Report # ___________________

TASK 2- LITERATURE SURVEY & NATIONAL PROGRAMS

LIVESTOCK WASTE MANAGEMENT PRACTICES SURVEY & CONTROL OPTION ASSESSMENT

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March 2003

CONTRACT #01226

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TASK 2

LITERATURE SURVEY & NATIONAL PROGRAMS

LIVESTOCK WASTE MANAGEMENT PRACTICES IN THE SOUTH COAST AIR BASIN

A. SUMMARY

S*ummary-* This report supplies information from research of various databases, summarizing the current and recent historical situation with respect to manure management associated with the United States Department of Agriculture Agricultural Research Service and other programs around the world.

Animal agriculture can be a source of gaseous emissions including ammonia and non-methane volatile organic compounds (VOC) that are produced or emitted inside and near animal production facilities and when waste products are land-applied. Numerous gaseous compounds and living organisms are generated from dairy manure decomposition shortly after it is produced or during storage prior to use as a fertilizer on cropland. The rate of generation of these gases, organisms, and particulates varies with time, species, housing, manure handling system, feed type, and management system used, thus making prediction of contaminant presence and concentrations extremely difficult.

Once these gases are generated they can be emitted from the sources (building, manure storage unit, or cropland) through the barn's ventilation system or by natural (weather) forces. Again, emission rates are dependent on many factors—time of year and day, temperature, humidity, and other weather conditions, ventilation rates or wind forces, housing type, manure properties or characteristics, and animal species.

Determination of emission rates for ammonia and VOCs is an active area of research in the US and Europe. Emission rates from point sources (buildings) and area sources (manure storage units and manure applied on cropland) are difficult to accurately determine because collection techniques have not been standardized, the large number of contaminants to measure, and the many factors and conditions at sites that affect them. Emission rates of only a few of the many gas compounds identified have been investigated. Ammonia is the most common gas studied and measured because of the negative environmental impact it can have on ecological systems.

C*onclusions*- The conclusions from this report are noted below.

1. Starting in 2000, the US Department of Agriculture Agricultural Research Service commenced a major research program into the air quality effects from livestock production and associated manure management. One component of the research focuses on understanding the processes of air pollution emissions from agricultural enterprises and the effects of air quality upon agriculture. Another component focuses on developing cost-effective management practices, technologies and decision aids that will allow producers to capture the value of manure without degrading environmental quality. The research results are not complete and will not be available for several years. The anticipated results are likely to be very relevant to the goals identified by SCAQMD for ammonia and VOC reductions.

2. The literature research discovered only one additional relevant project area of study underway outside the scope of coverage of the ARS National Programs. This research is underway in Sweden. The objective of the project is to demonstrate an efficient and innovative combination of methods to reduce ammonia leakage on the dairy farm. The direct relevance of the research to conditions in the SCAB is questionable. The value of the information is to identify processes and mechanisms by which ammonia is cycled through dairy systems.
3. There are major uncertainties regarding the exchange of atmospheric ammonia with ecosystems because quantitative emission and deposition fluctuations are poorly defined. Ammonia is the most abundant alkaline component in the atmosphere that neutralizes acid gases of sulfur and nitrogen oxides. Consequently, with large amounts of acid gases from fossil fuel combustion, ammonium is a major component of atmospheric aerosols.
4. Emission of gases and particulates from all phases of livestock production and manure handling, storage, processing, and application is poorly understood; and perception of emission rates varies among the public. A range of compounds is released from production systems, and these compounds vary among production facilities and across time. Thus, it has been difficult for producers or the public to compare production systems or evaluate the efficacy of control techniques. Studies on emission rates from different livestock systems are limited, and there is no comprehensive database across a range of systems. Knowing rates of emission is necessary to understand how management practices or alternative manure-handling processes could reduce impacts of these emissions on the environment and neighbors.
5. Manure storage systems interact with the atmosphere differently depending upon the surrounding land surface and design of the manure storage system. Observations on ammonia reveal that ammonia as a gas is transported only short distances while ammonia attached to water droplets can be transported large distances. Particulates released by livestock production units vary greatly with production practices and management and affect release of odors from facilities. However, this information has not been assembled into a comprehensive understanding of the transport of gases and particulates from livestock production, manure storage and handling, and manure application areas.

B. TASK 2– LITERATURE REVIEW OF FARM WASTE MANAGEMENT PRACTICES AND TECHNOLOGIES

Overall Approach- The work in this project builds from an understanding of the interrelationships between livestock agriculture as practiced in the Chino Basin Dairy Area and the atmospheric emissions situation associated with those practices. In order to address the needs of this project and the South Coast Air Quality Management District (District), our team draws on our own extensive local experience and the expertise of researchers being led by the United States Department of Agriculture-Agricultural Research Service National Programs on Manure and Byproduct Utilization and Air Quality.

***Background* – Scope of Work** The scope of work for this project includes four tasks. Task 2 surveys the literature for livestock waste management practices at the national level and throughout the world. This task brings together information from research of various databases to summarize the current and recent historical situation with respect to ammonia and VOC emissions from dairy production systems and manure management. Contacts were made with researchers and manure management contractors, product vendors and manufacturers who manage livestock waste management technology. The sequence of activities and methodology for this task began with literature search of various databases including AGRICOLA from the National Agricultural Library. An evaluation of the pertinent papers from each of these searches was conducted.

Introduction to Ammonia Release on Dairy Farms- Two different processes on the average dairy farm emit ammonia (NH3). It volatilizes rapidly from fresh manure and urine, and is a byproduct of the anaerobic degradation of older manure. Most of ammonia's nitrogen comes from the breakdown of uric acid.

This initial loss of ammonia to the atmosphere occurs very rapidly. In one experiment, dairy manure was tested continuously for a week. Starting with fresh manure the rate of release stayed constant, until after 72 hours a plateau was reached, at which time 15% of the organic matter had been released. From this, one could conclude that there are only few hours in which to prevent initial losses through ammonia volatilization (Lefcourt A., et al; 1998).

After this initial loss, further release proceeds through ammoniafication, the biochemical process whereby ammoniacal nitrogen is released from nitrogen-containing organic compounds. Soil bacteria decompose organic nitrogen forms in soil to the ammonium form.

If hydrogen ions are plentiful, or the pH<7 than the NH_3 can be rapidly converted to NH_4+. However if the microbes have too much N for their own requirements they excrete the excess as NH_4+ into the soil. In high pH soils NH_4+ (ion in solution) is unstable and changes to NH_3 (gas) which is then lost via volatilization. NH_4+ on the other hand is held by the soils cation exchange capacity (negative charge sites) and thus will not leach.

The following chart relates how ammonia release is effected by a number of variables (Bergstrom, S. et al; 2001).

	NH_3 emissions		
	Low		High
Meteorology	Low Low	Air temperature Wind speed	High High
Manure	Low Low Low Low	pH-value Nitrogen content Manure temperature Dry matter content[1]	High High High High
Storage design	Small Yes	Storage surface area Cover	Big No
Storage period	Short	Storage period	Long

Atmospheric Ammonia Loss from a Typical Farm (Bergstrom, S. et al; 2001)- It was not possible to find comprehensive data on ammonia release from dairy operations similar to those found in the Inland Empire. However an intensive study on ammonia release and possible treatment is underway in Sweden. Their study commenced in 1999 by gathering typical ammonia emission data from each of the three areas of ammonia release; the milking parlor, during manure storage and upon the spreading of manure.

The studied farm, the Brogarden Farm, keeps all 40 of their cows inside a barn year round. From the period of November 1999 to August 2000 continuous ammonia measurements were made of the barns exhaust air. Because the dairy was regularly cleaned of all manure and urine, which was then taken to storage tanks for further curing, we can assume that all ammonia measured is the result of rapid volatilization, and not a by-product of anaerobic composting. Furthermore, because the cows spend all of their time in the barn, ammonia measurements should completely capture all of the immediate nitrogen loss. This is particularly relevant to the problems at the Chino Dairies. Much of the cow's time is spent, and thus manure is deposited, outside.

The researcher's measured the barn's exhaust air with an infrared analyzer (see below). The average ammonia emission from the barn was 42 g per hour, which corresponded to 24 g per cow per day, which was equivalent to a nitrogen loss of 7% of the total manure nitrogen. The average ammonia concentration in the cow shed was 7.9 p.p.m. Studies in Holland showed significant variation between different housing styles and the resulting ammonia emissions. A cowshed with a tie-stall and manure stored in a deep pit produced as little as 5 g/cow/d, while 45 g/cow/d was emitted from a shed with slats and a deep pit.

Characteristics of typical 1-day old manure(Bergstrom, S. et al; 2001)

	Manure Solids	Urine
Dry matter, %	18.6	3.4
Total nitrogen, kg/ton	5.6	4.1
Total ammoniacal nitrogen (TAN), kg/ton	1.8	3.7
Phosphorus, kg/ton	1.2	0.1
Potassium, kg/ton	4.3	7.4
pH	8.4	8.6

Twice a day the barn was cleaned of manure. The urine was separated from the manure and moved into a large storage tank. The manure was deposited on a three-walled solid storage pad where a system of passive flux samplers (see below) recorded emissions. The farm produced 1.5 tons per day of solid manure and .7 tons per day of wastewater and urine. Solid manure storage led to a mean loss of 220 g/day, while the urine lost approximately 80 g/day. This corresponds to not more than a 5% yearly storage loss of the total nitrogen content. However, because measurements were conducted during the coldest time, and thus emitted ammonia the slowest, they expect a yearly Nitrogen loss would be closer to 10-15%.

While the spreading of manure does not typically take place at the local dairies, it is a significant cause of ammonia emissions. If the manure is shipped anywhere else in the area, our air quality will still be affected by the resulting releases. Solid manure was spread in autumn 1999 and spring 2000, in three different periods. The application rates were approximately 30 tons ha -1 on straw stubble (autumn) and on bare soil (early spring). When spreading on ley (spring) the application rate was restricted to 15 tons ha -1. Ammonia losses after spreading were measured using the stirred dynamic chamber method. It was found that 9-21% of applied total nitrogen was lost to the ambient air. Often ammonia losses are measured in relation the sample's total ammoniacal nitrogen (TAN) since this nitrogen part is the major source to ammonia emissions after spreading. If this comparison is made, the measured emissions correspond to 43-53 % losses of TAN after spreading.

In total between 26 and 43% of the excreted nitrogen escaped into the atmosphere.

Government and Academic Waste Management Research Programs The two government programs that are most closely related to our current research are both conducted under the auspice of the US Department of Agriculture Research Service. One is dedicated to air quality protection and the other to manure utilization.

The USDA Air Quality program intends to, through research, understand the processes of air pollution emissions from agricultural enterprises and the effects of air quality upon agriculture. The work includes development and testing of manure management control measures. The results will create decision aids that are useful in minimizing agricultural air pollution emissions. The research focuses on five problem emissions: particulates, ammonia, malodorous compounds, ozone impacts, and pesticides. In some areas, the work is mandated by National Ambient Air Quality Standards (NAAQS), to help reduce agriculture emissions.

The second national program is the USDA Manure and Byproduct Utilization project. The research concentrates on the three central areas: nutrient management, atmospheric emission, and pathogens. The program views manure as a resource rather than a waste. To promote this belief the work intends to develop cost-effective management practices, technologies and decision aids that will allow producers to capture the value of manure without degrading environmental quality. To prevent environmental degradation, new management practices and treatment technologies will be developed to reduce emissions at production facilities, storage areas and field application sites.

USDA-ARS NATIONAL PROGRAMS-AIR QUALITY PROGRAM (Amerman, 2001)

Ammonia and Ammonium Emissions The central environmental issue is agriculturally emitted ammonia as a major source of secondary, PM-2.5 particulates as a result of its interactions with other atmospheric compounds. The focus of this national program component is on understanding ammonia emissions and their role in forming secondary particulates, developing methods to measure emissions, establishing emission factors for various agricultural activities, and suppressing ammonia and ammonium emissions beyond farm boundaries.

Program Vision The program vision is to create productive animal and cropping systems that minimize ammonia-containing nitrogen emissions to the atmosphere.

Program Mission The program mission is to develop systems to reduce ammonia emissions from cropping and animal production systems while improving productivity.

Research Area- Systems to Contain Nitrogen Compounds Within Farm Boundaries

Rationale Nitrogen compounds are imported onto farms through animal feed or fertilizer. This nitrogen is essential for efficient animal and crop production. Life cycle analysis systems approaches are needed to link nitrogen imports tightly to production, thus limiting the potential nitrogen losses to surrounding ecosystems. These approaches need to include entire farm management plans that maximize nitrogen use efficiency and limit excess nitrogen output. Excess nitrogen can degrade water quality through leaching and runoff of nitrate or air quality through volatilization of ammonia.

What is known Substantial research has been conducted on ammonia volatilization resulting from application of synthetic fertilizer and animal manure. In general, factors such as soil pH, soil moisture content, air temperature, and method of application affect the quantity of ammonia lost to the atmosphere. Method of application probably is the most critical factor. Injection or immediate incorporation of the fertilizer into the soil greatly reduces ammonia volatilization compared to surface applications. Most of the studies, however, were conducted in the laboratory or with static chambers in the field and may not accurately measure net ammonia under field conditions or accurately emulate true field conditions.

Gaps We have limited ability to recommend whole-farm management systems that economically reduce ammonia emissions. Changes in one component, e.g., feed quality, may greatly affect ammonia volatilization rates from waste storage facilities or land application. Thus, whole-farm ammonia absorption and desorption, including domestic animals and cropping systems, need to be considered. Specific gaps include

- Net changes in ammonia emissions from crops after animal waste applications, including the effect of crop management practices, the ability of the crop to utilize both atmospheric ammonia and applied nutrients, and the type and quality of waste applied;
- The role of riparian and buffer zones in amelioration of ammonia and ammonium aerosol transport before leaving the farm site;
- Methods to maximize the fertilizer value of nitrogen stored in animal waste products; and
- Nutritional management strategies to reduce volatile nitrogen emissions.

Goals

- Develop productive management practices that maximize nitrogen use efficiency through a tighter coupling between animal and crop production;
- Reduce nitrogen imports onto the farm through improved feeds;
- Develop techniques to convert nitrogen compounds in waste to nitrogen gas or conserve the nitrogen in the waste as a valuable source of nitrogen for crop production;

Approach A multidisciplinary research effort is needed to develop whole farm management plans that reduce ammonia emissions from farms. Researchers should include soil scientists, animal nutritionists, engineers, and modelers. A basic understanding of the processes involved in nitrogen transport and ammonia emissions will be needed to develop models for whole-farm nitrogen management.

Outcomes The anticipated outcomes from this component of the national program include:

- Management systems that improve animal and farm-level nitrogen utilization and contain atmospheric ammonia within farm boundaries.
- Models that allow producers to predict potential ammonia losses resulting from changes in any component within their production system.
- Develop management strategies to prevent ammonia release at all areas of the farming system.

Impact These results will increase efficiency in nitrogen utilization and decrease ammonia emissions.

Research Area- Measurement of Atmospheric Ammonia Exchanges under Field Conditions

Rationale There are major uncertainties regarding the exchange of atmospheric ammonia with ecosystems because quantitative emission and deposition fluctuations are poorly defined. Emission inventories are commonly prescribed as the emissions per animal, allowing no flexibility for more complex classifications or combinations of different systems, management practices, animal sizes, types, classifications, stages of growth and production, level of production, level of technology adaptation, and waste treatment. As concentrated animal feeding operations continue to increase, better emissions inventories are needed to evaluate effects of emissions on local and regional soils, groundwater, and atmospheric environments and to develop means to reduce emissions and conserve the nitrogen resource.

What is known Ammonia is the most abundant alkaline component in the atmosphere that neutralizes acid gases of sulfur and nitrogen oxides. Consequently, with large amounts of acid gases from fossil fuel combustion, ammonium is a major component of atmospheric aerosols. Ammonia and ammonium aerosols have different residence times in the atmosphere and may affect ecosystems in many different localities. When ammonia and ammonium are deposited on soils, the effect may have a destabilizing effect on existing plant communities. The decomposition of domestic livestock waste is the largest contributor of ammonia to the atmosphere.

Gaps Gaps in knowledge that preclude field, farm, and regional assessment of ammonia and ammonium aerosols include, but are not limited to the following:

- Ability to assess ammonia emissions from animal housing, waste storage and application systems, and crops;
- Exchange processes and how they are affected by management and climate variability;
- The effect of crop management and its ability to utilize both atmospheric emissions and application of stored nutrients;
- Limited knowledge of the rapidity of ammonia conversion to ammonium aerosols and their transport from the farm site;
- Whole-farm ammonia absorption and desorption, including domestic animals and cropping systems;
- The relationship of ammonia emissions to nitrogen oxides and sulfur oxides to form particulates that may travel relatively large distances; and
- A lack of understanding of the effects of reduced atmospheric ammonia on natural ecosystems, given the large amounts of acid gases produced by automobiles and industry.

Goals To preserve environmental quality while enhancing crop and animal productivity, specific goals of this research are to

- Provide information and technologies to improve national ammonia and ammonium inventories;
- Quantify the role of buffer and riparian zones on atmospheric ammonia exchange; and
- Quantify the deposition and localized impact of increased ammonia concentrations from nearby concentrated animal feeding operations.
- Quantify ammonia emissions from animal housing, waste management and storage, and waste application techniques, and develop abatement and conservation technologies;

Approach Multidisciplinary research is needed to assess impacts of management on nitrogen budgets (input vs. output) at the concentrated operation, field, farm, regional, and national scales. These efforts will require input from agronomic, engineering, natural and physical, and atmospheric scientists who utilize a variety of methods to measure, assess, and mitigate ammonia gas exchange relationships. These methods, which include different measurement techniques as well as synthetic and analytical methods such as modeling, will need to be evaluated at the appropriate temporal and spatial scales.

Outcomes The anticipated outcomes from this component of the national program include:

- Improved measurement techniques will be developed to obtain ammonia concentrations and fluctuations.
- Fundamental understanding of atmospheric ammonia and ammonium aerosols and interactions with the environment will be improved.
- Seasonal and annual ammonia emissions from farming practices will be more predictable.
- National inventories of ammonia emissions will be improved.

Impact

- Increase ability to measure and interpret atmospheric ammonia levels, and a better understanding of the processes that determine that level.

Malodorous Compounds

Although not regulated, offensive odors from animal production operations are a major nuisance and may have negative health impacts. Odorous compounds commonly associated with livestock facilities include ammonia, volatile organic compounds including amines and fatty acids, and sulfur-containing compounds. Basic and applied research will be done to identify odor-producing agents and to understand the biological and chemical processes that control them. It is the intention of this component to develop mitigating measures for application at the emitting source. The objectives of the Manure and Byproduct Utilization National Program are to (1) address the measurement of compounds associated with animal production and manure storage; (2) elucidate the mechanisms responsible for the formation of these gases; (3) determine the rates of emission; (4) evaluate the role of environmental conditions on emission generation and transport; (5) define impacts of emissions; and (6) develop cost-effective methods to control emissions.

Vision Livestock production systems with no atmospheric impact

Mission Develop practices and technologies for animal production systems that minimize gaseous and particulate emissions and human health impacts and provide information for science-based policy and regulation decisions

Research Area- Emission Rates of Manure-Related Systems

Rationale Emission of gases and particulates from all phases of livestock production and manure handling, storage, processing, and application is poorly understood; and perception of emission rates varies among the public. A range of compounds is released from production systems, and these compounds vary among production facilities and across time. Thus, it has been difficult for producers or the public to compare production systems or evaluate the efficacy of control techniques.

What is known Current information on emission rates shows a large variation across time and among types of manure storage and handling systems.

Gaps Studies on emission rates from different livestock systems are limited, and there is no comprehensive database across a range of systems. Knowing rates of emission is necessary to understand how management practices or alternative manure-handling processes could reduce impacts of these emissions on the environment and neighbors. Major gaps that need to be addressed are

- Emission rates of volatile organic compounds, ammonia, methane, nitrous oxide, and hydrogen sulfide from different building, manure-handling, and storage systems;
- Emission rates of particulates passing through the air above manure storage systems; and
- Comparison of emission rates from different livestock systems and management practices, e.g., animal stocking rates, age, diet, siting, or general hygiene of the buildings.
- The role of riparian and buffer zones in amelioration of ammonia and ammonium aerosol transport before leaving the farm site

Goals Specific goals of this research are to

- Quantify emission rates from livestock production buildings for ammonia, methane, nitrous oxide, hydrogen sulfide, volatile organic compounds, and particulates;
- Identify the composition of particulates and interactions of gaseous compounds with particulates;
- Quantify emission rates related to environmental and management factors to develop a tool to predict emission rates from a range of livestock production and manure-handling systems

Approach Quantifying emission rates will require a novel experimental approach to measure spatial and temporal changes in different gases across different systems. Data will be needed that represent the range of animal age within a facility along with variations in management systems.

Outcomes The anticipated outcomes from this component of the national program include:

- Differences among systems will be defined, and variations in emission rates will be quantified.
- Scientific evidence of linkages between management practices and facility design and operation will be available to producers.

Impact An economically and environmentally sustainable role for modern livestock production systems.

Research Area- Transport Processes of Odors and Particulates

Rationale Variations among environmental conditions have not been addressed in either gaseous or particulate emission and transport from livestock production facilities. Understanding transport processes of particulate and gas emission is necessary for evaluating management practices that reduce emissions. Understanding the microbial ecology and the dynamics of emissions for different populations will be critical to the success of this effort.

What is known Manure storage systems interact with the atmosphere differently depending upon the surrounding land surface and design of the manure storage system. Observations on ammonia reveal that ammonia as a gas is transported only short distances while ammonia attached to water droplets can be transported large distances. Particulates released by livestock production units vary greatly with production practices and management and affect release of odors from facilities. However, this information has not been assembled into a comprehensive understanding of the transport of gases and particulates from livestock production, manure storage and handling, and manure application areas.

Gaps Eliminating specific gaps are crucial to improving our understanding of the transport processes associated with livestock production and manure systems:

- Transport of gases and particulates from livestock facilities and manure storage will require understanding the turbulence induced by an uneven landscape around livestock facilities.
- Air movement patterns and the ability of the air to transport gases and particulates for long distances require atmospheric models that are beyond the present simple dispersion models.
- New approaches are needed to quantify atmospheric transport and dispersion over nonuniform landscapes.

Goals

- Develop transport models that can quantify movement patterns and transport capacity of air moving away from livestock and manure facilities;
- Determine the environmental impacts on transport and dispersion of gases and particulates from livestock production, manure-handling, and manure application sites;
- Evaluate the efficacy of dispersion models for a range of livestock production and manure handling and storage facilities and manure application sites; and

Approach Addressing this problem will require the development of experimental and theoretical approaches to quantifying emission rates and then coupling these emissions with transport factors. Existing atmospheric models potentially could be used; however, these need to be applied to the topographic setting and arrangement of livestock production, manure handling, and manure application sites. Dispersion models capable of incorporating digital terrain models along with meteorological data and site characteristics have been evaluated. These applications need to be extended to a larger range of livestock production sites and across species.

Outcomes The anticipated outcomes from this component of the national program include:

- Siting and management of livestock production facilities with an emphasis on atmospheric transport processes will significantly improve air quality; these models will provide an assessment for local and long-range transport.
- The immediate benefit would be enabling producers to make management changes in facilities that would increase neighbor acceptance.

Impact Realistic atmospheric transport models for livestock production systems.

USDA-ARS NATIONAL PROGRAMS-MANURE UTILIZATION (Jawson, 2001)

Atmospheric Emissions Three types of emissions (gases, particulates, and aerosols) affect air quality changes around animal operations, manure storage areas, and manure field application sites. Gases of particular interest include ammonia, odorous compounds, and greenhouse gases such as methane, carbon dioxide, and nitrous oxides. Ammonia emissions appear to have the greatest potential for adverse environmental and health impacts, while generation and transport of malodorous compounds provoke the greatest public concern. To develop cost-effective methods of emissions reduction and control, improved methods to measure and quantify emissions will be required. A greater understanding also will be needed of the mechanisms responsible for emissions, emission rates resulting from a variety of animal management practices, and methods to predict dispersion and transport of emissions across the landscape.

Vision Reducing problem emissions from animal production systems

Mission Develop cost-effective management practices to reduce emissions based on understanding and quantifying the emission and dispersion of gases and particulates from animal production systems.

Research Area- Methods to Measure and Quantify

Develop methods to measure and quantify emissions from livestock facilities based on physical and chemical properties, including size and composition of particulates and aerosols.

Rationale Emission of gases from livestock facilities, manure storage, or manure application has been difficult to quantify. Recent attempts to quantify emissions have demonstrated that development of accurate and consistent methods is necessary to provide consistency among experiments and locations.

What is Known We know that there are a large number of gases emitted from farms and that a variety of measurement techniques are necessary to quantify the various emissions. However, the detection limits of many instruments are not capable of detecting the low concentrations often encountered in natural environments. These compounds are normally emitted at very low concentrations and require both concentrating techniques in order to capture a sufficient sample and varied measurement techniques to quantify specific gases. Ammonia and particulates are critical components to be measured and yet information on the forms of ammonia and the size range of particulates is lacking.

Gaps Research is needed to develop and evaluate methods that provide a consistent assessment of the emission rates from livestock operations. To accomplish this will require development of new techniques and refinement of existing methods for measuring air quality. There are no quantitative measures of the particulate formation and emission from livestock facilities. One of the major problems is that current models of emissions use point measurements to infer mass release. Variability of point measurements, particularly in relation to sampling methods, must be quantified if these models are to have any value.

Goals

- Develop certified methods to accurately measure emissions, e.g., ammonia, particulates, odors, volatile organic compounds, and other greenhouse gases (CO_2, CH_4, N_2O, and NO_x), related to livestock facilities.

Approach

- Evaluate methods for detection of gases that would be responsive to concentration ranges of gases that would be encountered in typical livestock production systems and natural environments. Develop and evaluate methods for sample collection and off-site analysis.

Outcomes The development of methods for measuring the types of compounds and sizes of particulates emitted during different phases of livestock management, manure generation, and storage will begin to create a database upon which future decisions can be made.

Impact We will have a greater ability to understand and identify emissions problems.

Research Area- Mechanisms and Processes

Elucidate mechanisms responsible for emissions, and identify the underlying substrates and processes. Examination of the role of microorganisms is central to this area of research.

Rationale Generation of gases is primarily the outcome of various microbial processes either in the gut of the animal or in the manure storage and handling process. Understanding these processes will help develop a basis for recommending specific management practices and facilities design. Without understanding the basic formation processes for different emissions, it will be difficult to develop management strategies that can be implemented on farms.

What is Known Microbial activity is the primary mechanism for the generation of gases. Current research has identified that anaerobic processes generate a wide range of compounds and are responsible for the release of large masses of nitrogen and methane to the atmosphere.

Gaps An understanding of the microbial mechanisms controlling gas emissions within all phases of manure generation, handling and application.

Goals

- Understand ecology of aerobic and anaerobic microorganisms that are associated with emissions.
- Identify mechanisms to change the ecology or metabolism of organisms to reduce undesirable emissions.

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Approach Examine the ecology of microorganisms in animal production environments. Conduct in-depth biochemical, metabolic, ecological analyses of microorganisms identified in animal production systems. Develop and evaluate modifications of current practices that will alter microbially mediated emissions.

Outcomes Understanding the microbial role in gaseous emissions from animals and manure would provide a major impetus for the development of effective solutions. There are many proposed solutions, however, most have no rational basis or link to any biological, chemical, or physical mechanism. These results will begin to define the biological activity of a livestock system with a target of understanding the mechanisms controlling gas emissions.

Impact A well founded scientific rational for different proposed solutions.

Research Area- Rates of Emissions

Determine rates of emissions in relation to manure production, handling, storage, processing, and application.

Rationale There is little information on the emission rates of gases from different farm environments. Likewise, hydrogen sulfide emission rates vary with type of manure system and management activities, e.g., manure handling and application. Knowing the rates of emission is necessary to understand how management practices or alternative manure handling processes could reduce the impact of these emissions on the environment and neighbors.

What is Known Information related to the broad spectrum of existing manure storage practices and facilities is lacking. The information base upon which we can make decisions about new methods is very limited. Current use of uncovered manure storage systems is coming under greater scrutiny for their environmental impact due to release of ammonia into the atmosphere.

Gaps The major gaps are knowledge of the emission rates of ammonia, methane, and hydrogen sulfide from different manure handling and storage systems. The emission rates of different gases and the movement of particulates over manure handling and storage systems needs to be quantified for a range of systems and environments.

Goals

- Quantify the emission rates in relation to handling, storage, processing, and application practices commonly used in U.S. livestock production systems.
- Correlate emissions with management practices to allow identification of best management practices for adoption by producers.

Approach Collect accurate information from a range of livestock production and manure systems in the U.S. Use the available data to identify and evaluate best management practices.

Outcomes Results from these studies would begin to define the differences among systems and the variation in emission rates. This knowledge base is critical for the assessment of manure processing systems and to understand the linkages among management practices and facility design and operation.

Research Area- Generation and Transport

Investigate the effect of environmental conditions on generation and transport of emissions.

Rationale The effects of environmental conditions have not been addressed for either gaseous or particulate emissions. Understanding transport processes of particulate and gas emission is necessary for evaluating management practices that reduce emissions. Understanding interactions with microbial ecology and the dynamics of emissions for different populations will be critical to the success of this effort.

What is Known We know through qualitative observation that air quality around livestock facilities and manure storage changes from day-to-day and throughout the year. We also have observed that manure storage systems interact with the atmosphere differently depending upon the surrounding land surface and design of the manure storage system. There are complicated exchange processes between manure storage facilities and the atmosphere that have not been fully quantified.

Gaps Transport of gases and particulates from livestock facilities and manure storage areas will require understanding the turbulence induced by the uneven landscape. This effort will require some new approaches to be able to quantify atmospheric transport and dispersion over non-uniform landscapes. Models will be critical for site characteristics to be evaluated and compared. The information generated from Problem Area 2 will need to be combined with transport processes to fully quantify environmental impacts.

Goals

- Determine the environmental impacts on transport and dispersion of gases and particulates from livestock production and manure application sites.
- Quantify the interactions of environment on generation, transport and dispersion processes.
- Quantify the interactions of emissions; gases, particulates, and aerosols, as factors influencing atmospheric transport and dispersion.

Approach

- Quantify relationships among environmental variables, e.g., temperature, atmospheric water vapor content, wind speed, and solar radiation, and emissions. Quantify relationships among environmental variables and transport and dispersion processes.

Outcomes Siting and management of livestock production facilities with an emphasis on atmospheric transport processes will have a major impact on the improvement of air quality. The immediate benefit would be for producers to make management changes in facilities that would increase neighbor acceptance.

Impact Less intrusive and less polluting agriculture.

Research Area- Reduce Emissions

Develop and evaluate cost-effective methods to reduce problem emissions.

Rationale Improvement of air quality can result from changing the emission rate from livestock facilities or manure or through implementation of management practices that increase the dispersion rate of gases and particulates into the atmosphere.

What is Known There are numerous potential solutions to altering the emission rates. There are methods for manure handling, e.g., liquid- solid separation, that could have a large impact on ammonia release and volatile organic compound formation and release. Chemical amendments, such as aluminum sulfate and urease inhibitors, have been shown to reduce ammonia emissions from animal manures.

Gaps Without an understanding of the composition or rate of emission of gases or particulates it is difficult to develop a framework to compare or evaluate methods of reducing emissions. Without this first step it will be impossible to quantify the effect of treatment systems across a wide range of facilities.

Goals

- Determine whether application of current best management practices can reduce emissions to acceptable on-site and off-site levels.
- Develop alternative management practices that can reduce emissions and achieve most efficient use of nutrients by animals.

- Determine the efficacy of various technologies and practices at a local, regional, and national scale.

Approach Evaluate the impact of the implementation of current management practices on emissions. Develop, apply, and evaluate new and modified practices.

Outcomes Producers and the public are looking for potential solutions to reducing the emission of gases and particulates from livestock operations. This research will provide a strong foundation for decision-making and also sufficient information for economic assessments of different alternatives.

Impact Significantly improved manure handling on farms nationwide, and a reduction in the emission of noxious gases.

SPECIFIC RESEARCH PROJECTS

A number of research projects are underway that directly address the emissions of concern to the South Coast AQMD. These projects are summarized below.

Surface Interactions Influencing The Management of Agrochemical Loss to Air and Watersheds (Hapeman, 2001)

Research Location
Animal and Natural Resources Institute
10300 Baltimore Blvd. .
Bldg. 200, Rm. 217, Barc-East
Beltsville MD 20705

Research Objective Develop theory and experimental approaches for determination of atmospheric transport, deposition fluxes and transformation of agri-chemicals in support of sustainable agriculture with a focus on the Chesapeake Bay. Discern chemical and environmental factors that impact agrochemical partitioning to better define components in fate and transport models. Measure volatilization over a range of soils, climate conditions and agronomic practices. Determine best management strategy to minimize pesticide loss

Research Approach Quantitative processes (volatilization, sorption, chemical transformation) impacting atmospheric fate and transport of volatile and high use pesticides. Experimentally determine partition coefficients (including Henry's Law constants) at vapor/liquid/solid interfaces relative to critical environmental variables (e.g., temperature, salinity, pH, organic carbon). Investigate environmental factors influencing agrochemical transformation and sorption, discern mechanisms of agrochemical transformations, and determine rates and significance of processes. Assess relative contributions of atmospheric input pathways and runoff to sensitive non-target ecosystems such as the Chesapeake Bay watershed. Determine agrochemical losses from sustainable versus high input agricultural systems. Model regional and long-range atmospheric transport of agrochemicals using data collected.

Atmospheric Impacts Of Agricultural Management Practices (Hatfield, 2001)

Research Location
National Soil Tilth Laboratory
2150 Pammel Drive
Ames IA 50011

Research Objective 1) Develop a fundamental knowledge of the identity and flux rates of particulates, trace gases, pesticides, and volatile organic compounds from soil and manure systems; 2) Develop a fundamental understanding of the air movement patterns across complex agricultural landscapes; 3) Evaluate the potential impact on air quality of changes in soil structure and soil management practices associated with agricultural production.

Research Approach Atmospheric fluxes are combined with soil flux measurements of CO2 over a number of studies to relate soil management with atmospheric exchanges. Many of the studies are conducted using measurements collected throughout the year to quantify the variation in emission rates throughout the year. Many of these objectives require that we develop new methods for quantifying atmospheric constituents and improve upon the current understanding of measurement techniques. The primary focus for the first stages of this project will be the measurement of CO2, ammonia and nitrous oxide, and energy balance from soils and agricultural crops on a continuous basis coupled with efforts on atmospheric transport of gases across complex terrain. Development of measurement techniques for particulates and collection of gases that are emitted from agricultural operations including manure application are necessary first steps in the fulfillment of the project goal.

<u>Integrated Management Regimens That Minimize the Environmental Impact of Livestock Manure</u> (Cole 2001)

Research Location
USDA Conservation and Production Research Laboratory
P. O. Drawer 10
Bushland TX 79012

Research Objective Develop management practices to reduce losses of phosphorus to the environment including modification of animal diets and development of cropping systems for effective use of phosphorus; develop manure application strategies to ensure that manure is applied at sustainable rates; and develop nutritional strategies and land application protocols, that decrease atmospheric emissions of ammonia, odor, and particulates. Determine the survival and transport of pathogens from livestock manures.

Research Approach An integrated approach to solve the objectives is used by considering issues from the diets fed to the soil, water and plants after land applications of manure. Atmospheric emissions and pathogen survivability will be determined in each phase of the manure cycle. Studies will be conducted at cooperating commercial feeding operations, in our research feedlot, in laboratory-scale systems, and during storage, treatment and application of manure to land. The effect of different diets and feeding regimes on ruminant nutrient excretion and emissions of ammonia, odors, and(or) particulates will be measured in digestion and feeding trials. The effects of nitrogen-based and phosphorus-based manure and compost applications rates, and the effects of long-term application of manure on agronomic and soil properties will be measured for both cropland and range land. The effects of manure treatment and handling on population of viable pathogens/toxins will be determined.

Development of Sustainable Dairy Manure Management Practices to Enhance Farm Profitability (Byers, 2001)

Research Location
Animal and Natural Resources Institute
10300 Baltimore Blvd. .
Bldg. 200, Rm. 217, Barc-East
Beltsville MD 20705

Research Objective Develop management practices and decision aids for handling dairy manure. Specific objectives: manipulate diets of dairy cows to increase nutrient recovery in milk; develop improved methods for estimation of manure nitrogen, mineralization, and ammonia volatilization for nutrient management in the field; composting for dairy manure management; development of management practices to reduce nutrient flow from dairy farms to surface and ground water.

*Research **Approach*** Researchers and partners will identify deficiencies of current decision support systems for dairy farm nutrient management and manure handling. Then research will be conducted so that results are used to develop modules on diet manipulation for the cow, field applications of manure, composting, and water quality to control nutrient flow off the farm. Lactating cows will be fed different diets that decrease nitrogen excretion and improve milk protein recovery. Rapid tests for on-farm determination of manure N and mineralization rates of different manures will be evaluated and used to improve predictive equations. Ammonia volatilization studies will be used to estimate ammonia loss from field applications of dairy manure. A composting database of key process parameters will be developed and a compost system model will be developed. A wetland system adjacent to the dairy will be evaluated. Several chemical parameters will be analyzed in monthly samples of water, as well as survival of different species of vegetation, growth and nutrient accumulation in vegetation in the wetlands.

Manure Treatments and Uses to Protect Soil-Water Air Quality, Food Safety, and Improve Manure Value (Sikora; 2001)

Research Location
Animal and Natural Resources Institute
10300 Baltimore Blvd. .
Bldg. 200, Rm. 217, Barc-East
Beltsville MD 20705

Research Objective Develop methods, technologies, and guidelines to improve the handling and treatment of animal manures, thereby reducing their deleterious impact on air and water quality and improving their benefit in soils and crops. Quantify odor emissions and bioaerosols to evaluate management practice effects on air quality. Evaluate the presence and movement of pathogenic microorganisms as related to manure management practice. Develop and test methods to improve and certify manure value.

Research ***Approach*** Collaborative laboratory, growth chamber, and field studies will evaluate nutrient stabilization, conservation and conversion, pathogen and vector attraction and reduction, and their association with odor and bioaerosol control when manures are treated/handled by composting, alkaline stabilization, algal scrubbing, or simple mixing with other by-products. By-products tested include those that reduce solubility of nutrients such as phosphorus, adjust pH to reduce emissions or pathogen numbers, or improve the value of the final manure product. Candidates include water treatment sludges, coal combustion residuals, and industrial metal by-products. Accurate assessment of pathogen number, fate, and survival in environmental samples will be attempted using new molecular, immunological and cultural techniques. Final manure products will be evaluated for agronomic and horticultural value, benefit to environment, and safety for use in food chain crops.

<u>Conservation of Manure Nutrients & Odor Reduction In Swine and Cattle Confinement Facilities</u> (Varel, 2001)

Research Location
Roman L. Hruska U.S. Meat Animal Research Center
P. O. Box 166
Clay Center NE 68933

Research Objective Reduce nutrient loss and odor emissions from manure produced in swine and cattle confinement facilities by: Developing methods to inhibit microbial activities that produce offensive gaseous and volatile organic compounds, Developing microbially enriched biofilters and biocovers to efficiently metabolize offensive odors to non-odorous compounds.

Research ***Approach*** A variety of environmentally amiable compounds including bacteriostatic, bacteriocidal, and other microbial inhibitors will be evaluated for their ability to control odor production, limit greenhouse gas emissions, and reduce nutrient loss from livestock manures. Microbial enrichments from agricultural soils will be selected for high efficiency odor consumption and characterized using culture-based and molecular techniques. The most efficient bacteria will be seeded into air biofilters, waste biocovers, and feedlot soils for maximum removal of odor compounds.

<u>Comprehensive Manure Management For Improved Nutrient Utilization and Environmental Quality</u> (Eghball, 2001)

Research Location
344 Keim Hall, E.C.
University of Nebraska
Lincoln NE 68583

Research Objective Develop site-specific manure management strategies and tools for manure application to spatially variable land. Evaluate the environmental impacts of manure application on water and air quality with emphasis on P and N losses through runoff and leaching and greenhouse gas emissions. Develop a nutrient management strategy for low phytate corn that reduces environmental impacts resulting from manure application to land.

Research ***Approach*** Experiments will be conducted on farmer fields with variable soil characteristics under center pivot irrigation in central Nebraska. Aerial photography and electro-magnetic induction

(EMI) will be used to characterize soil variability. Soil spatial variability will be used to calculate manure application rates. Changes in soil N and P will be assessed after repeated manure applications and runoff losses of N and P and emissions of greenhouse gases will be measured from soils receiving manure. Crop utilization of N and P and losses of N and P in runoff from soil receiving manure from swine fed either low phytate or traditional corn diets will be determined and nutrient management guidelines for use with low phytate corn will be developed.

Comprehensive Systems for Managing Nutrient Flows And Gaseous Emissions in Relation to Dairy Manure (Meisinger; 2001)

Research Location
Animal and Natural Resources Institute
10300 Baltimore Blvd. .
Bldg. 200, Rm. 217, Barc-East
Beltsville MD 20705

Research Objective Redirect whole-animal carbon & nitrogen to reduce carbon and nitrogen emissions/unit animal product and enhance environmental sensitivity. Develop efficient strategies for management of nutrient flows and gaseous emissions by identifying major loss pathways. Develop manure treatment, handling, and use practices that reduce release of nutrients, ammonia, odors, bio-aerosols and dust particles to air & water. Develop rapid methods of analysis for both inorganic and organic nitrogen in manures.

*Research **Approach*** We will employ five methodologies for addressing nutrient capture, nutrient flows from animals and emissions reductions in confined vs. grazing cattle systems, both of which are extensively utilized in dairy and beef production systems in the US. The combination or elimination of individual methodologies will be considered throughout the conduct of the research to eliminate redundancies and increase efficiency and economy where possible. All procedures with animals will be subject to review and approval of the Beltsville Area Research Animal Care Committee and the Livestock and Poultry Sciences Animal Care and Use Committee.

Conclusions

The answers being sought by these USDA initiative are crucially important to any attempt to reduce area ammonia emissions. Because of the wide variety and depth of the research being conducted, by the conclusion of the study it is expected that the USDA will have developed some very applicable and implementable technologies and recommendations.

However, it is unlikely that this research will be completed before AQMD’s proposed rule goes in to effect. Several crucial studies are not expected to be completed until before 2005, in particular the results of the “Atmospheric Impacts of Agricultural Management Practices” and “Comprehensive Systems for Managing Nutrient Flows And Gaseous Emissions” studies will be essential to fully understanding the ammonia problem.

We recommend that SCAQMD support these studies to both help speed the research process and ensure the agency is the first to hear of any research results and recommendations.

Other Area Farming Practices

Our literature research discovered only one additional relevant project area of study underway outside the scope of coverage of the ARS National Programs. This research is underway in Sweden as reported below. The objective of the project is to demonstrate an efficient and innovative combination of methods to reduce ammonia leakage on the dairy farm and to increase knowledge in this field among authorities, farmers, extension workers and agricultural students in Sweden and Europe.

The Swedish research farm Brogården has extensive data on ammonia emissions (Bergstrom; 2001). The milk barn was built as a stanchion barn for tied up cows, specially designed for the experiments and tests carried out there. The farm consists of about 95 hectares (ha) of farmland, of which five ha is natural pasture and 68 ha is forest. The herd consists of 42 Swedish Red and Black (SRB) cows with an average milk production of about 10,000 liters ECM per cow per year.

Brogården uses IndividRAM, a feed calculation program operated by the Swedish Dairy Association. Feeding is based on forage and cereals produced on the farm and bought-in concentrate as outlined below:

- Silage (clover-grass)- 6-7 kg DM
- Ground wheat- 1-2 kg
- Ground oat- 3-7 kg (depending on lactation stage)
- Concentrate UNIK- 3-8 kg (depending of lactation stage)
- Minerals

Grass-clover silage is stored in one tower. In individual feed-bunks, the cows are fed approx. 70-80 metric tons of home-produced oats and 50-55 tons of a commercial concentrate each year, together with grass-clover silage and hay. Hay is distributed manually, while semi-automatic feed trucks distribute all other feeds.

Waste Management Practices & Technologies

To fully explore the available ammonia treatment options, the researchers constantly measure Brogården's ammonia release while handling the manure by a variety of different methods. Their measurements are intended to inform future decisions as to which waste management practices are the most effective at preventing ammonia release.

Ammonia Measuring Technologies (Bergstrom; 2001)

The project team is using three techniques to gather ammonia data as described below.

Infrared Analyzer- Used to measure emissions from the cow barn.

A small pump draws a sample of the air to be analyzed through a chamber between the infrared source and the detector. A zero gas filter containing activated charcoal was used every week to set the zero level. The measuring range was 0-50 parts per million (p.p.m.) and the accuracy of the instrument was ± 5% at the full-scale deflection. The ventilation rate through the cowshed was continuously measured with an impeller in the exhaust duct. The impeller was calibrated before and after the measuring period using a hot wire anemometer to measure the average air velocity through the cross section area of the exhaust duct. A data logger recorded the ammonia concentration, the air velocity as well as the carbon dioxide concentration, the outside and inside air temperature and air humidity.

Stirred Dynamic Chamber Method- Used to measure the emissions from fields recently applied with manure.

Ammonia emissions after spreading in the field were measured according to the stirred dynamic chamber method with passive diffusion samplers (PDS). After spreading of manure, a set of ventilated chambers was put in place on the manured ground surface where the ammonia equilibrium concentration was measured. Simultaneous measurements were also made of the ammonia concentration in the air outside the chambers, and the transfer velocity for ammonia from the soil surface to the air above it. Both of these parameters were measured using PDS close to the ground surface. Each ambient condition meter consisted of a bracket with space for four PDS.

Passive Flux Samplers- This method was used to measure the ammonia emissions from manure storage areas.

The micrometeorological method with passive flux samplers was used to measure ammonia emissions from both the solid manure storage pad and the urine storage tank. The passive flux sampler consists of two glass tubes, each with a length of 100 millimeters (mm). The glass tubes are connected in series and each tube is coated with oxalic acid on the inner surface. To achieve a low friction resistance and a high NH_3 collection efficiency, one end of each sampler is fitted with a thin stainless steel disc having a 1-mm hole in the center to decrease wind speed inside the sampler. The passive flux samplers were mounted at four heights (0.45, 1.35, 2.60 and 5.00 m above the storage wall) on four vertical masts attached with equidistant spacing along the periphery of the urine storage tank.

Treatment Alternatives

The farm is experimenting with different barn design, storage facilities and land application techniques. Additionally, they are feeding the cows special diets designed to lower nitrogen excretion without decreasing milk production. Some of the technologies listed below are being implemented at the Brogården farm.

<u>The Dairy Barn</u>

- The use of peat and straw as litter for the manure acts to lower pH and thus decrease ammonia release. Ammonia release is also beneficially affected by the higher carbon/nitrogen ratio. (Sikora; 2001)
- In forced air ventilation buildings, air leakage through manure channels into livestock buildings is common. This air movement dramatically increases the rate of ammonia release. It is essential that all manure channels be well sealed, or, if feasible, make the dung channel relatively deep. Furthermore, air inlets should be designed to minimize velocities over any channel openings. (Bergstrom; 2001)
- Ammonia release is increased as the size of the surface covered by feces and urine increases. Buildings can be planned to minimize these dirty surfaces, e.g. tie-stall systems, or the adjustable neck tie system. Cleaner stalls and a lower ammonia concentration in the air have a positive influence on animal health, well being and production. Both udder and foot health are linked to the stall hygiene. (Bergstrom; 2001)

- The type of cleaning regimen can reduce ammonia release. In one experiment, a barn with a solid floor and a 3% slope to the center was scraped and cleaned 12 times/day using 1.5 gallons/cow/day resulting in a 65% decrease in ammonia volatilization. (Bergstrom; 2001)
- It was proposed that a combination of methods would have an additive effect on the ammonia release. However, no experimental work has been completed based on this comprehensive view of ammonia loss. (Jawson; 2001)

<u>Manure Handling</u>

- Research by Sommer reported in 1985 showed that ammonia release was twice as high when manure was stored as solid manure and urine as compared with storing of slurry (dry matter between 12-20%). Under the worst conditions, it was found that urine could quickly lose 50% of its nitrogen content as off-gassed ammonia. Solid manure loses up to 40% of its nitrogen while semisolid manure only loses about 20% of its nitrogen, and one study recorded as low as 3%. (Bergstrom; 2001)
- Ammonia release can be further impeded by the formation of a surface crust on cattle slurry. Some experiments have shown this method to decrease ammonia release 80% as when compared with slurry left standing. Crusts can be stimulated artificially by adding chopped straw or Leca (clay) pebbles. (Bicudo; 2001)
- Depending upon the type of cover or crust formation a 50-95% reduction in ammonia release can be expected. (Bergstrom; 2001)
- Studies were also done to immobilize the ammonia by composting manure with municipal refuse compost. Municipal refuse compost made from city trash has a high carbon content that was ideal for immobilizing nitrogen. Using a laboratory composter, mixing municipal refuse compost with dairy manure reduced the ammonia loss to one tenth that from the composting of dairy manure alone. (Sikora; 1997)

<u>Manure Spreading</u>

- Directly injecting, or incorporating the slurry into the soil soon after spreading better protects the ammonia from volatilization than when it is just spread on the surface. In the soil, the nitrogen binds to the soil. In addition, crops growing over the injected area will protect the ammonia from blowing winds, which is especially important in dry warm areas like California. (Mesinger; 2000)
- By using either of these two techniques, ammonia losses can be reduced as much as 80-95% over traditional spreading methods. The overall effect though depends on a number of other factors, such as weather, soil type, and time of year.

<u>Feed Adjustment</u>

- The possibility of decreasing the nitrogen content in the cattle's diet, thus a decrease in emitted ammonia, seems promising. However, in practice this is quite difficult to accomplish without hurting milk production. One study (Lefcourt; 2001) showed that small changes in dietary protein had little effect on the amount of ammonia emitted.
- Another study that is more comprehensive is underway in Sweden though which might present more data. In particular they are trying to tweak the ratio of digestible protein to indigestible protein. A proper ratio should make a lower ammonia count without a concurrent lower volume of produced milk.(Bergstrom; 2001)

Vendors, Manufacturers, and Contractors Control Technologies

The purpose of this task is to review control technologies that could be used for manure handling and disposal capable of reducing VOC and ammonia emissions at and/or from livestock operations. The work will research, gather, compile, review, and summarize all possible control technologies identified during Task 1 and Parts 1 and 2 of Task 2. Information from vendors, manufacturers, and suppliers of technology and systems relevant to this topic will be obtained and included in the report. Emission factor information for various practices and methods will be catalogued and updated as available.

PRODUCT ADDITIVES

As a result of the increased public, regulatory, and legal attention directed to the odor issue, many producers are considering the use of commercial manure and/or feed additives as an effort to minimize odor and other air emissions from livestock farms. In addition to odor control, many of these products are marketed as having other beneficial effects such as improved nutrient value of the manure, improved animal performance, fly control, etc. Product additives are generally described as compounds that can be added directly to freshly excreted or stored manure for purposes of odor abatement. They are generally made of enzymes, of a mixed/selected culture of microorganisms or are chemically based. Each product has a specific method of application, frequency, quantity, and length of time before the product is "most effective". Some products are pH and temperature dependent and only work within narrow ranges of pHs and temperatures. Although bacteria usually to certain extent are able to adapt themselves to the changes in the environment, large deviations from their optimum growth conditions undoubtedly will interfere with the normal metabolic activities, thereby resulting in a slow growth. This was already evidenced by an evaluation on a commercial product containing enzymes and selected bacteria, which showed that the product did not accelerate the degradation of the malodorous substances even at $15^{o}C$ (Bourque et al, 1987).

The idea of using manure additives to control odors and other emissions was proposed about twenty years ago and a considerable amount of research effort has been spent in this field. Past researchers rarely found any of the pit additive products to be effective in reducing odor levels of swine manure. This is probably due to the complexity of odorous components in animal manure. However, Zhu (Zhu 1999) points out the fact that the key difficulty in the development of effective manure additive products rests with a lack of understanding of the biological activities occurring within the stored manure. The widely used trial-and-error methods to evaluate manure additive products not only are time consuming, but also provide little information on the biochemical mechanisms.

Commercial additives may control specific parameters such as ammonia and hydrogen sulfide from the array of odorants. Objective information regarding the actual impact of the products on odor, as perceived by smell, is becoming available through laboratory and field tests being carried out in different places. Zhu et al. (Zhu and others 1996), for example, tested the effects of five different commercial pit additives on the release of odor and volatile compounds from swine manure. Their results showed that all five products reduced the levels of odor threshold by different degrees ranging from 58 to 87% as compared to the control samples. Three of the five products showed reductions in volatile fatty acids and total volatile solids. Johnson (Johnson 1997) ran field tests with eight different pit additives. The tests were run comparing a barn treated with a manure additive product, against an untreated control barn on the same site with variables isolated. Results obtained showed statistically significant reduction in ammonia levels in the treated barns as compared to untreated control barns.

Odor threshold results were variable, and most products tested had only a slight effect on odor reduction.

Microbiological Additives

Microbiological additives, or digestive deodorants, generally contain mixed cultures of enzymes or microorganisms designed to enhance the degradation of solids and reduce the volatilization of ammonia and/or hydrogen sulfide. The microorganisms are meant to metabolize the organic compounds contained in the manure. Digestive deodorants may act to inhibit selected biological or digestive processes by changing the enzyme balance (ASAE 1994). Most digestive deodorants are applied directly into the manure collection area and/or the lagoon and must be added frequently to allow selected bacteria to predominate.

Although there exist bacterial genera or species that can decompose odorous compounds like VFAs to reduce odor emission, little success has been reported in using these microbes as manure additives to control odor generation in the field.

According to Grubbs (Grubbs 1979), the key in using bacterial cultures for deodorization of manure is to have the added bacteria become the predominant strain of bacteria in the manure. In order for the added bacteria to flourish, the real environment should not deviate tremendously from the optimum growth range for the bacteria. Past work was mainly focused on determining the bacterial functions in digesting odorous compounds under optimum conditions. This usually does not guarantee that bacteria growing well under optimum conditions will also grow well in the field. Bourque (Bourque et al 1987) showed in their study that none of the inoculated microorganisms became dominant in the non-sterilized swine manure samples. The indigenous flora (not necessarily those reducing odors) of the wastes always grew better than the inoculated microorganisms. In addition, the selected microorganisms may even use other organic compounds in preference to the malodorous substances when inoculated in some wastes, which impairs the values of the additives.

Miner (Miner 1995) reviewed several studies of digestive deodorants and concluded that “the variable success measured for the effectiveness of microbial and digestive agents to control odor may be due to the inability of these products to degrade many of the compounds which collectively make up odor from a swine operation.” And “supplemental microorganisms, as additives, may not readily adapt to the natural conditions in manure handling systems and are often susceptible to competition from the naturally occurring indigenous microbial populations.”

Chemically-Based Additives

This type of additive acts by chemically altering odorous compounds or enzymes. They may also kill the bacteria, which produce the volatile organic malodorous compounds. Chemical additives are made from chemical compounds that can promote oxidation or precipitation of undesirable odor compounds. Chemical compounds can also be added for pH control and also as electron acceptors. If properly applied, the operating cost of reactive chemicals may actually be less than for masking agents or counteractants.

When dosing chemicals into manure, side reactions will occur in addition to the desired reaction. In calculating dosing rates, a generous factor of safety must be allowed to account for these side reactions. Most of the chemical products are pH dependent and only work within a very narrow range. Pilot testing is recommended for all chemical-dosing systems. Chemical additives are usually classified in terms of their mode of action:

Oxidizing Agents: chlorine (as gas or sodium hypochlorite), potassium permanganate, and hydrogen peroxide will oxidize sulfides and inhibit sulfide production. Ozone has also been used as an oxidizing agent.

Precipitants: iron and zinc salts will react with sulfides to form insoluble compounds. Ferrous and ferric chloride have been used for that purpose.

pH Control: sodium hydroxide or lime can be added to manure to raise the pH, inhibiting sulfide production and preventing hydrogen sulfide off-gassing, but probably increasing ammonia production.

Electron Acceptors: electron acceptors are taken up preferentially to the sulfate ion, and thus prevent sulfide formation. Sodium nitrate can be used for this purpose.

Researchers in Iowa and Indiana are experimenting with products that are injected into the building air climate through high-pressure mister systems. The function of a periodic mist injection is to neutralize volatile odor compounds that accumulate in the building prior to being exhausted. Heber et al. (Heber and others 1997) reported on a 63-day field test in a 1000-head commercial naturally-ventilated swine finishing house. The chemical solution was sprayed into the top of the pit creating an aerial mist in the headspace and covering the entire surface of the manure slurry. Their results show a reduction of mean NH3 emissions from 5.9 to 1.8 g/pig-day as compared to an identical untreated house. The mean H^2S emission rate of 0.15 g/pig-day did not change with the treatment. No current conclusive results on odor emissions have been published on this type of system.

Miner (Miner 1995) pointed it out that long-term use of chemical additives may require large amounts and frequent applications, making their continual use expensive and potentially damaging to the environment (soil, surface water and groundwater). However, chemical additives may be effective at controlling odor and gas emission during agitation and pumping of manure storage facilities. Researchers at the University of Minnesota (Clanton unpubl.) and at University of Kentucky (Turner unpubl.) are currently testing various chemicals that are capable of reacting with sulfides, thus minimizing hydrogen sulfide emission during agitation and pumping of manure." (Jacobson. L. D., et al, 1999)

Research of available additive vendor products was conducted and is reported as follows:

UltraTeck Inc.
www.ultrateck.net/detox.html

- Manufacturers of biological aid to the manure degradation process
- Both bacteria and nutrient additives are available
- Products for both liquid lagoons and solid manure
- We found no independent verification of the product's effectiveness

Eco-Chem
www.ecochem.com/manure_odor.html

- Producers of CPBA, an anti pollutant bio-stimulant
- CPBA is a concentrated solution of beneficial bacteria and bacteria
- Applied appropriately it abruptly eliminates odor, and reduces pathogens
- We found no independent verification of the product's effectiveness

ECOLO of Illinois
www.ecoloofillinois.com/aboutbio.html

- Manufactures BIOLOGIC™
- BIOLOGIC™ products do not contain bacteria or enzymes, but rather are designed to stimulate existing bacteria found in biological systems.
- Also manufacture ECOLOGIC™**,**
- ECOLOGIC™ controls airborne odors by degrading the gases once they are already airborne
- We found no independent verification of the product's effectiveness

Highwood Resources
www.highwood-resources.com/gypsum.html

- Manufactures an agricultural gypsum product
- Powdered Gypsum applied to manure piles accelerates decomposition without heating the piles and traps nitrogen
- We found no independent verification of the product's effectiveness

ManureX
www.manurex.com/

- ManureX MP adds microbes to anaerobic pits and lagoons.
- It speeds the digestion of manure, decreasing odor, liquefying sludge, reducing the nutrient count to create a better fertilizer.
- Works on all different types of manure
- We found no independent verification of the product's effectiveness

Super-F Inc.
www.super-f.com/pro_en1.html

- Manufactures a product named SFA-PLUS-Agriculture K123
- It is applied to outdoor lagoons and storage facilities
- Made from plant extracts, which react with odorous compounds
- We found no independent verification of the product's effectiveness

Manufacturer Technologies- *Lagoon Covers*

BEI Environmental Contracting
www.bei-ec.com/html/biocap.html

- Manufactures and installs its Bio-Cap system
- Bio-cap is a floating cover for an anaerobic lagoon
- Claims a 60-90% reduction in malodorous compounds

Lemna Technologies
www.lemnatechnologies.com/wwt.html

- Offer a diverse line of products and processes to clean and control agricultural waste problems
- Technologies include a lagoon cover system, and activated sludge system, and a gas collection system

Max-Mor Technologies
www.recycledfoam.com/

- Manufactures a simple foam cover for manure lagoons
- Cover is made of 100% recycled post industrial, cross-link, closed cell polyethylene foam sheet or panels.
- Can be welded, thermoformed, and laminated

Reef Industries
http://www.reefindustries.com/

- Manufactures plastic sheets for use in various industrial applications
- They have six different plastic products, each designed for specific applications
- Their Permalon floating cover is appropriate for covering manure lagoons

Summer Green Systems
http://www.summergreen.com/products.htm

- Manufactures a floating cover

Manure Management Contractor Technologies

Ag-Chem Equipment Co.
http://www.agchem.com/

- Manufactures heavy equipment for use in agriculture
- Has some products that are specific to manure transport and application
- They claim their manure handling technologies are environmentally friendly

Knight Manufacturing Products
www.knightmfg.com/products.htm

- Sells both manure spreaders and mixers
- Efficient and quick mixing and spreading of manure will significantly reduces manure emissions

McLanahan Agricultural Machinery Systems
http://www.mclanahan.com/agweb/

- Large producer of agricultural supplies
- Sells Sand/Manure separators, Lagoon Aerators, and system designs
- Machinery designed to minimize ammonia and odor emissions

Manure Storage & Treatment Manufacturers

Biothane corporation
www.biothane.com/anaerobic.html

- The provide a wide array of waste treatment technologies
- Their anaerobic line includes a stirred tank reactor, a sludge bed, and a sludge blanket

Engineered Storage Products Company
www.slurrystore.com/36/OdorMgt.html

- Manufactures a manure storage container named Slurrystore
- It has a smaller surface area than lagoons or storage pits
- Design creates a chimney effect which lifts the odors above ground level
- Application of straw creates a biolayer that will reduce emissions

RCM Anaerobic Digesters
www.rcmdigesters.com/

- Largest manufacturer of methane recovering digesters
- They will build and sell supplies for Plug Flow, Complete Mix, Covered Lagoon and Heated Mixed Covered Lagoon
- Almost half of the digesters operating in the United States are run by them

C. END NOTES

1. Dry Matter Content- indicates the ash and dry organic portions of the manure

D. REFERENCES

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E. GLOSSARY

The main source of this section are the Glossary of Soil Science Terms (SSSA, 1997), the Resource Conservation Glossary (NRCS, 1982), and the Manure Management Practices for the Minnesota Pork Industry (Schmidt and Jacobson, 1994).

Aerobic-Occuring in the presence of molecular oxygen (said of chemical or biochemical processes such as aerobic decomposition)

Ammonia-the nitrogen component of the gas (NH3) released by the microbiological decay of plant and animal proteins. Loss of ammonia to the atmosphere is commonly referred as **“ammonia volatilization**”.

Ammonium- ion (NH_4^+) form when ammonia gas comes in contact with water. Ammonium binds tightly to soil particles and is not typically leached into the ground water.

Anaerobic-occurring in the absence of free oxygen (such as biochemical process).

Broadcast-the spreading of manure on top of soil surface.

Chelates- Organic compounds that can bind with metals to increase the soluble fraction of some metals.

Deep pit-a deep (6-8 feet) storage area directly below an animal confinement building.

Denitrification-the chemical or biological process in which nitrate or nitrite is reduced to gaseous nitrogen.

Earthen basin-a large hole dug in the ground, typically lined with clay or some synthetic material, in which manure is stored. The basin is emptied at least once per year.

Facultative-having or occurring in the presence or absence of free oxygen.

Fertilizer-any organic or inorganic material of natural or synthetic origin that is added to a soil to supply one or more plant nutrients essential for the growth of plants.

Flushing system-a flushing system is a manure collection system that uses large volumes of water flowing down shallow gutters to scour and clean the dung area several times per day. The shallow gutters can be open gutters or gutters under open flooring.

Gravity drain-a system where manure is temporarily collected in shallow gutters under a slotted floor. The gutters are drained on occasion by means of a plug or valve. Manure then drains or is pumped to along-term storage area.

Ground water-the supply of fresh water that forms a natural reservoir under the earth's surface.

Immobilization-the conversion an element (e.g. nitrogen, phosphorus, etc.) from the inorganic form to various organic compounds in microbial or plant .

Incorporation-the tilling of the soil after the broadcasting of the manure to move the manure from the surface of the soil to under the soil surface.

Inorganic nitrogen-nitrogen in the form of ammonia, ammonium, nitrate, nitrites, nitrogen gas or nitrogen oxides.

Lagoon. A treatment structure, typically earthen, for agricultural wastes. Lagoon can be aerobic, anaerobic, or facultative depending on the loading and design. Lagoon can be one stage or multi-staged. An anaerobic lagoon is different from earthen storage in that the lagoon is managed to allow for treatment of the manure. Anaerobic lagoons are only partially pumped each year (approximately one third of the total volume) whereas earthen storages are emptied once or twice a year.

Leaching-the removal of soluble materials, such as nitrates or chlorides, from soils or other material via water movements.

Manure-manure is the fecal and urinary excretion of livestock and poultry. Often referred to as a livestock manure, this material may also contain bedding, spilled feed, water or soil. It may also include wastes not associated with livestock excreta, such as milking center wastewater, contaminated milk, hair, feathers, or other debris (ASAE, 1998). Manure is stored until it is recycled to cropland or treated so it may be recycled for uses such as potting soil, compost for gardens, and other off farm uses.

Nitrate (NO_3^-)-the nitrogen component of the final decomposition product of the organic nitrogen compounds. Nitrate is extremely water-soluble and is negative charge excludes it from adsorption on to soil particles. This characteristic render it highly susceptible to leaching.

Nitrification-the biological oxidation of ammonium to nitrite and nitrate.

Nitrite (NO_2^-)-nitrite is an intermediate product in the conversion of ammonium to nitrate. Nitrite is extremely unstable (nearly immediately converting to nitrate) and therefore is rarely detected in groundwater.

Nitrogen cycle-the succession of biochemical reactions that nitrogen undergoes as it is converted to organic or available nitrogen from the elemental form. Organic nitrogen in waste is oxidized by bacteria into ammonia (NH_3). If oxygen is present, ammonia is bacterially oxidized, first into nitrite (NO_2^-) and then into nitrate (NO_3^-). If oxygen is not present, nitrate and nitrite are bacterially reduced to nitrogen gas, completing the cycle.

Nutrients- elements or compounds essential as raw material for organism growth and development. For plant growth, seventeen elements have been found to be universally essential, three mostly from air and water (carbon, hydrogen, oxygen) and fourteen from soil solids (nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, manganese, boron, molybdenum, copper, zinc, chlorine, and cobalt)(Brady, 1984). Six of the fourteen (nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur) are used in relatively large amounts by plants and so called **macronutrients**. The other eight, even though as just essential as the macronutrients, are required in such a small quantities, thus so called **micronutrients**

Odor-foul scent or aroma. Most odors emanating from manure are due to decomposing manure.

Organic matter-the organic fraction of plant, animal, and microorganisms at various stages of decomposition.

Organic nitrogen-nitrogen in the form of urea, protein, or amino acids.

Phosphorus-one of the primary nutrients required for the growth of plants. Phosphorus is often delimiting nutrient for the growth of aquatic plants or algae in lakes and rivers.

Pollutant-any introduced substance that limits a resource use for a specific purpose.

Pollution-the condition caused by the presence in the environment of substances of such character and in such quantities that the quality of the environment is impaired or rendered offensive to life.

Runoff-the portion of precipitation or irrigation water on an area that does not infiltrate, but instead is discharged from the area by flows across land surface or subsurface and eventually appeared in streams and other water-bodies.

Settling basins-a concrete or earth bottom settling structure where the solid in runoff or the waste settles out.

Stock pile-long term solid manure storage.

TAN- total available nitrogen; that portion of the nitrogen applied to soils readily available for plant uptake from organic matter, soil nitrate-nitrogen, manure, and fertilizer. Ammoniacal nitrogen is the ammonia (NH 4 –N) for of the available nitrogen.

VOC- volatile organic compounds; A sampling of typical VOC's found in manure include:

(2-)butanone methylethylketone
carbon disulphinde
carbonylsulphide carbon oxysulphide
dimethylsulphide methylthiomethane
diethylsulphide ethylthioethane
dimethyldisulphide methyldithiomethane
dimethltrisulphide methyldithiomethane 2,3,4-trithiapentane
methanethiol methyl mercaptan
propanethiol n-propylmercaptan
hydrogen sulphide
pentane
hexane
hexene
heptane
octane
undecene
dodecane
benzene
toluene
ocimene