Cumulative Evaporation from Surface-Applied Manure Using a Closed Dynamic Chamber Technique

1Pakorn Sutitrarnnontr, 2Rhonda Miller, 3Markus Tuller, and 1Scott B. Jones
1Dept. of Plants, Soils and Climate, Utah State University, Logan, UT
2School of Applied Sciences, Technology, and Education, Utah State University, Logan, UT
3Dept. of Soil, Water and Environmental Science, University of Arizona, Tucson, AZ

ABSTRACT
Manure surface application is considered one of the most effective best management practices in reducing the nutrient impacts of livestock operations on surface and ground waters. Manure and its use as fertilizer can also contribute to gaseous and particulate emissions, significantly degrading air quality to the detriment of human health and the environment. The objective of our study was to estimate evaporation water loss to correlate with CO₂, NH₃, and NH₄ emissions from surface-apatplied manure. We established manure surface application plots at the USU Greenville Research Farm during the summer of 2013 to quantify gaseous emissions from four types of manure source (i.e. dairy manure, beef manure, dairy compost, and beef compost) and to investigate the temporal and spatial characteristics of the emissions. The temperature and relative humidity (RH) were monitored using a thermistor and relative humidity sensor mounted inside each of 12-surface chambers. Soil/manure moisture contents were determined using dielectric sensors. Results from our study enhance development and implementation of surface chamber-based assessment of gas loss by demonstrating correlation between gas emissions, water vapor mass loss and surface moisture measurements.

CHAMBER COMPONENTS

The system is based on the closed dynamic chamber principle and includes state-of-the-art moisture sensors, thermistors, and relative humidity (RH) sensors to monitor and examine the primary physical factors directly influencing gas production and transport mechanisms.

THEORETICAL CONSIDERATIONS

A. Determination of Soil/Manure Moisture Content

Volumetric water content (θv) of soil/manure was determined from the dielectric permittivity (ε) outputted from the GS3 sensor. A generic calibration expression used in converting ε to θv is shown below and plotted on the left.

θv [cm³ cm⁻³] = 0.118 ∙ [ε] - 0.117

The surface evaporation process was estimated to occur in the top 5 cm (± 2 inches) of soil.

B. Monitoring RH with Closed Chamber Technique

The absolute humidity (AH) in units of g m⁻³ was calculated from the relative humidity (RH) measured inside the closed chamber:

\[ AH = \frac{C \cdot P_v}{(T + 273.15)} \]

\( C = \text{Constant} \)

\( P_v = \text{Vapor Pressure in Pa, determined from:} \)

\[ P_v = A \cdot \frac{T}{100 + RH} \]

A, m, and Tc are constants listed in the table below (for temperatures in range of -20 to 50°C).

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>m</td>
<td>Tc</td>
<td>Max. error</td>
</tr>
<tr>
<td>6.116441</td>
<td>7.591386</td>
<td>240.7263</td>
<td>0.083%</td>
</tr>
</tbody>
</table>

EXPERIMENTAL SETUP

Manure surface application plots were set up at Greenville Research Farm in North Logan, UT (below left) during August 2013 to quantify gaseous emissions from four types of manure source (i.e. dairy manure, beef manure, dairy compost, and beef compost). The soil/manure moisture content sensors were inserted into the surface to a depth of 2 inches. In addition to gas emissions, primary meteorological factors affecting evaporation, including ambient temperatures were monitored (below right).

RESULTS AND DISCUSSION

An example of regression of chamber relative humidity versus time is shown on the left. Approximately after 40 seconds, the relative humidity gradient under the measuring chamber decreases with time as the sampled air accumulates. This is most likely affected by change in temperature inside the chamber after closing, particularly during the day time. To overcome potential underestimation of evaporation rate, we assumed a constant evaporation rate and used a linear model in a short period (±40 seconds) to determine the increasing rate of the relative humidity.

Each custom-made chamber is equipped with an external GS3 moisture sensor and thermistor (above left). The surface chamber is designed to house a circuit board with a fan and sensors to measure temperature and relative humidity inside the chamber (above right). The chamber volume and exposed soil area are 4,076 cm² and 317.8 cm² (49.3 in²), respectively.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge support from the USDA NIFA AFRI Air Quality Program grant # 2010-65112-50524 and Western Sustainable Agriculture Research and Education Program (WSARE) grant # GW13-006. Special thanks go to Bill Maneu for technical assistance and to Ricardo Tejeda and J.C. Almonte for their assistance with design and development of the microcontroller unit and system interfaces for the multiplexing system.

Poster presented at the 2014 Spring Runoff Conference held April 1 – 2, 2014 at Utah State University, Logan, Utah