AMMONIA EMISSION FACTORS FROM SWINE FINISHING OPERATIONS

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ABSTRACT

Concentrated animal feeding operations (CAFOs) are being examined in several regions of the U.S. as major sources of ammonia and particulate matter precursors. The National Risk Management Research Laboratory (NRMRL) has previously measured ammonia concentrations around and estimated emissions from a swine production facility. In this paper we present the results from two new studies at swine finishing facilities. New data are collected for tunnel-ventilated pull-plug swine finishing barns using chemiluminescent ammonia measurements from the exhaust fans. Open-path Fourier transform infrared (OP-FTIR) measurements of a naturally ventilated pit recharge barn and its lagoon are used to develop emission factors in the second study. The data suggest that the barns are a significant source of ammonia, and that the current emission factors are not markedly different from these new data.

INTRODUCTION

Ammonia (NH_3) is the major alkaline component of Earth's atmosphere.[1] Ammonia has a relatively short lifetime due to its rapid conversion to the ammonium (NH_4^+) radical and deposition of NH_3 to natural surfaces.[2,3] Its reaction with the acid gases produced by fossil fuel combustion provides a major portion of the ambient fine particulate matter.[4] The Heath Effects Institute recently intensively reanalyzed two studies that associated increased mortality with increased fine particles in urban areas and found no reason to change those conclusions.[5] Excess reduced nitrogen has induced adverse effects in forest systems.[6,7] Pearl reports advanced signs of eutrophication in several estuarine and coastal ecosystems impacted by atmospheric nitrogen deposition.[8,9]

EPA's inventory of ammonia sources nationally, based upon 1996 data, shows animal husbandry operations responsible for 73%.[10] For 15 states these operations contribute more than 75%. Emission factors for individual operations were reviewed by Battye et al.[11] which relied upon data from the European Community. Many European swine farm operations are very similar in comparison to American practices, but there are some significant exceptions, and the existing European ammonia emission factors should not be used for American inventories without verification. As part of its mission to understand processes that emit air contaminants, NRMRL's Air Pollution Prevention and Control Division initiated a program to examine American swine farm emissions.

MEASUREMENTS

Reported elsewhere are measurements we previously made as part of a larger site characterization effort by the State of North Carolina to understand the environmental impact of swine waste.[12] While others concentrated upon the emissions from the lagoon, we explored the concentration of ammonia and other gases around the pit recharge production barns of a farrow-to-finish swine facility. A single-beam OP-FTIR system was situated along several downwind paths that allowed separation of the different production phases. The long path capability of the OP-FTIR enabled us to measure all the exhaust plumes from the nine finishing barns continuously. To isolate the hogs from human contact and risk of infection, a fence ringed the facility. We could not sample the exhaust ducts directly with a probe; nevertheless, we could monitor the ammonia emissions by aiming the OP-FTIR beam through the fan plume 1 m from the duct exit. By monitoring the number of fans operating and estimating their flows from the manufacturer's literature, we developed seasonal emission factors.[13] Because we had to make several assumptions regarding the air flow around the facility to estimate the emission factors, an opportunity to sample a finishing-only facility with direct access to the exhaust ducts presented by a major swine producer was accepted.

This new study facility consists of four separate farms each consisting of ten tunnel-ventilated pull-plug barns and a fifth farm with five tunnel-ventilated barns. We tested a minimum of two barns at each farm housing young (Y), middle (M), and older (O) animal age groups. Two chemiluminescent ammonia analyzers sampled the exhaust from a rake mounted inside the exhaust cones. Collocation studies[14] have shown very good agreement between paired analyzers, which we confirmed during these tests. Data were stored as 1-minute averages. Exhaust fan flow rates were calculated from factory calibration curves provided by the fan manufacturer. The pressure difference, measured from inside to outside the barns, was measured and used to calculate the individual fan flow rates. Sail switches were used to record the frequency of operation for each of the fans operated. The total flow rate was determined by adding together the flow rate of all the fans operating. Mass emission rate was determined from the product of total flow rate and concentrations measured. These data are summarized in Table 1 by farm (F), age group (Y, M, or O), and test (T) number.

The second study used an OP-FTIR to monitor the emissions from a small (0.30 hectare) swine lagoon holding the waste from a single, naturally ventilated finishing barn. The sampling was done to evaluate the control capability of a porous bioactive cover system.[15] A scanning OP-FTIR system[16] was combined with a radial computed tomography technique[17-20] to develop a concentration profile of the lagoon plume. The vertical wind profile, obtained with weather sensors located at 2 and 10 m heights, was integrated across the plume concentration to yield the mass emission fluxes shown in Table 2. The lagoon was not covered for the first test, but was for the second. The 75% reduction observed in the ammonia emissions represent the initial effects of the cover before surface bioactivity was established. Increased retention of nitrogen in the lagoon waste liquid was also observed. Methane emissions were unaffected by the cover, and their flux increase may result from the higher wind speed.

Table 1. Swine finishing barn ammonia emissions.

Test	Age	Population	Weight	Concentration	Emission Rates		
	weeks		lb	ppm	g/min	g/hr/hog	g/hr/100 lb live weight
F3-Y-T1	10	942	47,100	3.59	6.32	0.403	0.805
F3-Y-T2	13	932	69,900	6.68	11.65	0.750	1.000
F4-Y-T1	13	1000	60,000	5.40	8.60	0.516	0.860
F4-Y-T2	15	970	67,900	7.29	12.29	0.760	1.086
F5-Y-T1	14	936	65,520	3.28	6.04	0.387	0.553
F5-Y-T2	17	912	91,200	4.62	7.21	0.474	0.474
Average Y	14	949	66,940	5.14	8.69	0.548	0.796
F1-M-T1	22	937	159,290	4.17	5.43	0.345	0.203
F1-M-T2	22	937	159,290	7.41	7.24	0.476	0.280
F1-M-T3	22	937	159,290	7.50	8.47	0.542	0.319
F2-M-T1	21	916	155,720	4.12	5.26	0.345	0.203
F4-M-T1	22	895	143,200	3.32	4.38	0.294	0.184
F4-M-T2	22	895	143,200	4.25	5.34	0.358	0.224
Average M	22	920	153,300	5.13	6.02	0.393	0.235
F1-O-T1	30	370	92,500	5.51	8.51	1.380	0.552
F1-O-T2	26	760	160,600	2.67	4.35	0.343	0.163
F2-O-T1	26	822	180,840	3.38	6.13	0.447	0.203
F2-O-T2	29	570	142,500	3.08	9.18	0.966	0.387
Average O	28	631	144,110	3.66	7.04	0.784	0.326

Table 2 – Summary of methane and ammonia emissions from lagoon along with meteorological data.

	Ammonia Flux (g/min)	Methane Flux (g/min)	Wind Speed (m/s)	Wind Direction (degrees)
7/11/00	15.0	27.6	2.1	254
8/16/00	3.66	33.6	3.0	254

RESULTS AND CONCLUSIONS

Van Der Hoek, et al.[21] reported that the European Expert Panel on ammonia had determined default ammonia emission factors for animals across Europe. These factors for swine stables are 2.89 and 7.43 kg NH_3 per animal per year for "Fattening pigs" and "Sows," respectively. The "Fattening pigs" stables correspond to the hog finishing barns included in our test program, and the "Sows" stables that include the young animals correspond to our farrowing barns which are to be included in a future program phase. In North Carolina, all but the very youngest animals are housed in a finishing barn as are the older animals after being weaned. Thus, none of the barns in this study housed animals less than 10 weeks old. The measured ammonia emissions reported in Table 1 for this study are representative of the summer season. We annualize them for presentation in Table 3 as the summer factor for comparison to other reported annual ammonia emission factors. We expect actual annual emissions to be lower due to the effect of ambient temperature on the vapor pressure of ammonia. Based on our previous work, annual emissions for North Carolina fattening barns are estimated at 3.69 kg/hog/year (Table 3).

The age of the hog at 10 to 30 weeks did not have a statistically significant influence on ammonia emissions unless the data are normalized for weight. All fattening hogs older than 10 weeks had about the same impact on ammonia emissions on a per animal basis (Table 1). Only when the data are expressed on a per 100 pounds basis do the younger hogs appear to have higher emissions. In addition to the five mechanically ventilated barns tested (Table 1), a naturally ventilated barn was examined in the second study. The ammonia emissions from this barn (4.0 to 12.0 g/minute) are in the same range as the mechanically ventilated barns. Other factors influencing the emissions results which will be examined in future work include the use of recycled lagoon water used to flush the holding pit below the barn floor, the influence of the diurnal cycle, and seasonal variation.

The summer emission factor developed from our current data for the 16 tunnel-ventilated barns tested is slightly higher than the summer value included in our earlier work (4.81 versus 4.75 kg/hog/yr), but within the variation of the method. Recent data[22] from Midwestern deep-pit barns yield similar emissions for the summer (4.68 kg/hog/yr).

Our data and other recent tests suggest that an annual emission factor for the tunnel-ventilated barn currently being used by the industry is not markedly different from the one developed by Battye et al.[11] The seasonal effect is real and may lower total emissions in areas or seasons where temperature control is not the reason for fan operation. Completion of the seasonal component of our current studies should provide additional data to examine possible modifications to the current EPA emission factor.

Table 3. Swine confinement facility emission factors, kg/hog/yr.

Source	Emission Factor	Reference
1985 Emission Inventory, annual	1.95	23
Asman, annual	2.52	24
Battye report, annual	4.01	11
European Community, annual	2.89	21
North Carolina, annual	3.69	13
North Carolina, summer	4.81	Current work
USDA, annual	2.68	25

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