Gas Emissions from Manure Storages and Abatement Challenges and Opportunities

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Overview

- Introduction
- What emits from manure storages?
- How much and so what?
- Abatement options: challenges and opportunities
- Summary

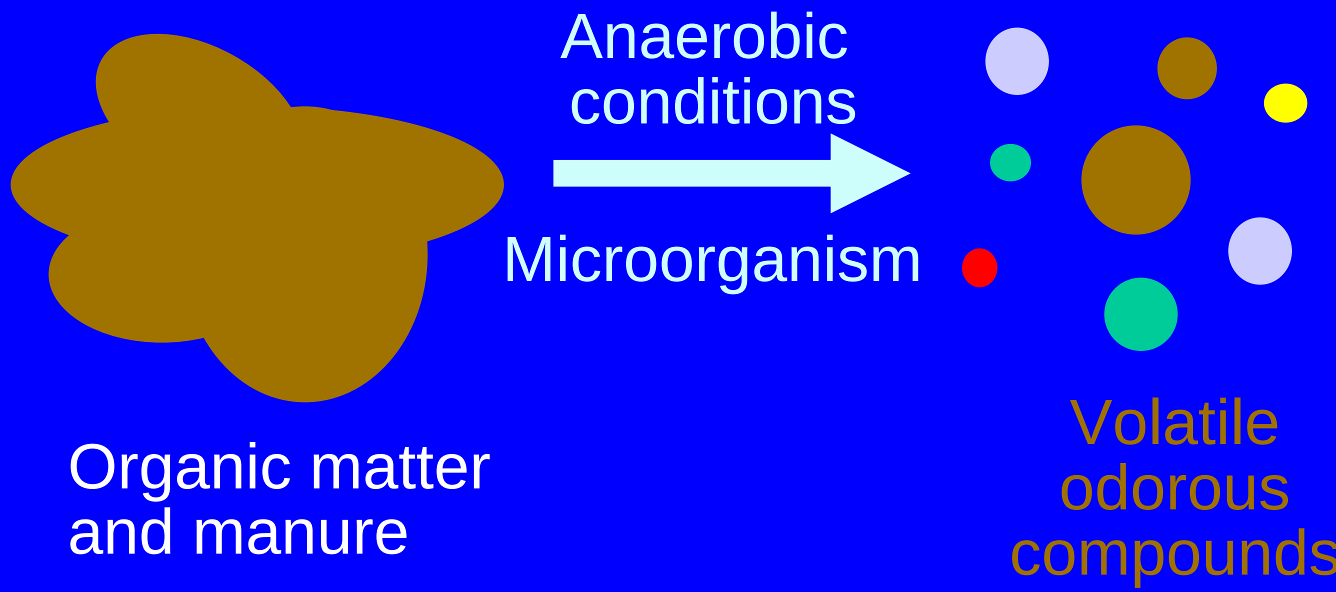
A free-stall dairy facility

Manure Storage Ponds and Lagoons

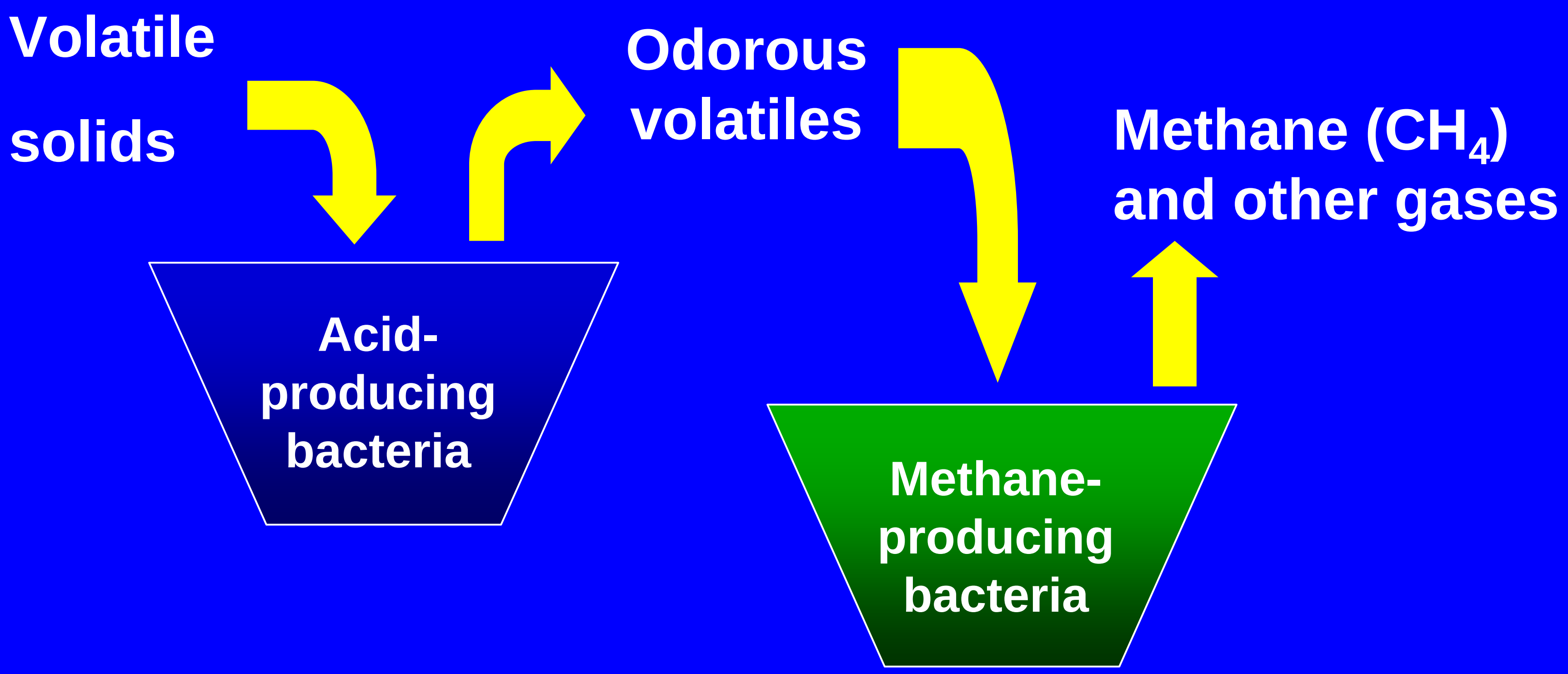
Gas Emissions from Manure Storages—
Is Odor the Only Concern?

Odor and VOCs from AFOs

- Odor -- unpleasant smells caused by gases and more than 160 odorous Volatile Organic Compounds (VOCs).



Complete Anaerobic Digestion



Ammonia and Hydrogen Sulfide Gas

- ***Ammonia (NH_3),*** is generated because inefficient conversion of feed N to animal products resulted in N excretion in urine of pigs and cattle and in the uric acid of poultry.

- ***Hydrogen sulfide (H_2S)*** is a colorless gas and generated from anaerobic fermentation of manure.

Greenhouse Gas emissions (GHGs)

- ***Nitrous Oxide (N_2O)*** is a potent greenhouse gas produced by microbial processes of nitrification and denitrification.
- ***Methane (CH_4)*** is an odorless natural gas, odorless, and produced by microbial degradation of organic matters under anaerobic conditions.
- ***Carbon dioxide (CO_2)*** is a part of natural air, odorless, and mainly caused by animal breathing and manure decomposition.

How much?--Gas Emission Rates and Factors

Methane (CH_4) Emission

- According to the USEPA NEI, in 2006, methane emissions from enteric fermentation and manure management represent 23% (126 Tg CO_2 Eg.) and 8% (41 Tg CO_2 Eg.) of total methane emissions in the U.S.
- Preliminary research:

  >12 g per cow per hour (UC Davis research, Sun et al., 2008)

  8.5-13.7 g CH_4 per day per cow from manure storages (Kulling et al. 2001)

  1.5 kg CH_4 per pig per year (Guimont et al. 2007)

Ammonia (NH_3) Emission

- The EPA NEI estimates 2,418,595 tons of NH_3 emission from agricultural sources in 2002, which is about 80% of total ammonia emissions to the atmosphere.
- USDA estimates suggested that 36-90% of the nitrogen inputs to anaerobic lagoons were lost to the atmosphere (Hatfield et al., 1993).
- Research findings: NH3 emission rates from the open manure storages varied significantly: 1-40 g NH_3 per square meter per day (Hobbs et al. 1999； Gay et al. 2002； and Aneja et al, 2000).
- In Ohio, annual mean NH3 emission rate was 71.6 ± 57.8 μg/s-m^2 and ranged from 5.7 to 174.8 μg/s-m^2. (Zhao et al 2007), which is within the range of NH3 emission (46.1-198 μg/s-m^2) from dairy manure storages at Minnesota (Gay et al., 2003).

Impact of Gaseous Emissions

Aerial Environmental Impacts - Atmosphere visibility, acidity, and ozone formation

- Ammonia (NH_3)—Environmental acidity and precursor of small particles ($PM_{2.5}$) affecting atmosphere visibility
- Hydrogen sulfide (H_2S)—forming small particles affecting atmosphere visibility
- VOCs— Ozone formation due to interaction of VOCs with oxides of nitrogen. Ozone is toxic to breath and is a precursor of toxic chemicals and fine particles.

Aerial Environmental Impacts – Global Warming

- ***Carbon dioxide (CO_2)–*** a greenhouse gas (GHG)
- ***Methane (CH_4) --*** a GHG and bioenergy gas and has 23 times global warming potential than CO_2.
- ***Nitrous Oxide (N_2O)*** **– a** potent GHG and has 296 times global warming potential than CO_2.

Odor-Nuisance and trigger of public complaints

- Odor may cause great mood disturbance, and in turn cause nuisance.
- Odor is often a trigger of other public complaints.
- Limitation of odor measurement and subject response of human being, make it difficulty to assess impacts of odor on people's quality of life quantitatively.

Abatement Options

Best Management Practices (BMPs) and Best Available Technologies (BATs)

- Feed Management and Manure Additives
- Aeration of lagoon
- Anaerobic lagoon, digester
- Covers
- Other

Additives

Many additives are available to add to pits, lagoons, or animal feed. They work in different ways. Some are chemical, microbial, enzymatic, disinfectants, deodorants, adsorbents, and others. Some work; some do not.

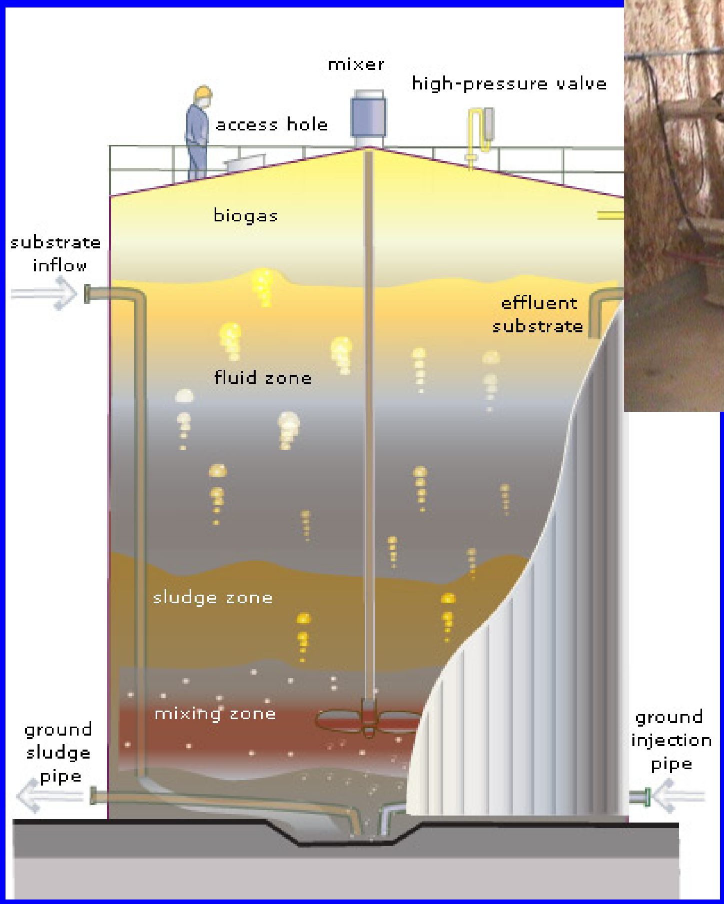
Surface Aeration of Lagoons

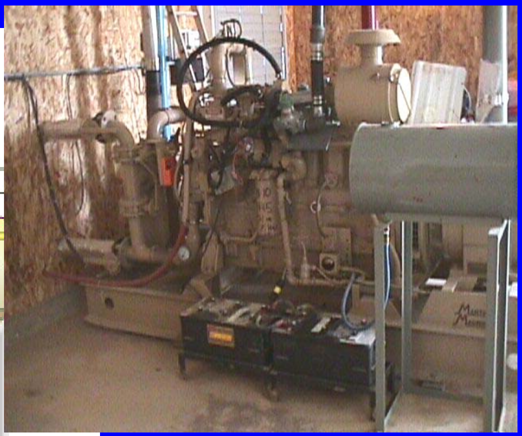
- Complete aerobic treatment eliminates odors, but may promote ammonia emission and other gas emissions.
- Aeration requires large amounts of energy.

Anaerobic Lagoons

- **Anaerobic lagoons--Anaerobic treatment of manure taking place in the absence of oxygen**
- Designed as an Odor abatement
- Do not function well in cold climate (<50^{o} F)
- Generate methane and other gas emissions

Anaerobic Digesters





- Produce methane gas
  - Generate electricity
  - Convert to hot water
- Digesters can be expensive
  - require additional management
- Odor and gas reduction

Floating Permeable Covers

- Natural crust
- Biomass material, such as straw
- Clay ball cover on concrete slurry pit

Impermeable Synthetic Covers

- Rigid (wooden or concrete) or flexible (plastic) covers hold gases and odors inside manure storages
- Most flexible covers float on the liquid surface.

Effects of Permeable Covers

- Reductions of odor and H_2S are generally >50%
- Increased emission of CH_4 (up to 30%)
- NH_3 reductions by >70%

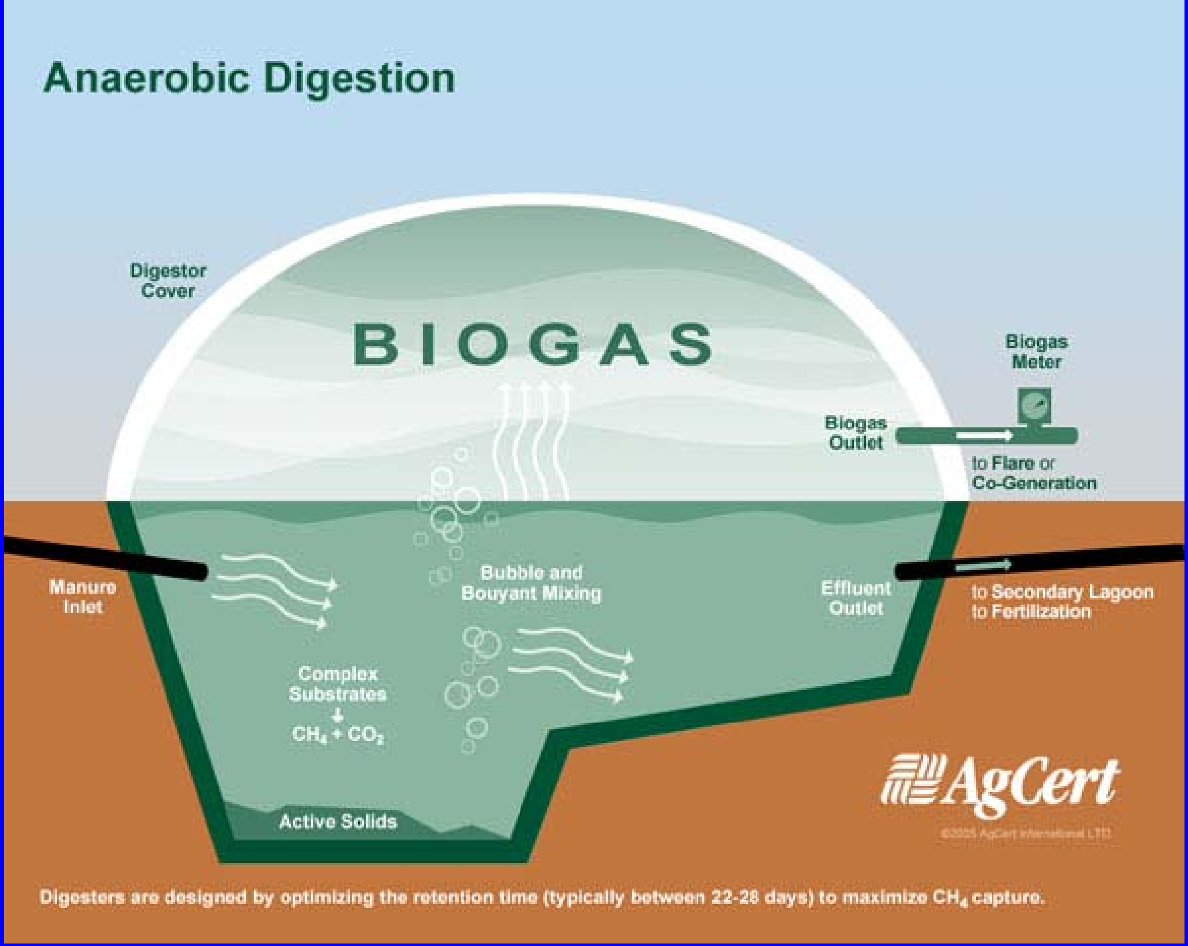
Effects of Impermeable Covers

- Gas emissions reduction efficiencies of an inflated cover 80% - 95% (Funk et al.,2004)
- Odor reduction 50-80% (Bicudo et al., 2001)
- NH_3 reduction 50% to 90% (Misselbrook et al., 2005)
- H_2S reduction emission up to 80% (Bicudo et al., 2001)

- Effects on GHG have not been reported

Manure Storages with Covers -- Natural Temperature Digester

- Reduced odor, NH_3, and H_2S emissions
- Captured CH_4
- Relatively low cost
- Simple management
- Fluctuated CH_4 production



Flaring CH_4 for Carbon Credits

- Flaring methane captured by covers creates carbon credits
- Carbon credits are another line of income to farmers
- ECC has contracted several dairies across the US under its **lagoon cover program** to carbon credits
- Methane captured is a potential source of on-farm energy. Better use of the biogas collected need to be explored.

Summary of Covers and Performance

Type of cover	Material	Effectiveness (%) Odor	H_2S	NH_3	Life expectancy	Capital cost (US$/yd^2)	Reference
Impermeable	Concrete lid	95	N/A	N/A	10-15 years	N/A	1
	Wood lid	95	N/A	95	10-15 years	N/A	1,2,3
	Inflatable plastic	95	95	95	10 years	7-15	1,4
	Floating plastic (HDPE)	60-78	90	N/A	10 years	3-5	5
Permeable	Straw	40-90	80-94	25-85	Up to 6 months	0.25-1	1,5,6,7,8,9
	Geotextile	40-65	30-90	0	3-5 years	1.25-1.6	9
	Geotextile + straw	50-80	60-98	8-85	N/A	1.5-2.6	9
	Leca®	90	N/A	65-95	10 years	15.45	3,7
	Macrolite®	60	64-84	N/A	10 years	15.45	5

References

1 Mannebeck, 1985
2 DeBode, 1991
3 Sommer et al., 1993
4 Zhang and Gaakeer, 1996
5 Clanton et al., 1999
6 Anonymous, 1993
7 Bundy et al., 1997
8 Jacobson, 1998
9 Clanton et al., 2001

Cover Design Considerations

- Purpose of the cover
  - Reduction of odor
  - Reduction of specific gases
  - Reduction goal
- Type of storage
  - Permeable cover on earth structures
  - Impermeable covers not easily installed on earthen structure
  - Concrete lids don’t work on steel tanks or earthen structures

Cover Design Considerations

- Size of storage
  - Bio-cover not practical on structures +2 acres
- Manure Management
  - Geotextile/HDPE fabrics not recommended for storages that are pumped frequently or rigorous agitation
  - Impermeable covers do not permit rainfall from entering system or for evaporation out of the system
  - Permeable covers allow rainfall in but may restrict evaporation
- COST!!!

Summary

- Manure storages are major sources of air emissions on farms including odorous gases and greenhouse gases.
- Air emissions are of significant environmental impacts.
- Among gas emission abatement options, covers and anaerobic digesters not only reduce gas emissions, but also generate carbon credits.
- Research is needed to quantify methane emissions from manure storages for better reporting and accurate calculation of carbon credits.