Measurements of Air Quality around Various Open Area Sources in USA


Abstract—Air quality around open-air contaminant sources, including dairy corrals, dairy and swine manure storage lagoons is being measured for two years at ten different sites in seven U.S. states. Ammonia is being measured with tunable diode lasers (TDL) in an open path configuration. Methane (Innova Model 1412), and hydrogen sulfide (Thermo Environmental 450i) are measured in air drawn through a line of inlets, positioned alongside the source. This is referred to as a Synthetic Open Path System (S-OPS). Measurements of the lagoon temperature, pH and oxidation reduction potential are also conducted, as these play a vital role in gas emissions. Although the study will not conclude until mid-2009, data collected thus far shows that the average concentrations of ammonia around open sources is below 0.2ppm; CH4 is found to be less than 50ppm; H2S less than 20ppb. The lagoon pH ranges from 7.1 to 8.8 while ORP ranges from -49 to -544 mV.

Keywords—Open air source, synthetic open path system, tunable diode laser.

I. INTRODUCTION

GASEOUS emissions from animal production represent a significant economic and environmental problem. Most research has focused on quantification of ammonia (NH3) and hydrogen sulfide (H2S) emission from animal housing due to the potential health effects to animals and humans in confined spaces, rather than emissions to ambient air from anaerobic lagoons [1]. However, anaerobic lagoons have been shown to contribute 70-80% of odor emissions from swine facilities in Australia [2].

Animal agriculture is the largest global source of NH3 emissions and on per cow basis dairy operations are the largest emitters [3]. NH3 emissions from swine lagoons originate from the large input of urea in swine urine [4]. Urea is readily hydrolyzed into ammonium, which volatilizes from solution as NH3. Deposition of NH3 in nutrient sensitive areas is suspected of contributing to eutrophication of surface water, and has deleterious health effects including irritation to the eyes, skin, mucous membranes, and upper respiratory system [5].

H2S is a colorless, potentially harmful gas released from swine manure [6]. It is produced when manure decomposes anaerobically, resulting from the mineralization of organic sulfur compounds as well as the reduction of oxidized inorganic sulfur compounds such as sulfate by sulfur-reducing bacteria [6]. Low concentrations of H2S and other gases associated with animal agriculture can potentially impact human health [7].

Methane (CH4) is formed by breakdown of fatty acids and simple organic compounds by methanogenic bacteria in anaerobic lagoons. It is the most rapidly increasing greenhouse gas and accounts for about 27% of all climate forcing [8]. Total CH4 emissions from the decomposition of animal manure in North America have been estimated at 2,300,000 metric tons per year with about 40% of the total from swine [9].

Previous studies on animal waste have also found lagoon temperature & pH to be a strong factor in controlling the release of NH3 into the atmosphere [10]

As there are no long-term observations of air emissions throughout the USA, the present work aims to determine the air quality around the open air sources, including dairy corrals and dairy and swine manure storage lagoons and basins which can be used to develop a baseline of emissions.

II. MATERIALS & METHODOLOGIES

A. Selection of Sites

Sites for monitoring (Fig.1) were selected on the basis of the location (relative to climate and typical practice), method of manure collection, type of manure storage, availability of power and communications, and physical configuration of buildings and lagoons/ basins. Average ranges of temperature and precipitation along with the Köppen classification of the selected sites are given in Table I.

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Fig. 1 Ten sites in 7 states

195
Table I

<table>
<thead>
<tr>
<th>Sites</th>
<th>Average precipitation (mm)</th>
<th>Range of monthly average temperature (°C)</th>
<th>Köppen classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (dairy)</td>
<td>203.15</td>
<td>19 - 5.5</td>
<td>BW</td>
</tr>
<tr>
<td>2 (swine)</td>
<td>783</td>
<td>18 - 6</td>
<td>Cwa</td>
</tr>
<tr>
<td>3 (swine)</td>
<td>515</td>
<td>22 - 7</td>
<td>BS</td>
</tr>
<tr>
<td>4 (swine)</td>
<td>515</td>
<td>22 - 7</td>
<td>BS</td>
</tr>
<tr>
<td>5 (dairy)</td>
<td>515.112</td>
<td>21.6 - 6.6</td>
<td>BS</td>
</tr>
<tr>
<td>6 (swine)</td>
<td>1080</td>
<td>21 - 7</td>
<td>Cfb</td>
</tr>
<tr>
<td>7 (swine)</td>
<td>1080</td>
<td>21 - 7</td>
<td>Cfb</td>
</tr>
<tr>
<td>8 (swine)</td>
<td>984</td>
<td>19 - 6</td>
<td>Cfa</td>
</tr>
<tr>
<td>9 (dairy)</td>
<td>883</td>
<td>23.3 - 5.1</td>
<td>DaB</td>
</tr>
<tr>
<td>10 (dairy)</td>
<td>659</td>
<td>12.1 - 1.2</td>
<td>DBb</td>
</tr>
</tbody>
</table>

B. Respondent Schedule/Producer’s Event Form

Each farm owner or manager was asked to complete activity diary/questionnaire providing information related to farm characteristics, animal numbers, different activities of storing wastes etc. A questionnaire survey is a common way to document problems associated with the procedures at the farm. It also gives us an idea about the potential storage (basin, lagoon or tank), lifestyle and different activities of animals. An indication of whether adequate procedures/methods are being followed can be determined from the survey. A questionnaire (respondent schedule) was prepared for the personal interview with the producers’ of all monitoring sites. It was aimed to obtain a real picture of farm in general and about different activities, methods, problems, interferences which may be caused during monitoring the sites. Table II gives an example of the producer’s completed questionnaire for one of the sites.

C. Methodology

Measurements at ten sites in 7 states of the USA began in the summer of 2007, and will continue through the summer of 2009. Two sites out of ten are each measured continuously for one year. Eight sites are sequentially measured for 10-20 days during each season of the year for two years.

An open-path tunable diode laser absorption spectrometer (TDLAS) is used for the measurement of NH₃ concentration near open-air area sources. The minimum detection limits of TDLAS units are about 2 ppm-m or less. A multigas analyzer (INNOVA Model 1412) is used to measure CH₄ in the air drawn from the gas sampling system (GSS) analyzer manifold. The analyzer oxidizes the H₂S to determine the concentration as SO₂. The manufacturer stated MDL is 1 ppb. Both instruments analyze air drawn from a line of inlets along the side of the open source. The line is called a Synthetic Open Path System (S-OPS). Apart from the above mentioned measurements, ultrasonic anemometers are used to characterize the wind; sensors for other meteorological variables (air temperature, relative humidity, barometric pressure, surface wetness and solar radiation) are also used.

Lagoon/basin measurements are used to characterize the wind; sensors for other meteorological variables (air temperature, relative humidity, barometric pressure, surface wetness and solar radiation) are also used. Lagoon/basin measurements are used to characterize conditions during the measurement periods. The lagoon pH and ORP (oxidation reduction potential) state are measured using submersible plunger-style glass electrodes with a Teflon liquid junction (Innovative Sensors Model CSIM11 Sensor). The only difference between pH and ORP sensor is that ORP probe has a platinum band wrapped around the glass electrode to cause a response to the electron density of the fluid. The temperature is measured using a Campbell Scientific Model 107-L Thermistor. A probe float is used to place the pH, temperature, and ORP state probes at a depth of 0.3 m below the surface of the lagoon. Detailed descriptions of all the equipment used are presented by Grant et al [11].

D. Quality Assurance

In order to ensure the validity of the data generated from the study and to meet the data quality objectives set forth by the study, it is imperative to establish quality assurance and quality control measures in each aspect of the study. Hence, to make the study more efficient and accurate, regular quality assurance checks are made. Every instrument is calibrated.
before and at the end of every monitoring period or 20 days, which—ever is less. The acceptance criterion for TDLAS for NH\textsubscript{3} is ±10 ppm-m, TEC450i for H\textsubscript{2}S is ±0.05 ppm, INNOVA for CH\textsubscript{4} is ±1 ppm, all three represent ±10% of the calibration check concentration, CSM11 pH sensor acceptance criterion is ±0.3 pH units and for CSIM11 ORP it is 30 mV. While conducting calibration, calibration forms and control charts are completed; all these Quality Control records including calibration forms and control charts will be added to the final report.

III. RESULTS & DISCUSSION

Data collection in this study is ongoing. From the data collected so far we find that the concentrations of NH\textsubscript{3} around open sources are around 0.2 ppm; CH\textsubscript{4} concentration is generally found to be less than 50 ppm; however, at some sites, regular peaks above 100 ppm concentration are also observed; H\textsubscript{2}S concentrations are typically less than 20 ppb, but sometimes exceed 40 ppb.

Atmospheric NH\textsubscript{3}, H\textsubscript{2}S and CH\textsubscript{4} concentrations downwind of the open source are influenced by wind speed, wind direction, and wind direction deviation over the sampling period: An example of trends in concentration downwind is shown in Fig. 2 a, b, c & d. The trends in this data show that the emission patterns of different gases are dissimilar. Wind speed has effects on NH\textsubscript{3} and CH\textsubscript{4} gases but the entry of fresh waste from the barns has greater effects on H\textsubscript{2}S, as during the period of fresh waste, there is an increase of H\textsubscript{2}S concentration.

The emission of NH\textsubscript{3} is being determined from the concentration and wind measurements using a Gaussian plume fit approach (Radial Plume Mapping or ‘RPM’ method). The emission of H\textsubscript{2}S is being determined ratiometrically from the RPM NH\textsubscript{3} emissions calculations and the difference in upwind and downwind concentration measurements along paths similar to NH\textsubscript{3} concentration measurements as well as using a backward Lagrangian stochastic method (bLS) [11].

$$p(\text{NH}_3) = RT \left(10^{1.6 - \frac{4.32}{pH}} \right) \frac{[\text{NH}_4^+]}{[\text{H}^+]}$$ (1)

Several previous studies of animal waste emissions have observed temperature to be a strong factor controlling the release of NH\textsubscript{3} into the atmosphere. Studies have also found that lagoon pH played an important role in the potential for NH\textsubscript{3} volatilization. In a lagoon, [NH\textsubscript{3}] will be in solution with [NH\textsubscript{4}+] according to following equilibrium reaction:

$$\text{NH}_3(aq) + \text{H}_2\text{O}(aq) \leftrightarrow \text{NH}_4^+(aq) + \text{OH}^-(aq)$$ (2)

The pH controls the direction of equilibrium in (2). Increasing the pH implies that the concentration of hydroxyl...
ions ([OH−]) increases, thereby shifting the equilibrium to the left, and subsequently more NH3 is liberated. Likewise, increasing the water content of the lagoon, e.g. precipitation events, shifts the equilibrium slightly towards the right, causing the NH3 to be more tightly bound in solution [10].

Table III summarizes lagoon chemistry (temperature, pH and ORP) during the fall of 2008, and highlights some of the differences in the lagoons included in the study. Lagoon chemistry characterizations were not done at sites 1 & 10 (lagoons are always dry/crusted or frozen), 2 (a basin), 5 (a corral) and 9 (monitoring did not start).

Table III: Lagoon Chemistry during Fall of 2008

<table>
<thead>
<tr>
<th>Site</th>
<th>Measurement Period</th>
<th>Temp (°C)</th>
<th>pH (pH units)</th>
<th>ORP (mV)</th>
<th>Normalized NH3 concentration (ppb/animal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>5/8/08 to 5/29/08</td>
<td>19.5</td>
<td>7.8</td>
<td>-489</td>
<td>0.17</td>
</tr>
<tr>
<td>4</td>
<td>4/25/08 to 5/8/08</td>
<td>14.8</td>
<td>8.8</td>
<td>-462</td>
<td>0.076</td>
</tr>
<tr>
<td>6</td>
<td>3/5/08 to 3/26/08</td>
<td>17.1</td>
<td>7.5</td>
<td>-507</td>
<td>0.083</td>
</tr>
<tr>
<td>7</td>
<td>4/20/08 to 4/16/08</td>
<td>17.6</td>
<td>7.7</td>
<td>-515</td>
<td>0.096</td>
</tr>
<tr>
<td>8</td>
<td>5/14/08 to 5/31/08</td>
<td>17.2</td>
<td>7.1</td>
<td>-424</td>
<td>0.16</td>
</tr>
</tbody>
</table>

From the data obtained so far lagoon temperature has a positive relationship with NH3 concentration except at Site 8. At a specific lagoon pH has a very narrow range; thus, no significant relationship is seen between NH3 and pH. ORP shows entirely different values as compared to previous studies [13], it shows higher reduction in lagoon.

IV. CONCLUSION

In absence of complete data we cannot make any definitive conclusions but the preliminary observations suggest a higher level of all these pollutants and their levels effects on seasonal variation. A long term database of pollutants levels around open sources in USA will be useful to sate and federal regulatory agencies, the livestock’s industry, researchers, consultants, and the general public, and will help decision makers formulate and implement policies to manage and control environmental pollution.

REFERENCES