FY-2005 Annual Report Manure and Byproduct Utilization
National Program 206

Introduction

The total amount of manure, biosolids (treated sewage sludge), and other municipal and industrial byproducts generated annually in the U.S. exceeds 1 billion tons. The majority of all animal manure and significant amounts of selected municipal and industrial byproducts are spread, sprayed, or otherwise applied to agricultural land; because of the benefits they can provide. These benefits include providing nutrients for crop production and organic matter to improve soil properties. Improperly managed manure and other byproducts, however, can pose a threat to soil, water, and air quality, and to human and animal health.

Animal production in the U.S. is valued at over $100 billion annually. New technological innovations and the economic advantage of size have driven a structural shift from small to large operations where animals are grown in houses, feedlots, and other confinement facilities. These production facilities are referred to as animal feeding operations (AFOs). Large AFOs are called concentrated animal feeding operations (CAFOs). The largest 2% of all livestock farms now produce over 40% of all animals. The amount of manure generated in the U.S. at CAFOs and AFOs is estimated to exceed 335 million tons of dry matter per year. Often sufficient agricultural land is not available within the vicinity of animal operations to safely use all the manure produced. These developments have increased the challenge of using manure on agricultural lands while protecting the environment. In addition, there is a great demand for scientific information about effective management of manure to guide policy and regulatory decisions.

Each year millions of tons of industrial and municipal byproducts are produced. These byproducts are generally considered to have little value; and are often disposed in landfills or incinerated at considerable expense. However, many of these byproducts are potentially useful in agriculture or horticulture, either applied individually or in mixes or blends with other materials. Research and development activities are needed to determine the composition and bioactivity of these materials, to determine risks and benefits of using the materials, and to develop guidelines for appropriate uses of the byproducts across a range of soils, climate, landscape position and cropping systems.

The mission of the Manure and Byproduct Utilization National Program is to develop cost-effective management practices, control technologies and decision tools that will allow producers to capture the value of manure and other byproducts without degrading environmental quality or threatening human and animal health. This National Program is focused on four major areas of research: (1) atmospheric emissions, (2) nutrient management, (3) pathogens and pharmaceutically active compounds, and (4) municipal and industrial byproducts. Selective accomplishments from these four components are described in the following section.

Accomplishments

Atmospheric Emissions: ARS research on air emissions from animal production operations and land application of manure and other byproducts is directed toward developing management practices, control technologies and decision tools that will allow producers and their advisors to reduce or eliminate emissions of particulate matter, ammonia, volatile organic compounds associated with odor and formation of tropospheric ozone, hydrogen sulfide, methane, oxides of nitrogen and pathogens. The research is conducted at swine, poultry, dairy cattle and beef cattle production operations by ARS scientists from 10 laboratories and their cooperators. The research is coordinated across locations and is designed to: (1) develop new methods and improve existing methods to measure particulate matter and gaseous emissions from animal production operations; (2) develop and determine the effectiveness of management practices and control technologies to reduce emissions; and (3) develop tools to predict emissions and their dispersion across a range of animal production systems, management practices and environmental conditions. Measurement and prediction of emissions from animal production operations will provide the scientific background for State and Federal regulatory and management decisions.

Measurement of gas and particulate matter emission rates from animal production operations is a complex and time-consuming task. ARS scientists from Watkinsville, Georgia, and their cooperators from the University of Alberta in Canada have developed and tested an atmospheric dispersion model (backward Lagrangian stochastic dispersion model) that can be used to estimate gas emission rates from a source using time-average concentration data measured in the emission plume using an open path laser. The method was validated using controlled releases of methane gas under a range of micrometeorological conditions. Model estimates of methane emission rates were within 2% of the actual release rate, with a variability of 20-22% depending on micrometeorological conditions. Emission rates of ammonia and methane from a beef cattle feedlot estimated using the dispersion modeling approach were comparable, but much easier to obtain, than emission rates determined by the flux-gradient meteorological technique. Use of the dispersion modeling technique to determine air quality and global change gas emission rates will improve understanding of emissions from animal production operations and facilitate development of management practices to reduce emissions.

There is a paucity of U.S. data on ammonia volatilization from field application of manure. ARS scientists from Beltsville, Maryland, measured ammonia volatilization from land application of manures using micro-meteorology and wind tunnel techniques. Surface applied dairy slurries had the highest emission rates losing from 40% to 80% of their ammonium–N within 24 to 48 hours after application. Surface applied solid manures, such as poultry litter, had smaller losses of 10% to 30% of their ammonium-N over approximately one week. Compared to unincorporated surface applications of manure, chisel plowing to incorporate the manure reduced ammonia losses by 80% while disking reduced ammonia losses by approximately 90%. Moldboard plowing virtually eliminated all ammonia losses, but removed surface residues leaving the soil vulnerable to erosion. Research on ammonia losses from dairy slurry showed that addition of 6.25% zeolite or 2.5% alum reduced ammonia emissions by approximately 50%. Data from these studies have contributed to the development of an ammonia volatilization decision support system that is being used to update ammonia loss estimates in state Nutrient Management Programs.

Respirable particulate matter of less than 2.5 microns mean aerodynamic diameter (PM2.5) can negatively impact human and animal health. ARS scientists from Bushland, Texas, collected dust particles, over 8-day periods in both summer and winter, from upwind and downwind locations at four large beef cattle feedyards. Mean dust concentrations of particle matter PM10 or larger were significantly greater at positions downwind from the feedlot, while concentrations of PM2.5 size dust particles were the same at upwind and downwind locations. The mean upwind PM10 collection was 1.5 mg/24 hour period compared to 3.3 mg/24 hour period downwind. The mean PM2.5 collection was 0.4 mg/24 hour period at both upwind and downwind locations. These results suggest that beef cattle feedyards are not significant generators of dust particles (PM2.5) that are respirable and can negatively impact animal and human health, but are sources for larger PM10.

Laboratory studies conducted by ARS scientists at Clay Center, Nebraska, indicated that antimicrobial plant oils are effective additives to cattle and swine manure for control of odor emissions and fecal coliforms. Additions of thymol, carvacrol, or eugenol at 0.15 to 0.2% inhibited essentially all microbial metabolism in these manure slurries, whereby no volatile fatty acids or gaseous products were produced. Concentrations of 0.1% destroyed fecal coliforms, which represent the majority of pathogenic microorganisms in manure slurries. Results from eugenol addition to cattle and swine manure were unique because eugenol stops volatile fatty acid production (odorant), yet allows lactate accumulation. This effect rapidly lowers pH, and will likely conserve nutrients such as ammonia-N in manure slurries. Thymol incorporated into a granule and applied to the feedlot surface, reduced odor production (58%) and fecal coliforms (89%). Plant oils are natural compounds classified as GRAS (generally recognized as safe). Thus, if further field trials are successful and the economics are favorable an effective biological agent may be available for use by cattle and swine producers to reduce odorants and pathogens in manure.

Nutrient Management: Movement of nutrients in excess amounts from manure and other byproducts to soil, water and air can cause significant environmental problems. Nutrient losses to the environment can occur at the production site, during storage, and during and after field application. Nitrogen and phosphorus from manure and other sources have been associated with algal blooms and accelerated eutrophication of lakes and streams. Utilization of nutrients in manures in an environmentally sustainable manner is one of the critical management issues facing the U.S. livestock industry. ARS scientists are conducting research to develop management practices, control technologies and decision tools for effective agricultural use of nutrients from manure and other byproducts, while protecting environmental quality, human health and animal health. A systems research approach involving all phases of animal feeding; manure handling, storage and treatment; land application; and crop production is being employed to solve problems in this area.

Nitrogen composition of manure is variable, thus a rapid test for ammonium-N and organic-N is needed to calibrate accurate manure fertilization rates based on nutrient content. ARS scientists from Beltsville, Maryland, evaluated a set of 107 dairy manures for ammonium-N and total N using conductivity tests based on the chemical reaction between chlorine bleach and ammonium, and colorimetric test-strips with a portable strip reader. All procedures estimated ammonium-N with an accuracy of approximately 90%, but none of the methods accurately determined organic N. Rapid tests are useful for managing ammonium-N driven processes, such as ammonia volatilization, but ineffectual for managing organic-N driven processes, such as mineralization. ARS scientists then assessed the ability of near-infrared diffuse reflectance spectroscopy to determine ammonium-N and organic-N in dairy and poultry manures. Using either a fiber-optic probe or sample scanning, they found that wavelengths from 400 to 2400 nm allowed determination of both ammonium-N and organic-N with an accuracy of 90% or greater.

These results show that near-infrared spectroscopy has the potential to be used for rapid on-site determination of dairy or poultry manure ammonium-N and organic-N without the need for a slow chemical analysis. The consequence of these investigations has been construction of a portable, filter-based, battery-operated near-infrared meter for the direct, on-site determination of ammonium-N and organic-N in dairy manures.

Animal feeding operations continue to move into areas, such as southern Idaho, where irrigation is used for crop production. ARS scientists from Kimberly, Idaho, developed information on how to use composted and non-composed manures in irrigated cropping systems on calcareous soils. The research showed that 2.5 tons/acre of dairy manure compost reduced the average N fertilizer requirement by 100 lbs/acre for potato, sugarbeet and malt barley production on irrigated calcareous soils. Surface runoff from soils receiving non-composed manure contained 2- to 4-fold more reactive P than runoff from soils receiving compost for two consecutive growing seasons. Surface runoff from soils receiving manure had 2- to 4-fold higher ammonium-N and nitrate-N concentrations than non-manured soils receiving equivalent commercial nitrogen fertilizer. Delaying surface irrigation until spring after a fall manure application reduced runoff nitrogen losses 90% to 95%. Polyacrylamide (PAM), PAM+alum, and PAM+hydrated lime applied to soil reduced soluble nutrients transported in surface runoff 10-fold, and eliminated leaching losses of ammonium-N, and soluble and total P. The compost industry, producers, land-use planners, private crop and environmental consultants, and the Natural Resources Conservation Service are using this information.

ARS scientists from Madison, Wisconsin, in cooperation with Cornell University and University of Wisconsin faculty members developed software to address a range of nutrient management decisions on dairy farms, including optimizing dairy herd and feed management, manure and fertilizer management, and assisting land-use planners in dairy herd expansion. A six-part video seminar series was designed to: (1) present and review the science and methodology supporting the major nutrient management tools being used in New York, Wisconsin and elsewhere; (2) exchange information and share ideas for tool improvement and expansion; (3) identify gaps in knowledge about nutrient management planning and identify future research and extension needs; and (4) provide content for a published proceedings that will systematically catalog tool criteria, and provide a reference for consultants, researchers, educators, policy makers and other professionals that assist dairy farmers in nutrient management issues. The video series at Cornell University and University of Wisconsin covered eight nutrient management tools and provided an overview of the scale and focus, application, knowledge and data transferability, outputs, and limitations of these tools. This information is available at http://www.dfrc.ars.usda.gov/powell/.

Small beef cattle feeding operations need a cost-effective solution for managing feedlot runoff.

ARS scientists from Clay Center, Nebraska, developed and evaluated a runoff control and treatment system designed to reduce the volume of long-term liquid storage, provide adequate solids separation, and evenly distribute basin discharge water for grass hay production. The system consisted of a grass approach, a terrace with a debris basin, and a vegetative filter strip. The system effectively reduced the cumulative mass of total and volatile suspended solids and reduced chemical oxygen demand by

80%, 67%, and 59%, respectively. No water was measured exiting the vegetative filter strip during the three-year period of this study. Therefore, the discharge water was effectively contained and used for hay crop production. Estimated total nitrogen load in the discharge water entering the vegetative filter strip was equivalent to or less than the total nitrogen removed by the crop. This system will provide smaller beef cattle feeding operations with a robust, cost-effective system to meet requirements of EPA's National Pollution Discharge Elimination System Permit Regulations and Effluent Guidelines for Concentrated Animal Feeding Operations.

Pathogens and Pharmaceutically Active Compounds: **Error! Hyperlink reference not valid.**Pathogens and pharmaceutically active compounds in manure, biosolids, and other byproducts can be transmitted to animals and humans through food supplies, water, and possibly air. Animals on the farm or at AFOs can also be re-infected not only via water and air, but also from other vectors such as birds, rodents, and insects that can directly infect the animal or contaminate animal feeds or water. The most significant of the manure-borne zoonotic pathogens are the protozoan parasites Cryptosporidium parvum and Giardia duodenalis, and the bacterial pathogens Salmonella, Campylobacter, Escherichia coli, and Listeria monocytogenes. Large amounts of pharmaceutically active compounds (PACs) such as hormones and antibiotics also may be present in animal wastes (wastewater and manure) and disseminated in the environment. Pathogenic microorganisms in livestock and poultry can become resistant to antimicrobial agents, and the practices that have been traditionally relied on to eliminate or prevent their growth are not always effective. Knowledge of the processes that control the transport and persistence of pharmaceuticals and pathogens in livestock manure and the environment is therefore needed to accurately assess risks and vulnerabilities, and to develop control mechanisms.

Studies were conducted by ARS scientists from Beltsville, Maryland, to determine if fecal bacteria concentrations in air were affected by manure or biosolid application to land. The surface application studies involved two different application methods: a low-solids (<12% solids) tank sprayer and a high solids (>22% solids) hopper spreader. The release point on the sprayer was about 4m above the land surface, while the spreader release point was approximately 0.6m above the land surface. Results so far indicate that inhalable and respirable particulate matter and bacterial bioaerosols (<10 um aerodynamic diameter) are not significantly increased in the immediate vicinity of the sprayer and spreader, or at the field fence-line (15- 300m) during manure or biosolids applications.

Numerous variables affect rates and extent of pathogen transport including slope, soil characteristics, vegetation and rainfall intensity/duration. Pathogens applied or deposited onto soil surfaces may infiltrate into the soil profile or, alternatively, may runoff to surface waters. Since both processes can occur simultaneously, a thorough understanding of the controlling factors is critical in predicting which process will predominate. Scientists at Beltsville, Maryland, used a two-sided lysimeter with 20% slope instrumented to monitor surface transport of manure-borne microbes. Each side of the lysimeter was divided into sub-plots, one with grass and the other bare soil. Bovine manure was applied at the top of the slope of each plot and a portable rainfall simulator was used to induce runoff. Surface flow was measured and sampled at three different transects. Fecal coliform (FC) bacteria data indicated that while 100% of the initial population could be lost to runoff from bare plots, less than 1% of the initial population was lost from vegetative plots. FC bacteria concentrations decreased with distance along the slope from the point of application. Results also show that bare plots offered no resistance to surface flow; FC bacteria were detected in total runoff at the bottom of the slope within 10 minutes of rainfall initiation. These data show that vegetative filter strips can dramatically reduce pathogens in runoff.

Tools are needed to assess fate and transport of pathogens at the watershed scale. ARS scientists from Beltsville, Maryland, and Temple, Texas, have incorporated a microbial component into the watershed-scale model, Soil and Water Assessment Tool (SWAT). The microbial component describes processes such as bacterial die-off and re-growth rates, bacteria transport with runoff and sediment, stream transport, and filter strip efficiency. The module considers fate and transport of bacteria as related to weather conditions, topography and soil properties, manure and soil management, and presence of vegetated buffer strips; and has been tested in the U.S. and Canada. This modeling tool can be used by the Natural Resources Conservation Service and the Farm Services Administration to perform risk analysis for major USDA Conservation Programs, and by the Environmental Protection Agency to estimate pathogen movement and loading into water resources.

Byproducts: Each year millions of tons of agricultural, industrial, and municipal byproducts are generated that have been considered to have little value, are classified as wastes, and often disposed in landfills. Alternative uses for these byproducts are needed to promote sustainable agriculture, as well as to reduce landfill requirements, greenhouse gas emissions, and disposal/remediation costs. Many of these byproducts have characteristics that make them prospectively useful for direct land application, soil reclamation and remediation, production of manufactured soils and composts, or feedstuffs for value-added products. Research must be conducted to determine benefits and risks of the materials, to develop and demonstrate byproduct uses, and to provide regulatory and advisory agencies with information that will allow use of the byproducts.

ARS scientists at Beltsville, Maryland, conducted research to measure changes in metal adsorption and phytoavailability in soils amended with manures, biosolids and composts. Amended soils had higher cadmium (Cd) adsorption capacity than unamended soil from the same set of field plots. These soils were further examined to characterize whether the organic matter or mineral fraction of the amended soil had caused the increased adsorption. This was done to clarify whether biodegradation of the organic matter of organic amendments will cause an increase in phytoavailability of soil metals. The research indicated that the inorganic fraction of the amended soil controlled long-term metal adsorption. Both total and amorphous iron (Fe) and manganese (Mn) oxides provided persistent increase in Cd adsorption by soils amended with biosolids. Fe oxide in amended soils increased the specific adsorption of metals by soils. Incorporation of Fe from inexpensive by-products or ores into manures or biosolids could result in products useful for soil remediation. These results offer important evidence that metals added in biosolids, manures and composts do not suddenly become more phytoavailable and comprise risk to soil fertility and human health. Biosolids amended with Fe oxides have been used to remediate trace element contaminated Environmental Protection Agency “Superfund” sites.

Application of manure or other residuals with high levels of phosphorus (P) relative to other nutrients, especially nitrogen (N), or excessive applications have led to soils with high levels of P. Soluble P from these soils could pose a threat to surface water quality and would benefit from remediation strategies. Scientists at Beltsville, Maryland, and Florence, South Carolina, added water treatment residue rich in aluminum, an iron-rich titanium ore processing byproduct, and alkaline calcium-rich fluidized bed ash from coal combustion at different rates to high P soils. At moderate application rates the drinking water treatment residue was especially effective in lowering soluble P in the soil. The iron-rich byproduct was less effective than the drinking water product. In another study, a drinking water treatment residual produced from addition of “polyhydroxy aluminum” was mixed with poultry litter and applied as fertilizer. A reduction in soluble P was observed, but corn yield was not reduced by this treatment. Addition of alum treated drinking water residuals to sandy soils, commonly used for manure application, increased P retention in soil by 3 to 6 fold. Adoption of water treatment residuals as a treatment to reduce P movement to surface and ground water could turn a waste product into a useful agricultural amendment.

Lead (Pb) contamination at mine and smelter sites, or in urban soils (from paint and automotive emissions) comprise risk to wildlife or children by soil ingestion. Biosolids composts rich in iron (Fe) have been shown to strongly reduce the absorption of Pb from soil fed to rats. Further tests were conducted and Fe and P were clearly important in Pb inactivation. In cooperation with US-Environmental Protection Agency and others, ARS scientists from Beltsville, Maryland, tested different phosphate amendments and high Fe biosolids compost for inactivation of Pb in soils at Joplin, Missouri. A 3-year field trial was conducted during which the bioavailable fraction of soil Pb was measured by chemical extractions or feeding trials. After 3 years, a human feeding test demonstrated that phosphate reduced soil Pb bioavailability by 69%. The human test used stable isotopes of Pb in the contaminated soil. This approach was extended to urban soils in the inner-city area of Baltimore, Maryland. A high Fe composted biosolid containing 10% limestone, permitted for use on lawns and gardens, was applied at about 200 tons/hectare to Pb contaminated sites. Before application, lawns were compacted and poorly vegetated; in that condition, one is advised to remediate or remove soils with over 400 mg Pb/kg. Where the compost was incorporated, lawn grass grew strongly, reducing soil transfer and Pb bioavailability; vegetated soils with up to 1200 mg Pb/kg do not require removal or further remediation. This approach could be used to reduce soil Pb risk to urban children at low cost.