NP 206 FY 2002 Annual Report

Introduction

The economics of livestock and poultry production in the United States has concentrated operations into relatively small areas of the country. Manure generated at animal feeding operations (AFO) is valuable as a fertilizer for crops, as an amendment for improving soil properties, and potentially for alternative uses such as energy production. However, improperly managed manure poses a threat to soil, water and air quality, and to human and animal health. The US Environmental Protection Agency has developed Concentrated Animal Feeding Operations (CAFO) Regulations and Effluent Guidelines to protect surface waters from sediment, nutrients, pathogens, and other discharges from AFOs. Concerns about air emissions from AFOs have prompted air quality regulations in some states and a recent report by the National Research Council assessed current knowledge and future needs relative to air emissions from AFOs.

The 2002 Farm Bill provided substantial funding increases for Conservation Programs that address animal waste management issues on a much larger scale than was previously possible. These programs provide producers with technical assistance, cost-sharing and incentive payments to manage animal waste in a manner that will protect the environment and human health. In addition, marketing systems are being developed for pollution abatement credits that producers can earn by adopting practices that result in water, air and soil quality improvements. ARS scientists in the Manure and Byproduct Utilization National Program are developing management practices, treatment technologies, and decision tools that will allow producers and their advisors to manage animal waste in an effective manner. Research will document the environmental benefits (improved water quality, reduced air emissions, improved soil quality) that result from use of management practices funded by the Conservation Programs. This information can be used to determine the effectiveness of expenditures in the Conservation Programs and to support development of a price structure for pollution abatement credits. To address these and other critical issues the Manure and Byproduct National Program is organized into three main areas: nutrients, atmospheric emissions, and pathogens.

Nutrients

Utilization of manure nutrients in an environmentally sustainable manner is one of the critical management issues facing the U.S. livestock industry. At many points in an animal production system the manure nutrients can be lost to the environment or they can be conserved. ARS research is conducted to make more efficient use of nutrients in animal feed; to develop improved technologies for manure handling, storage, and treatment; to develop better tests for nutrients in manure and soil treated with manure; to develop tools to identify areas on a farm or in a watershed that are most susceptible to nutrient losses; and to develop integrated animal and cropping systems to more effectively use and recycle nutrients. This research will result in the development of economically viable management practices that will allow producers to utilize manure in an environmentally protective manner. In areas of the country where livestock and poultry populations are high, cropland is limited, and /or environmentally sensitive areas are present, systems of treatment technologies that capture nutrients, reduce emissions, and kill pathogens will be developed and evaluated.

Field trials in various areas of the U.S. have demonstrated the value of manure use in crop production systems. ARS scientists at Mississippi State, Mississippi, have developed management practices to maximize yield and minimize pollution risks when using poultry litter to fertilize forages. They found that bermudagrass yields and nutrient uptake-efficiency were highest when poultry litter was added one month after the start of active growth of the grass. Multiple fertilizations during the year did not improve nutrient status or productivity of bermudagrass. ARS scientists from Tifton, Georgia , in cooperation with scientists from the University of Georgia, demonstrated that application of poultry litter to irrigated double-crop and tilled-rotation systems increased yields of cotton, pearl millet, wheat, and canola when compared to fertilizer application. Scientists from Lincoln, Nebraska, showed that site-specific application of manure could help overcome field-level variability in soil quality. Site-specific application of manure resulted in greater corn yields than uniform application of manure or inorganic fertilizer. These findings will contribute to the development of guidelines for manure application in many areas of the country.

A Workshop for ARS scientists conducting research on different aspects of animal waste treatment technologies was held in September 2002 in Raleigh, North Carolina. Two areas of cooperation were identified and will be developed: (1) integrated treatment technology systems that can be used at the production site to manage nutrients, emissions and pathogens in swine and dairy wastewater, and (2) treatment systems such as algal scrubbers, overland flow, runoff management systems, constructed wetlands, in-stream wetlands, and floating vegetation mats that prevent buildup of nutrients in surface waters by removing nutrients at the production site, in the field prior to entry to surface waters, and after entry to surface waters.

Adoption of a specific manure management system by a producer is often based on economics of implementation and level of management required. To address both of these constraints, scientists at Clay Center, Nebraska, have designed and evaluated a simplified runoff control system that channelizes runoff from a beef feedlot to a terraced solids settling basin. The system releases the liquids to a grass field through outlets installed along the length of the basin using a gravity feed. This runoff control system offers the potential for substantially reducing handling costs by eliminating long-term storage needs and the associated risk of groundwater contamination.

Phosphorus concentration in manure is relatively high compared to other essential plant nutrients. Repeated use of manure as a fertilizer can increase phosphorus concentration in the soil, thus increasing the probability of eutrophication through phosphorus movement to water. One approach to this problem would be to modify animal diet to reduce phosphorus concentration in manure. ARS scientists at the Animal Manure and Byproducts Laboratory, Beltsville, Maryland, find the use of dietary phytase enzymes in animal feed formulations to improve the efficiency of P utilization or uptake by the animal must be carefully controlled. These enzymes have the undesirable effect of increasing the percentage of phosphorus in the manure that is very soluble and which is more likely to move into the water environment. To reduce the environmental risk of pollution with phosphorus, the level of P in the feed needs to be reduced with the use of the phytase enzymes. Other ARS Scientists in Beltsville, Maryland, have determined that composting animal manure decreases the percentage of P in the manure, which is the very soluble type that readily dissolves in water. Thus composting is a tool available to most farmers for reducing the possibility of phosphorus being dissolved in water and contaminating the environment. Logically, we have a two step system evolving where the phytase enzyme is added to the feed as the P concentration in the feed is reduced and then manure is collected and composted to reduce the hazard of phosphorus pollution to the waterways.
Inner city lead-contaminated soils can pose a health risk to children who inadvertently digest soil and house dust. Cost prohibits removal of the contaminated soils so an alternative inactivation of lead was evaluated. In a collaborative study with Johns-Hopkins University School of Public Health, ARS scientists from Beltsville, Maryland, have carried out tests high lead content soil samples from nine locations within inner city Baltimore, Maryland. Results demonstrated that soil lead bioavailability could be reduced by application of high-iron and high-phosphorus biosolids compost. A secondary effect of the compost treatment was establishment of turf on soil, which had been barren. This research demonstrated that persistent and inexpensive land treatments with composts rich in iron and phosphorous reduces the potential for children to be harmed by lead-contaminated urban soils.

A perennial hazard with long-term manure fertilization of any field is the loss of the phosphorus into the environment. One management practice, which addresses this problem, is the addition of alum (aluminum sulfate) to poultry litter. The repeated use of this procedure has heightened a concern that repeated application of alum-treated poultry litter to soil can cause an increase in aluminum availability to plants or increase aluminum in runoff. The results of an ongoing 7-year field study, comparing poultry litter, alum-treated poultry litter, and ammonium nitrate by scientists from Fayetteville, Arkansas, demonstrated that while the acidity and aluminum levels were very high in soil treated with ammonium nitrate, soils fertilized with either litter source had very low exchangeable aluminum. Thus it appears that alum-treated manure does not move substantial amounts of aluminum into the soil.

Cooperators from ARS in Florence, South Carolina, North Carolina State University, and private industry have developed an animal wastewater treatment system that does not use an anaerobic lagoon. The swine wastewater treatment system provides improved separation of manure liquids and solids using polymer technology, eliminates losses of ammonia and other noxious gases to the atmosphere, and recovers phosphorus from the liquid phase. The separated solids are converted through composting and other processes to energy and value-added products for horticultural and turf uses. Pathogenic microorganisms are destroyed during the treatment process, and the treated liquid can be reused in the animal production facility. The system is currently in operation at a 4300 head swine production facility in North Carolina. With further improvements in effectiveness and a reduction in cost, the system should provide producers a viable alternative to anaerobic lagoons.

Atmospheric Emissions

Gases and particulate matter can be emitted from animal production facilities, manure storage areas, and manure field-application sites. These emissions include: ammonia, particulate matter (PM10, PM2.5), volatile organic compounds (associated with odor or precursors for ozone formation), hydrogen sulfide, greenhouse gases (methane, nitrous oxides), and pathogens. Great improvements are needed in the measurement and prediction of emissions across a range of animal production systems, management practices, and environmental conditions. This would allow the environmental impact of current animal production systems to be determined, and cost-effective methods of emissions reduction and control to be developed and assessed. Many of the ARS scientists working on emissions from AFOs met in Ames, Iowa, in February 2002 to discuss current research and to develop targets and plans for coordinated future research. All participants contribute to an overall program designed to (1) measure emissions from animal production systems; (2) develop and determine the effectiveness of management practices and control technologies to reduce emissions; (3) develop tools to predict emissions and their dispersion across a range of animal production systems, management practices and conditions.

Emission rates of gases and particulate matter from livestock operations are expected to be quite variable over time, but most emissions measurements have been for relatively brief times, often less than a week. Measurements of the ammonia emission from deep-pit swine operations by ARS scientists at Ames, Iowa, demonstrated that large peaks in ammonia emission rates occurred when the curtain-walls were down and manure was being collected for removal. Ammonia concentrations were highly variable, but decreased quite rapidly with distance from the facility with concentration below 20 parts per billion at about 30 meters. These results suggest that the spatial and temporal variability of ammonia emissions will require improved methods for accurate determination of emission rates for animal production operations.

Scientists at Watkinsville, Georgia, and Beltsville, Maryland, have measured emissions of ammonia, methane, and nitrous oxides from swine and dairy housing, waste lagoons, and land-applied effluent. They used a mass balance approach to track fate of nitrogen in the system. They found that 10 percent, 5 percent, and 2 percent of the nitrogen fed to dairy cattle was lost as ammonia from animal housing, lagoons, and fields, respectively. The researchers found that approximately 43 percent of the nitrogen in the feed was converted to harmless dinitrogen gas, which was lost from the lagoon to the atmosphere. Although these ammonia losses are lower than most previous and current estimates of ammonia emissions from animal production operations, they still represent substantial losses that must be addressed through improved management practices and control technologies.

ARS scientists from Bushland, Texas, studied the effect of reducing crude protein in beef cattle diets on ammonia losses from feedyard surfaces. Ammonia losses from a 5-meter diameter simulated feedyard surface were determined in summer, fall and spring using the integrated horizontal flux method. Reducing crude protein in beef cattle diets from 13% to 11.5% significantly reduced nitrogen lost from manure as ammonia in summer, fall or spring, but not in winter; annual mean reduction was 24%. Potential ammonia emissions from beef cattle manure decreased with decreasing dietary protein concentration primarily due to decreasing urinary nitrogen excretion. These results demonstrate that ammonia emissions from feedyards can potentially be decreased by modification of the diet as long as the dietary modifications do not adversely affect animal performance.

ARS researchers at Fayetteville, Arkansas, have developed systems to reduce ammonia emissions in poultry facilities for broiler and egg production. Addition of alum (aluminum sulfate) to poultry litter in broiler houses at a rate of two tons per batch of broilers reduced ammonia volatilization by 97 percent during the first four weeks of growth and resulted in significantly healthier birds. Birds grown in alum treated houses weigh more, have better feed utilization, and lower mortality rates. In addition, heating costs during winter are lower since less ventilation is required to remove ammonia vapors. More than 500 million broilers are produced annually on alum treated litter. Producers make an additional $2 for every dollar spent on alum. An automated liquid alum spray system has been developed to control ammonia levels in high-rise laying hen houses. Ammonia sensors in the house activate the spray system for ammonia removal when ammonia levels pose a threat to poultry and worker health. Using this system, improved hen performance has resulted in a net benefit of $425/house/week.

As manure ages, a variety of malodorous products (alcohols, volatile fatty acids, and aromatic-ring containing compounds) accumulate and may be emitted. The biochemical origins of odor compounds, however, are not well understood. ARS scientists from Clay Center, Nebraska, determined that the primary substrates for odor formation in swine and cattle fecal slurries, in cattle feedlot manure and soil pan incubations were starch and protein, whereas there was no evidence that cellulose served as a source for production of odorous compounds. Furthermore, the relative contribution of fecal starch and protein differed between feedlot cattle and swine with most odor compound production in cattle feces coming from starch fermentation, while odor compound production in swine feces came from equal parts protein and starch. These insights into the mechanism of odor compound production will ultimately allow development of diet formulations that minimize odor production.

Pathogens

Pathogens and pharmaceutically active compounds in manure can be transmitted to other animals and humans through food supplies and water. Possible modes of water contamination include fecal deposition into surface waters; leaching to groundwater through preferential flow; runoff to streams, rivers, and reservoirs from land-applied manure or fecal deposition; attachment to particulates which get airborne; and vectoring by wildlife. Modes of pathogen contamination of fresh fruit and vegetables include preharvest application of untreated or improperly treated manure, use of contaminated irrigation water, use of contaminated water for postharvest washing and processing, and vectoring by plant pests. Research is needed to determine survival, transport, and dissemination of manure pathogens and pharmaceutically active compounds in the environment to assess risks to human and animal health, and to develop appropriate control measures. ARS scientists who are focused on this type of research met in May 2002 at Watkinsville, Georgia, to develop a multi disciplinary research program that will integrate and synthesize information to understand pathogen fate and transport, and to evaluate the effectiveness of treatment technologies to eliminate pathogens.

Rapid identification and quantification of human pathogens in manure, soil, and water are critical to identifying human risks and to measuring management effects on reduction of human risk. ARS scientists at Beltsville, Maryland, developed molecular-based methods for distinguishing various pathogenic and nonpathogenic forms of E. coli found in municipal water. This has led to characterizations of the forms of E. coli in the Baltimore, Maryland, and Washington, D.C., areas. Similarly, ARS scientists at Mississippi State, Mississippi, developed software in support of automated hardware systems to more rapidly quantify and characterize bacteria populations in poultry litter and swine effluent as impacted by different management systems and environmental conditions. The development of more accurate and effective pathogen assays is critical to reducing human risks linked to management and use of animal waste.

ARS scientists from Albany, California, conducted research to determine if human pathogenic *E.coli* O157:H7 and *Salmonella* survive in dairy lagoons. Laboratory scale microcosms of manure water from California dairies were used to monitor the survival and proliferation of *E.coli* O157:H7 and *Salmonella* marked with rifampicin and nalidix acid. Pathogen fate was expressed as the rate of population decline per day based on the first day of incubation under both aerated and non-aerated conditions. Inoculated pathogens failed to survive in both aerated and non-aerated manure lagoons and *Salmonella* appear to decline faster from aerated manure waters. In addition to rapid decline in manure waters, variation in survival with different strains of *E.coli* O157:H7 under both aerated and non-aerated conditions was observed. Furthermore, *E.coli* O157:H7 populations declined proportionately as the inoculum load of the pathogen increased in both aerated and settling pond manure waters. During the 13-day incubations organisms declined much more rapidly under non-aerated conditions. These studies on pathogen survival in manure lagoons are critical in determining the potential for pathogen transmission through water and crops grown on-site by fertilization and irrigation with manure water.

The movement of human pathogens from animal manure to surface water and into municipal water has been documented on a number of occasions with some devastating effects. The potential for dispersion into water of two parasitic organisms Giardia and Cryptosporidium, which can survive some of the municipal chlorine treatments, were modeled by ARS researchers at Riverside, California. This model estimates accumulation and fate of the parasites as impacted by temperature and other characteristics of the environment. This model provides effectiveness estimates of alternative manure management systems to reduce risk of movement of this organism to surface water and through the soil. Concurrent research by ARS scientists at Watkinsville, Georgia, in cooperation with scientists at Cornell University determined the effect of soil type (silty clay loam, silt loam, and loamy sand) , water potential, and temperature on survival of oocysts (propagules for dissemination by this organism) of Cryptosporidium. The water potential had no effect on longevity, but a moderate temperature and the silt loam soil resulted in persistence of the organism for several months. When the organism persists in the soil the potential for repeated movement into water poses a human health risk.