Ammonia Fluxes from Animal Housing at a California Free Stall Dairy

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ABSTRACT
Dairy facilities are a major source of ammonia emissions in California and the San Joaquin Valley (SJV). A program to monitor ammonia emissions using the USEPA Emission Isolation Flux Chamber began in 2006 and will continue through 2008. Data from two days of sampling in March will be discussed in this paper. Four sources within the animal housing are were evaluated which were the flush lane, bedding, feed, and open lot. The highest ammonia fluxes were from the bedding and the lowest were from the feed. Ammonia fluxes from the open lot were 3% of previous emissions monitoring conducted at the same facility in the fall of 2004.

INTRODUCTION
The (SJV), in the interior portion of California, is one of the most productive agricultural regions in the world where most of the state's 5 billion dollar dairy industry is located. Because of the its extent and continuing growth, agiculture is the major source of ammonia (NH_3) in California with cattle accounting for roughly 45% of statewide NH_3 emissions. Ammonia is of concern because of it's participation in the formation of secondary paticulate matter of 2.5 microns or less in a aerodynamic diameter ($PM_{2.5}$) as well as the passage of California State Bill 700 which has brought increased scrutiny to ammonia emissions. The SJV experiences elevated levels of $PM_{2.5}$ usually in winter months which decreases air quality. The dominant manure management practice at California dairies is a free stall flush system where water is flushed through barns where animals are housed and fed removing manure and depositing it eventually to a lagoon or storage pond. Cows housed in these systems have "free" choice to eat, lay down, or exit to a dirt corral sometimed called an open lot or exercise pen. The effluent is applied several times a year through irrigation systems to surrounding crop land as a means of applying nutrients, irrigation, and disposal of the effluent (Figure 1). Dairy producers and agronomist are currently working to develop nutrient mangement plans to apply agronomic rates of nutrients while achieving maxium crop yields of forages. Losses of ammonia through volatilization occur during liquid manure transport, storage, and application.

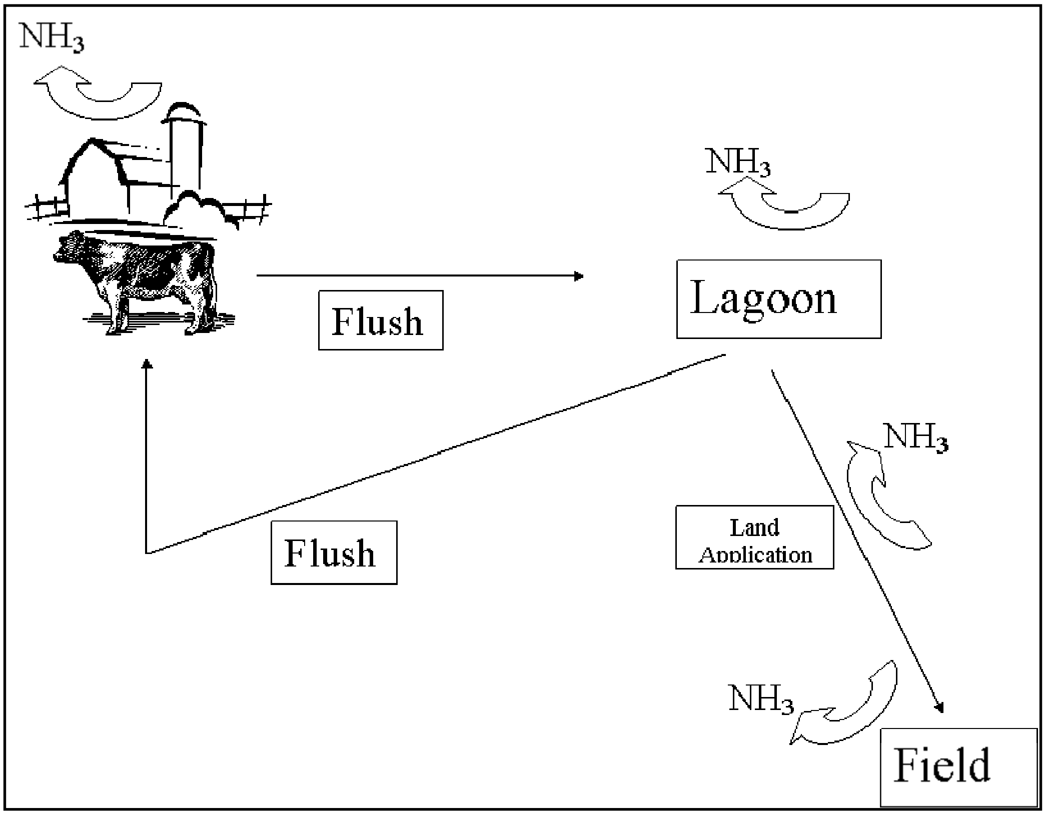

Figure 1. Diagram of free stall flush dairy liquid manure flow and ammonia loss.

Current nutrient management plans assume some percent loss of the total amount of nitgrogen applied through ammonia volatilization. This fraction is accounted for in the application of the liquid manure. An example would be a target application of 100 kg. ha^{-1} of nitrogen applied would be increased to 115 kg. ha^{-1} assuming a 15% loss of nitrogen through ammonia volatilization. Depending on a variety of factors this assumption could be grossly incorrect creating a overapplication of nutients which may have environmental consequences or an underapplication of nutrients most likely decreasing yields of crops.

Emission of ammonia is highly dependent on environmental factors such as ambient temperature and relative humidity which changes the emission characteristics of dairy souces both seasonally and dirunally. Emissions of ammonia from dairy facilites tend to be greater during summer months and less during winter months when particulate matter is of greatest concern. Previous research illustrates this relationship between ambient conditions and ammonia emissions (Cassel et al. 2005). Because of the considerable temoral fluctuations in emissions of ammonia, intensive samping throughout all seasons must be conducted to derive an accurate emission factor.

METHODS

Emissions were monitored using the USEPA Emission Isolation Flux Chamber. Ammonia samples were collected with active chemical filter packs consisting of 47mm glass microfibre filters treated with citric acid (3% in 95% Ethanol). The ammonium citrate was extracted from the filter with de-ionized water and analyzed with Nessler's Reagent and a spectrophotometer. Air was pulled out of the flux chamber with a personal air sampling pump at a flow rate of 2.0 L min^{-1} to sampling media for 10 to 30 minutes depending on ammonia concentrations. Ultra zero air was used to flush the flux chamber at a flow rate of 5.0 L min^{-1} for thirty minutes. Fluxes were calculated with formulas provided in the Measurement of Gaseous Emissions Rates from Land Surfaces Using an Emission Isolation Flux Chamber User's Guide.

Animal housing which includes the free stall and open lot area of the dairy were focused on during two spring sampling dates, March 15 and 27. Four general locations within the animal housing area were chosen to be monitored:

1. Flush Lane
    a. Pre-Flush
    b. Post-Flush
2. Bedding
3. Feed – Total Mixed Ration
4. Open Lot/Exercise Pen
    a. Higher elevation of pen
    b. Lower elevation of pen

The flush lane was monitored before and after a flush. Flush lanes at this facility are flushed from 1 to 2 times per day. The bedding was monitored both dates with the bedding source at this factility being comprised of manure scraped out of the open lots last fall. The open lot being the largest source in respect to area was focused on to characterize the emissions from this source. Two different surface types of the open lot were indenfified as high and low. Figure 2. is a picture of sampling at the low location within the open lot. The open lot is graded to drain any rainwater away from the area with a small ditch running through it and the sample locations described as low were from this area while the high location samples were located toward the crown of the grading. Samples of the manure pack at all of the open lot locations were collected to determine moisture content.

Figure 2. Sampling at a low area within the dairy open lot.

RESULTS

Fluxes of ammonia range from 21 to 1354 $\mu g\ m^{-2}\ min.^{-1}$ with the highest flux from the bedding and the lowest from the feed. Table 1. lists emissions data from individual sources along with moisture content of locations within the open lot locations.

Table 1. Ammonia flux data from spring sampling at a free stall dairy.

Ammonia Fluxes from a Free Stall Dairy			
Date	Surface Desciption	% Moisture	Flux ($\mu g\ NH_3$-$N\ m^{-2}\ min.^{-1}$)
3/15/2006	Flush lane (post-flush)		238
3/15/2006	Flush Lane (pre-flush)		562
3/15/2006	Bedding		1354
3/15/2006	Flush Lane (pre-flush;urine puddle)		959
3/15/2006	Open Lot (High)	41.4	97
3/15/2006	Open Lot (High)	52.1	135
3/15/2006	Open Lot (Low)	60.1	324
3/15/2006	Open Lot (Low)	60.2	84
3/27/2006	Flush lane (post-flush)		561
3/27/2006	Flush Lane (pre-flush)		799
3/27/2006	Bedding - No Manure		108
3/27/2006	Feed	40.4	31
3/27/2006	Feed	44.8	21
3/27/2006	Open Lot (High)	47.3	63
3/27/2006	Open Lot (High)	54.3	66
3/27/2006	Open Lot (Low)	59.6	113
3/27/2006	Open Lot (Low)	68.1	125

Feed

Emissions of ammonia from the feed in the free stall barn were the lowest of all sources. This agrees with previous work funded by the California Air Resources Board conducted at this same facility in the fall of 2004 by Dr. C.E. Schmidt presented at the 2005 USEPA

Emissions Inventory Conference in Las Vegas, Nevada (Schmidt et al. 2005). Much of this data will be used to compare for seasonal differences in ammonia emissions. Fluxes over most sources on both days of sampling (March 15 and 27) were consistent with each other except for the bedding location (Figure 3).

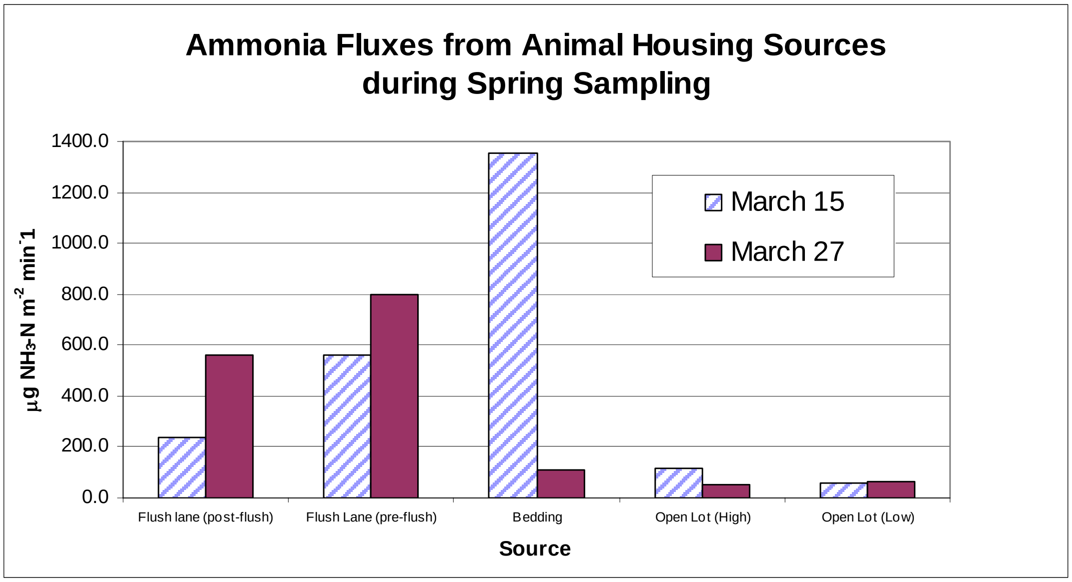

Figure 3. Ammonia fluxes of various dairy sources on two separate days.

Flush Lanes

Fluxes of ammonia from the flush lanes, both pre and post-flush yielded the second highest fluxes after the bedding source. The flush lane post-flush emitted roughly half that of the pre-flush.

Bedding

The animal bedding exhibited the highest fluxes of ammonia of all sampled sources. The bedding material at this dairy was manure scraped out of the open lot the previous fall and stored for use throughout the rest of the year. Fluxes of ammonia from the March 15 sampling were more than twelve times higher than those observed on March 27. The apparent reason for this variability was the different amounts of bedding found in the free stall during the sample periods. Less bedding material was observed on March 27 than on March 15 (Figure 4) due to removal by typical activity from the cows.

Figure 4. Sample locations of animal bedding with varying amounts of bedding material.

Open Lot

The open lot ammonia fluxes were the lowest of all sources evaluated other than the dairy feed. Two distinct sub-types were identified within the open lot which were classified as low and high areas of the open lot. The open lot was graded to channel away rain water to a drain on one end of the area. Low sample locations were in or around this channel while high sample locations were on the higher elevations of open lot. Moisture contents of sample locations within the low areas were higher than those in the low areas (Table 1). Neither of the surface types (low and high) emitted significantly more ammonia than the other. Ammonia fluxes from the open lot source may be low for spring conditions because of rain events the day before both sample dates which deposited approximately 6 mm at nearby weather stations. Fluxes from the open lot when compared to data collected by Dr. C.E. Schmidt in the fall of 2004 at the same facility are much higher than what was observed this spring (Figure 5). This seasonal difference in ammonia

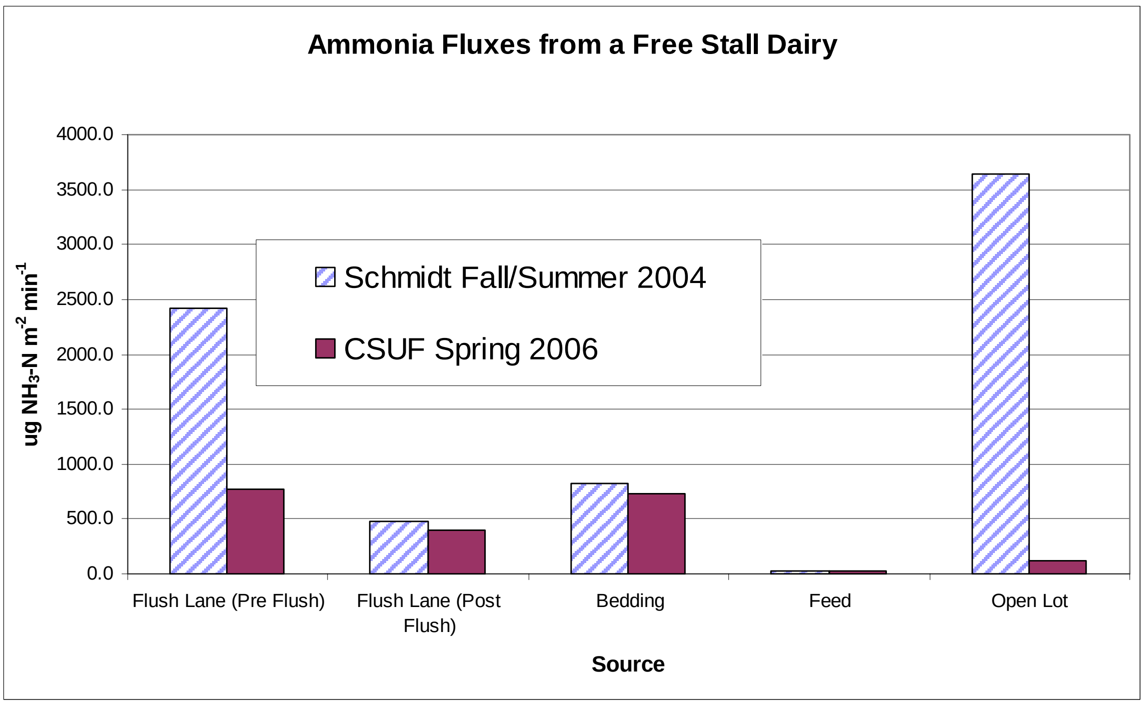

Figure 5. Ammonia flux data from CSUF spring 2006 and CE Schmidt fall 2004.

emissions was expected but the magnitude was somewhat surprising. The average ammonia flux from the open lot collected by CSUF was 3% of the average collected by Schmidt in September of 2004 (Table 2).

The flush lane pre-flush location also exhibited appreciably lower ammonia flux when compared to the fall 2004 Schmidt data. Lower ambient temperature may explain lower spring emissions from a source that should be is consistent over time. Ambient temperatures in during the sampling ranged from 9 to 18° C while temperature during the sampling conducted by Schmidt ranged from 37 to 30° C. The flush lane post-flush did not follow this pattern possibly because of the lack of an emission source available as the sampled surface lacked manure or urine to emit ammonia.

Table 2. CSUF spring 2006 average ammonia flux data.

CSUF Spring 2006 Ammonia Fluxes ($\mu g\ m^{-2}\ min^{-1}$) Source					
	Flush Lane (Pre Flush)	Flush Lane (Post Flush)	Bedding	Feed	Open Lot
Average	773.3	399.8	731.3	25.8	125.7
Std	199.7	228.2	881.2	7.4	111.4
% of Schmidt 2004 Data	32.0	83.7	88.3	83.2	3.4

The open lots, because of the large surface area and source strength may be the most important ammonia source on dairies. Given the variation in emissions of ammonia both seasonally and diurnally more field work must be done to collect this needed data in order to provide accurate yearly emissions data.

Conclusions

The highest ammonia fluxes were observed to be emitted from the animal bedding while the lowest were from the animal feed or total mixed ration in the barn. Fluxes from the open lot were relatively low when compared to the other sources monitored in the animal housing area of the dairy. A positive relationship between the amount of bedding material in the free stalls and ammonia fluxes was observed with the sample location having more bedding material emitting approximately twelve times more ammonia than a location with almost no bedding material present. Fluxes of ammonia collected during a wet spring were much lower than similar monitoring done at the same dairy during a warm and dry fall. Seasonal emissions may be more pronounced than previous work has indicated.

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KEY WORDS

Dairy Emissions
Ammonia
$PM_{2.5}$
California
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