There is growing interest in odor and gaseous emissions from livestock operations because of concern about global warming and enforcement of the Clean Air Act. This bulletin provides and evaluates best management practices for the control of ammonia lost to the air on dairy farms. Benefits are based on an approximation of ammonia emissions using currently available information. There are likely to be significant variations with region of the country, climate, and management of the dairy cattle housing system.

LIQUID MANURE STORAGE AND TREATMENT

**Synthetic Cover**
Impermeable lagoon cover with an air- and watertight seal over the manure surface. Requires a vent to release carbon dioxide and methane and a drain to pump the rainwater off. Cover concentrates nitrogen in the liquid in the lagoon. Manure samples should be taken to ensure that nitrogen is applied to crops at appropriate rates.

**Geotextile Cover**
Permeable cover constructed of nonwoven synthetic felt. Constructed to provide complete coverage over liquid surface. Cover concentrates nitrogen in the lagoon. Manure samples should be taken to ensure that nitrogen is applied to crops at appropriate rates. Loss of evaporation from surface reduces storage capacity. Monitor lagoon liquid levels frequently and adjust land application plan if needed.

**Solids Separation**
Gravity or mechanical separation system to remove manure solids from liquid waste stream. Separation pits should be cleaned on a regular basis. Holding times should be less than 1 month. Solids separated from mechanical systems should be removed from the separator on a regular basis, not to exceed 3 days.

**Separate Slurry and Liquid Manure Basins**
Construction and use of separate holding basins or lagoons to keep parlor wastewater and corral runoff away from concentrated slurry (manure and urine). Applicable systems include freestall scrape and open-lot dairies, which scrape their feeding alleys.

**Aerated Lagoon**
Biological treatment basin designed to decompose liquid manure and nitrify ammonia in the presence of oxygen. Systems should utilize submerged microbubble systems to reduce ammonia loss. Operational cost for lagoon aeration can be significant.
GENERAL PRACTICES

Vegetative or Wooded Buffers
Mixture of hardwood and evergreen trees or shrubs control, capture, and mix higher, elevated, cleaner air with lower, dust- and odor-laden air from the ground surface. Buffers are also effective on odor and dust. Should be installed between production facility or lagoon and neighbors. (An established stand has reached its mature growth stage; establishment refers to sites that have not reached mature growth.)

Benefits
Established
- Open lot: moderate
- Freestall scrape: moderate
- Freestall flush: moderate

Establishment
- Open lot: low
- Freestall scrape: low
- Freestall flush: low

FREESTALL BARNs

Scrape Built-up Manure
Removal of built-up manure around the yard and manure-handling system. Specific emphasis on ends of barns, around collection pits, mixing tanks, and manure loading areas. Effective for reducing odors and flies.

Benefits
- Open lot: no effect
- Freestall scrape: low
- Freestall flush: low

OPEN LOTS AND CORRALS

Rapid Manure Removal
Removal of wintertime manure and corral bedding from open-lot surface in spring or as quickly as practicable. Manure can then be stockpiled, composted, or exported from the dairy.

Benefits
- Open lot: low
- Loose housing: low

Corral Harrowing
Corral harrowing to distribute deposited manure, reshape corral surface, and/or remove manure from corral surface. Harrowing should be conducted no less than 3 times per week when weather conditions permit.

Benefits
- Open lot: low

Surface Amendments
Use of liquid and dry chemical products to bind or chemically target the conversion of urea to ammonia gas. Effectiveness of production and described use should be specified by manufacture testing. Products may include, but are not limited to, alum, magnesium sulfate, and acids.

Benefits
- Open lot: high
- Freestall scrape: low
- Freestall flush: low

In-Corral Composting/Stockpiling
Stockpiling and subsequent drying and potential decomposition of winter manure and bedding in corral through summer and fall. Practice promotes the timely stacking and cleaning of corral surfaces.

Benefits
- Open lot: low

Summertime Deep Bedding
One-time application of 6 inches of straw on open corral surface. An approximate 40% reduction in ammonia emission is achieved. This practice employs a layer of straw to prevent urine and feces from collecting in the same area in the open lot. Feces deposited on straw are allowed to dry and thus shed liquids if urinated upon. Ammonia emissions are reduced by minimizing the time that urine and feces are in contact, during which urea can be converted to ammonia.

Benefits
- Open lot: moderate

ANIMAL NUTRITION

Manage Dietary Protein
With the assistance of a professional nutritionist, develop and follow a feeding strategy that more closely follows National Research Council guidelines and meets the herd’s production requirement. Incorporate phase feeding, analyze all feeds, measure milk urea nitrogen (MUN) regularly, or use appropriate amino acids or enzymes.

Benefits
- Open lot: low
- Freestall scrape: low
- Freestall flush: low

COMPOSTING PRACTICES

Alum Incorporation
Regular incorporation of aluminum sulfate with fresh material to reduce ammonia volatilization. Dissolved phosphorus is also reduced in the applied product.

Benefits
- Open lot: moderate
- Freestalls scrape: moderate
- Freestall flush: moderate
Manipulation of the Carbon-to-Nitrogen Ratio
Management and material selection to ensure that the carbon-to-nitrogen ratio is greater than 35:1 in the finished compost material. Lower carbon-to-nitrogen ratios promote greater ammonia volatilization.

Benefits
- Open lot: moderate
- Freestall scrape: moderate
- Freestall flush: low

Composting with Windrows
Aerobic decomposition of manure or other organic materials placed in long rows. Can be actively turned windrows, passive windrows, actively aerated windrows, or passively aerated windrows.

Benefits
- Open lot: no benefit
- Freestall scrape: no benefit
- Freestall flush: no benefit

Composting with Static Piles
Engineered composting system through the aerobic decomposition of manure or other organic materials placed in long rows that are not turned or mixed, but have aeration pipes that improve air transfer. Bulking agents, such as shredded wood, should be used to ensure pile porosity.

Benefits
- Open lot: low
- Freestall scrape: low
- Freestall flush: low

Forced-Aeration Composting
Engineered composting method using long rows or containers in which air is drawn or forced into the piles by using mechanical blowers. These piles are not turned. Make sure air is dispersed evenly through the pile. Bulking agents, such as shredded wood, should be used to ensure pile porosity.

Benefits
- Open lot: moderate
- Freestall scrape: moderate
- Freestall flush: low

Incorporation of Manure within 24 Hours
Tilling of field surface following liquid or solid manure application within 24 hours after beginning the manure application. Also effective in reducing hydrogen sulfide emissions and fly propagation.

Benefits
- Open lot: moderate
- Freestall scrape: moderate
- Freestall flush: moderate

Irrigation with Freshwater Immediately after Applying Manure
Pumping fresh water immediately after applying manure helps incorporate manure into the soil and reduces ammonia volatilization.

Benefits
- Open lot: low
- Freestall scrape: low
- Freestall flush: low

Low Energy and Pressure Application Systems (LEPA systems)
Center pivot and liner-move irrigation strategy that applies liquids at low pressures using drop nozzles. Larger droplets result in lower emissions, but may cause infiltration problems in some soils. Designed systems and sprinkler packages should not exceed 35 psi. Low-pressure overhead sprinklers and wheel lines do not qualify as LEPA technologies. Also effective on hydrogen sulfide and odor.

Benefits
- Open lot: moderate
- Freestall scrape: moderate
- Freestall flush: moderate

Freshwater Dilution
Dilute irrigated wastewater by a minimum of 50% (waste to fresh water in a 1 : 1 ratio) during all irrigation events. Dilutions can be made in approved mixing pond or chemigation systems.

Benefits
- Open lot: low
- Freestall scrape: low
- Freestall flush: low

Pivot Drag Hoses
Low-pressure application method that allows the liquid to be applied on the soil surface directly in the row. This method decreases the amount of liquid lost to wind drift and decreases the energy costs associated with pumping enough liquid to maintain the high pressures required for the impact heads. Systems should use pressure regulators or ball valves to regulate flow from drag hoses. Also effective on hydrogen sulfide and odor.

Benefits
- Open lot: moderate
- Freestall scrape: moderate
- Freestall flush: moderate

LAND APPLICATION PRACTICES

Soil Injection: Slurry
Placement of manure slurry (manure of 8%-15% solids) or separated solids beneath the soil surface with a minimum of mixing or stirring of the soil. Injection of slurry or separated solids reduces ammonia emissions, odor, and flies. The nitrogen value of the slurry will be 15%-40% greater than if the manure is not incorporated.

Benefits
- Open lot: moderate
- Freestall scrape: high
- Freestall flush: moderate
**PRACTICES NOT FREQUENTLY CONSIDERED**

### In-House Separation
Specialized floor design allowing fecal material to remain in place while urine is removed. This practice uses floor designs that prevent urine and feces from collecting in the same area within the freestall barn. Ammonia emissions are reduced by minimizing the time that urine and feces are in contact, during which urea can be converted to ammonia.

**Benefits**
- **Open lot**: no benefits
- **Freestall scrape**: moderate
- **Freestall flush**: no benefit

### Anaerobic Digester
Treatment system that anaerobically digests organic matter from manure and by using bacteria converts it into methane. The methane may then be used to generate electricity or to replace natural gas as a fuel. A steady supply of manure is needed. Typically there is no change in nutrient concentration without additional treatment. Effective in reducing volatile organic compounds, biological oxygen demand, and odor.

**Benefits**
- Limited in any housing system

### Sequencing Batch Reactor
Single-tank treatment system that allows for the sequencing of anaerobic, anoxic, and aerobic conditions in the tank by scheduling the feeding and aeration of wastewater. Successful systems have been documented to reduce the total nitrogen in animal wastewater by 85%. Also effective in reducing volatile organic compounds, biological oxygen demand, and odor.

**Benefits**
- **Open lot**: moderate
- **Freestall scrape**: high
- **Freestall flush**: high

### Lagoon Nitrification and Denitrification System
Engineered lagoon modification or stand-alone system designed and operated to convert wastewater ammonia to nitrate and then to nitrogen gas. Quarterly monitoring of inflow and outflow nitrogen species is required to track system performance. Also effective in reducing volatile organic compounds, biological oxygen demand, and odor.

**Benefits**
- **Open lot**: low
- **Freestall scrape**: high
- **Freestall flush**: high

### Fixed-Media Aeration System
Stand-alone treatment system designed and operated to convert wastewater ammonia to nitrate by growing bacteria on a medium or substrate. Several systems have been shown to denitrify wastewater nitrate into nitrogen gas. Also effective in reducing volatile organic compounds, biological oxygen demand, and odor.

**Benefits**
- **Open lot**: low
- **Freestall scrape**: high
- **Freestall flush**: high

### Forced-Aeration Composting with Biofilter
Engineered composting method in which air is drawn through the compost and discharged into a biofilter composed of long rows or containers of carbon material. These piles are not turned. Bulking agents, such as shredded wood, should be used to ensure pile porosity. This practice works by filtering volatile compounds and ammonia, then allowing aerobic microorganisms to degrade the compounds.

**Benefits**
- **Open lot**: moderate
- **Freestall scrape**: moderate
- **Freestall flush**: low

### Subsurface Irrigation
Specialized irrigation method that allows for precise applications of liquid to the root zone of the plant. System requires a specialized filtering system to handle wastewater solids. Specialized wastewater-approved drip lines should be used to prevent clogging. Also effective on hydrogen sulfide and odor. For more information on wastewater subsurface drip systems, visit the site www.oznet.ksu.edu/sdi. The nitrogen value of the wastewater is 15%-40% greater than if the manure is not incorporated.

**Benefits**
- **Open lot**: moderate
- **Freestall scrape**: moderate
- **Freestall flush**: moderate
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