these lost habitats (Bukenhofer and Hedrick 1997).

The recognition of the detrimental effects of fire removal has led to the reintroduction of fire to forest ecosystems of Arkansas. In 2004, over 300,000 acres of land was burned in Arkansas using prescribed fire (personal communication, Lawrence Holm Arkansas Forest Commission) and land mangers are dramatically increasing the use of prescribed fires to 1) restore fire-dependent ecosystems that have been lost due to fire suppression, 2) protect endangered species, and 3) promote healthy forests. Current proposed land and resources management plans in Ouachita and Ozark National Forests include projected average annual increases in prescribed fires totaling 101,000 acres or an increase of 140% over current burning levels (USDAFS 2005a; USDAFS 2005b). A consortium of federal and state agencies have also formed to develop large restoration areas that utilize prescribed fire and other silvicultural techniques to demonstrate the feasibility of and potential for large multiple landowner scale forest restoration (Anderson et al. 2003).

Although prescribed fire is critical for restoring and maintaining healthy forests, particulates in smoke can pose a risk to public health and welfare. Particulates less than 2.5 micrometers (PM 2.5) are associated with human health problems and are the primary particulate constituent of prescribe fires (McMahon 1999). The Clean Air Act (CAA) in 1970 authorized national air quality standards to minimize health risks. Areas that do not meet these standards (termed nonattainment areas) are required to mitigate emissions. Currently no 'nonattainment areas' occur in Arkansas but heavily populated counties such as Pulaski, Faulkner, Garland, and Washington (Figure 1) have elevated levels of PM 2.5 and are located near the boundaries of the Ouachita and Ozark National Forest. Air quality in these population centers could be negatively impacted by large scale increases in prescribed burning. Other sensitive areas in Arkansas include the Buffalo National River (Ozark Mountains) and the Caney Creek Wilderness (Ouachita Mountains). The CAA prohibits visual impairment within the wilderness and park boundaries. Thus land management policies designed to modify forest ecosystems with fire at times clash with environmental policy to protect air quality.

Figure 1. Historic <2.5 μm particulate matter emissions for Arkansas

Recent fires and plans for increased use of fires have brought to the surface these inherent conflicts. For example, the Sierra Club has rejected the need for prescribed fire (Sierra Club-Arkansas Chapter 2004) and some members have advocated that the National Forest Service only wishes to use fire to increase timber harvests in Arkansas (Arkansas Democrat Gazette 2005a). In addition the health practitioners and residents of urban areas are becoming concerned with the effects of smoke from prescribed fire (Arkansas Democrat Gazette 2005b). Smoke from prescribed fires during 2004 impacted some of the most rapidly growing urban areas in Northwestern Arkansas such as Fayetteville, Rogers, and Springdale (Arkansas Democrat Gazette 2005c). Given the increased level of burning and concerns regarding prescribed fire disputes arising from the use of fire could become as volatile as the fires themselves. Ultimately these types of disputes could result in a reduction in the ability of land managers to use prescribed fire or result in costly air quality mitigation by government agencies. A better understanding of stakeholder concerns, attitudes, and beliefs relating to prescribed fire is needed to minimize potential disputes among stakeholder groups. In addition, dissemination of this information is needed to create a foundation upon which open discussions between divergent stakeholder groups can take place and provide infrastructure for solving disputes related to the application of fire as a land management tool.

Literature Cited

Anderson, McRee, J. Andre, M. Morales, S. Simon, and T. Whistsell. 2003. Collaborative partnerships and landscape-scale fire restoration on the Bayou Ranger District in the Interior Highlands of Arkansas, USA. 2nd International wildland fire ecology and fire man. cong.
http://ams.confex.com/ams/FIRE2003/techprogram/session_16360.htm

Arksansas Democrat Gazette: 2005a. Forest plans snag interest of observers. April 17, 2005. http://www.ardemgaz.com/ShowStoryTemplate.asp?Path=ArDemocrat/2005/04/17&ID= Ar02106&Section=Arkansas

Arksansas Democrat Gazette: NW Edit. 2005b. NW Arkansas Focus: Rangers give more notice before burns. April 1, 2005. http:///www.nwanews.com/story/adg/112243

Arksansas Democrat Gazette: NW Edit. 2005c. NW Arkansas Focus: Feedback pours in on forestry plans April 17, 2005. http:///www.nwanews.com/story/adg/113735

Bukenhofer, G.A. and Hedrick, L.D. 1997. Shortleaf pine/bluestem grass ecosystem renewal in the Ouachita Mountains. In: Wadsworth, K.G. (Ed.) Transaction of the Sixty-second North American Wildlife and Natural Resources Conference. March 14-18, 1997. Wash. D.C. pp. 509-515

Guyette, R.P and M.A. Spetich. 2003. Fire history of oak-pine forests in the Lower Boston Mountains, Arkansas, USA. Forest Ecology and Management 180:463-474.

McMahon, C.K. 1999. Forest fires and smoke-impacts on air quality and human health in the USA. In Proceedings, TAPPI International Env. Conf; April 18-21, 1999.; Nashville, TN. TAPPI Press 2:443-453.

Sierra Club-Arkansas Chapter. 2004. Sierra Club Analysis of U.S. Forest Service Rational forConducting Massive Burning Program in the Ouachita and Ozark National Forests: The Conclusions Do Not Fit the Facts. http://arkansas.sierraclub.org/ozark_headwaters/ControlledBurn.pdf

Stanturf, J.A., D.D. Wade, T.A. Waldrop, D.K. Kennard, and G.L. Achtemeier. 2002. Background paper: Fire in southern forest landscapes. In. Wear D.N., Greis, J.G. eds. Southern forest resource assessment. Gen. Tech. Rep. SRS-53. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. P:607-630.

USDAFS. 2005a. Proposed revised land and resource management plan. Ozark-St. Francis National Forest. January 2005. United States Department of Agriculture, Forest Service. Southern Region. http://www.fs.fed.us/oonf/ozark/projects/planning/dplan.pdf

USDAFS. 2005b. Proposed revised land and resource management plan. Ouachita National Forest. January 2005. United States Department of Agriculture, Forest Service. Southern Region. http://www.fs.fed.us/r8/ouachita/planning/onf_draft_plan.pdf

Wilson, C.W., R.E. Masters and G.A. Bukenhofer. 1995. Breeding bird response to pine-grassland community restoration for red-cockaded woodpeckers. J. Wildl. Manage. 59: 56-67.

First Biomonitoring Study of Agricultural Originating Atmospheric Pollutants in Romania

Simona Cucu-Man[1], Doina Dragan[1], Raluca Mocanu[1], Adrian Covaci[2], and Eiliv Steinnes[3]

[1]Department of Inorganic and Analytical Chemistry, Faculty of Chemistry, Al. I. Cuza University, 700506 Iasi, Romania;
[2]University of Antwerp, Toxicological Centre, Wilrijk, 2610, Belgium;
[3]Department of Chemistry, Norwegian University of Science and Technology, Trondheim, NO-7491, Norway.

Abstract

Monitoring heavy metals (HM) and persistent organic pollutants (POPs) from the atmosphere has been continuously improved, biomonitoring being a topical method to assess their occurrence in the atmosphere. Eastern Romania (province of Moldavia) is characterized mainly by plain relief, facilitating intensive agricultural activities: vineyards, orchards, crop cultivation and animal farming. In this area the moss-monitoring technique was firstly introduced in 2000, to evaluate the atmospheric heavy metal deposition. The study was followed within the catchment of the Prut River (~11000 km^2), an important transboundary river, and then repeated in 2001. In 2002, the sampling network was extended over the whole province of Moldavia (~45000 km^2). Samples of the epiphytic moss *Hypnum cupressiforme* were collected at a total of 44 sampling sites in rural areas and V, Cr, Ni, Cu, Zn, As, Mo, Cd, In, Tl, Pb and Bi were determined by ICP-MS. Principal component analysis was used to identify possible sources of metals in moss. One of the main factors represents agricultural activities (mainly Cu and Zn). The spatial distribution of Cu reflects local agricultural sources with high concentration in the areas with extended vineyards. The local high concentration of Zn in some areas is most probably associated with the use of Zn based insecticides for fruit trees and fungicides for fruits, as this area has many orchards. The temporal trend shows varying deposition values for metals from agricultural activities, possible due to different seasonal agricultural treatments. In 2005 moss samples were collected in order to evaluate atmospheric contamination with HM and selected POPs, as polychlorinated biphenyls (PCBs) and organochlorine pesticides (OCPs) with emphasis on agricultural emissions. In addition to 2002 sampling sites, moss samples were collected in the nearest vicinity of several important animal farms. Samples of surface soil, feedingstuffs, cow blood, meat and dairy products from these farms were also analyzed an d results were correlated with the moss data. All samples showed a relatively low contamination with OCPs and PCBs. Higher levels were found in dairy products and cow meat (up to 85 and 120 ng/g lipid weight for sum HCHs and sum DDTs). This is the first study of atmospheric contamination from agricultural sources in Romania. It gives an overview of the contribution of these sources to the general pollution level in one of the most important agricultural areas in the country. The obtained results are a very useful database of HM and POPs for future surveys.

Nitrogen Deposition via Atmosphera in Rural Zones in Cuba

Osvaldo Cuesta-Santos, Arnaldo Collazo, Maria Gonzalez, Patricia Castellanos,
and Antonio Wallo.

Air Pollution Control Center, Meteorological Institute of Cuba, Havana, 11700, Cuba

Abstract

The transboundary problems of global and regional atmospheric pollution are at current time, so our region is not considered as an exception on this matter. Acid deposition remains an important environmental issue in Europe and North America. Furthermore, it is emerging in new geographical areas, including parts of South/Central America, eastern and southern Asia and southern Africa. In these areas, emissions of nitrogen oxides are increasing rapidly as industrialization proceeds and the use of fossil fuels increases. In Cuba, main atmospheric nitrogen deposition compounds varies approximately from 19,0 to 70,0 kgN/ha.year in the rural place. The oxidized nitrogen forms being provided more 20% and wet deposition depends on our tropical rain climate features. The NH_3 and ammonium are the most important elements in our tropical conditions. This paper is showing more relevant results about main compounds of atmospheric nitrogen in Cuba from analysis of one long time series of data (more fifteen years) and its potential impact on agriculture.