Reducing Gas Emissions from Manure Storages by Anaerobic Digestion and Aeration Technologies

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Gases from Manure Storage

Gas emission involves two processes
- **Generation** by biochemical and chemical reactions
- **Mass transfer** at the surface

Gases
- Volatile organic compounds (VOCs)
- Methane (CH$_4$), Hydrogen sulfide (H$_2$S), ammonia (NH$_3$) and carbon dioxide (CO$_2$)
Factors Controlling Emission Rate

- Gas concentrations in the manure, related to generation in the manure
- Surface area of storage
- Environmental conditions (temperature and wind speed at the surface)
Methods for Reducing Emissions in Manure Storages

- Covering storages
- Treating manure prior to storage to reduce the gases generated in the storage
  - Solid-liquid separation
  - Biological treatment
    - Anaerobic Digestion
    - Aeration
Anaerobic Digestion and Aeration

- Both processes use bacteria to break down and convert organic matter under controlled conditions (retention time, temperature, organic loading rate, pH)

- Both processes provide these environmental and public health benefits
  - Reduce biochemical oxygen demand (BOD)
  - Destroy pathogens
  - Reduce odors (gases)
Research Objectives

- Quantify the effects of manure treatment by anaerobic digestion and aeration on emission reduction of gases (VOCs, CH$_4$, H$_2$S, NH$_3$) from manure storages
- Determine the costs and benefits of different biological treatment technologies
Manure Treatment System II

- Dairy
- S/L Separation
- Solids
- Water Recycling
- Aeration
- Irrigation
- Liquid Storage
Anaerobic Digester

Feed Tank

Aerobic Reactor

Biogas

Effluent Storage

Gas Collection Bag

Effluent Storage

Effluent Storage

Effluent Storage

Raw manure Storage

Aerobic Control

Aerobic Control

Aerobic Control
Raw dairy manure characteristics

- Total solids (TS) = 30 g/L (3%)
- Volatile solids (VS) = 21 g/L (2.1%)
- Biochemical Oxygen Demand (BOD₅) = 14 g/L
- Total Nitrogen (TN) = 3.8 g/L
- Ammoniacal Nitrogen (NH₃-N) = 1.6 g/L
- pH = 8.0
Operation Parameters of Anaerobic and Aerobic Reactors

- **Anaerobic Digester (4 L Volume)**
  - OLR = 1 gVS/L/day
  - HRT = 20 days
  - Temperature = 35°C

- **Aerobic Reactor (2 L Volume)**
  - OLR = 2 gVS/L/day
  - HRT = 5 days
  - Temperature = 25°C (room)
Performance of Anaerobic and Aerobic Reactors

<table>
<thead>
<tr>
<th></th>
<th>Anaerobic Reactor</th>
<th>Aerobic Reactor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Biogas Production (L/L/Day)</strong></td>
<td>0.31</td>
<td>N/A</td>
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<tr>
<td><strong>TS Reduction (%)</strong></td>
<td>22.2</td>
<td>15.8</td>
</tr>
<tr>
<td><strong>VS Reduction (%)</strong></td>
<td>41.8</td>
<td>28.5</td>
</tr>
</tbody>
</table>
Two experimental trials

- 35-day experiment in summer, 2004
  - VOC, VFA, CH₄, and H₂S measurement
  - Manure storage temperature = 20-29°C

- 180-day experiment in winter and spring, 2005
  - VOC, CH₄, VFA, H₂S, NH₃, CO₂ measurement
  - Microbial communities (anaerobic and aerobic bacteria)
  - Manure storage temperature = 10-19°C
Measurement of Effluent Storage

- **Gas phase**
  - Volume
  - VOCs (GC/MS, EPA TO-15)
  - CH$_4$, CO$_2$, (GC/TCD)
  - H$_2$S (GC/SCD)
  - NH$_3$ (acid trap and IC)

- **Liquid phase**
  - Volume
  - Volatile fatty acids (GC/FID)
  - NH$_3$-N
  - TS, VS, SS, BOD$_5$, COD,
**Data Analysis and Reporting Method**

- **Mass of a Gas in each storage**
  \[ \text{Mass in gas phase} + \text{Mass in liquid phase} \]

- **Mass production of a gas in each storage per unit of total solids in manure fed into the storage over 35 or 42 days**
  - VOCs – ug/gTS manure
  - VFAs – mg/gTS manure
  - CH\textsubscript{4} – mg/gTS manure
  - H\textsubscript{2}S – g/gTS manure
Findings from a 35-day lab study in Summer, 2004

- Anaerobic digestion achieved over 95% VOC, 90% VFA, and 83% CH$_4$ reductions in storage.
- Aerobic treatment achieved over 95% VOC, 79% VFA, and 39% CH$_4$ reductions in storage.
Major VOCs (EPA-TO15) found in Manure Storages

- Benzene
- Toluene
- Acetone
- Methalene Chloride
- Carbon Disulfide
- 2-Butanone
- Cyclonehexane
VFAs found in Manure Storages

- Acetic
- Propionic
- Isobutyric and butyric
- Iso-valeric and n-valeric
- Iso-caprioc and n-caprioc
- Heptanoic
Findings from 42-day Lab Study in Winter, 2004-2005.

- Anaerobic digestion achieved 64% VFA, 25% CH$_4$, 40% H$_2$S reductions in storage.
- Aerobic treatment achieved 84% VFA, 95% CH$_4$ and 31% H$_2$S reductions in storage.
VFA Production in Different Storages (Winter, 2005)

- Anaerobic Control: 84.22 mg/gTS as acetic acid
- Anaerobic Effluent Storage: 30.13 mg/gTS as acetic acid
- Aerobic Control: 83.81 mg/gTS as acetic acid
- Aerobic Effluent Storage: 13.82 mg/gTS as acetic acid
Methane Production in Different Storages (Winter, 2005)

<table>
<thead>
<tr>
<th></th>
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<th>Anaerobic Effluent Storage</th>
<th>Aerobic Control</th>
<th>Aerobic Effluent Storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH4 (mg/gTS)</td>
<td>0.0445</td>
<td>0.0335</td>
<td>0.0497</td>
<td>0.0026</td>
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</table>
Hydrogen Sulfide Production in Different Storages
VS Concentration in Different Manure Storages

VS Concentration (g/L)

- Anaerobic Control: 17.0
- Anaerobic Effluent Storage: 10.5
- Aerobic Control: 15.8
- Aerobic Effluent Storage: 12.5
Conclusions

- Anaerobic digestion and aeration have shown significant effects on the reduction of VOCs, VFAs, CH$_4$, H$_2$S in manure storage.

- Their gas reduction quantity for manure storages are influenced by the temperature variation in the storages, therefore these technologies should be evaluated for different seasons.
Continuing Research

- Determine the effects of anaerobic and aerobic treatment on gas production over a longer period (180 days) of storage time.
- Determine the effects of aeration in manure storages on gas production in the storage.
- Determine the costs and benefits of different biological treatment processes.