FY 2010 Annual Report
National Program 206—Manure and Byproduct Utilization

Introduction

According to the National Agricultural Statistics Service, over one billion tons of agricultural (e.g., manure), municipal (e.g. biosolids), and industrial (e.g. coal combustion products) wastes with potential uses in agriculture are generated annually in the United States. Many of these materials are spread, sprayed or otherwise applied to agricultural land because of the benefits they provide. These benefits include: providing a nutrient source for crops; improving soil chemical, physical and biological properties; improving soil water storage and use; reducing movement of contaminants to water and air; and reducing production costs and energy use. However, improperly managed manure and other byproducts can pose a threat to soil, water and air quality, and to human and animal health.

The goal of the Agricultural and Industrial Byproducts National Program is to develop and evaluate management practices and systems, control technologies, and decision tools to allow producers and their advisors to (1) use manure and other byproducts effectively and safely while protecting the environment and human and animal health and (2) provide policy-makers and regulators with information and tools to establish appropriate conservation and environmental credit trading programs, and make environmental protection decisions. To achieve this goal, this National Program is focused on four major areas of research: atmospheric emissions, nutrient management, pathogens and pharmaceutically active compounds, and municipal and industrial byproducts. Sustainable agriculture depends on effective management of manure and byproducts. Selected accomplishments from these four components are described in the following section.

Atmospheric Emissions

Air emissions from animal production operations and land application of manure and other byproducts include particulate matter, ammonia, volatile organic compounds (which cause odor or serve as precursors for ozone formation), hydrogen sulfide, greenhouse gases and pathogens. Research is being conducted to: (1) develop new methods and improve existing methods to measure particulate matter and gaseous emissions; (2) develop and determine the effectiveness and environmental benefits of management practices and control technologies to reduce emissions; and (3) develop and test decision tools to predict emissions and their dispersion across a range of animal production systems, management practices, and environmental conditions. Tools and practices for measurement, control and prediction of emissions from animal production operations will help provide the scientific background for management, policy and regulatory decisions.

Selected Accomplishments

Greenhouse gas emissions from dairy manure composting operations. The effect of pile mixing on greenhouse gas (GHG) emissions from stored dairy manure was determined using large flux chambers designed to completely cover pilot-scale manure piles. GHG emissions from piles that were mixed four times during the 80 day trial were about 20% higher than unmixed piles. Carbon dioxide, methane, and nitrous oxide accounted for about 75%, 20%, and 3% of GHG emissions, respectively. Approximately 70% of carbon dioxide and methane emissions from all piles occurred within first 23 days. In contrast, 60-75% of nitrous oxide emissions occurred during the later stages of composting. These results suggest that with respect to minimizing GHG emissions, farmers should store manure in undisturbed piles or, at the very least, delay the first turning of manure piles for at least four weeks.

Evaluation of various sources of condensed tannins on total gas and hydrogen sulfide production from in vitro swine manure slurries. Reducing overall bacterial activity in stored manure is important for lowering the production of greenhouse gases and odorous compounds such as hydrogen sulfide. Condensed

tannins have been studied for their abilities to affect bacteria present in stored manure. However, for the first time Bioenergy Research Unit scientists at the National Center for Agricultural Utilization Research in Peoria, IL, have demonstrated that only tannins from the quebracho plant will reduce overall gas and hydrogen sulfide production from manure slurries studied in the laboratory when compared to other plant tannins. These results can now be applied towards reducing odors and greenhouse gas emissions in on-farm evaluations at large-scale swine facilities (a patent application has been submitted for this technology).

Fluctuating Emissions Factors for Southern Idaho Dairies. In Idaho, the number of dairy cows has grown approximately 80% in the last decade, which has generated concern over the impacts of dairy facilities on regional air quality. ARS researchers at Kimberly, ID, collected ammonia and greenhouse gas emissions data monthly from a large open-lot dairy (10,000 milk cows) in southern Idaho. Emissions can vary by a factor of ten during the day, and similar variations can occur among pens depending on surface conditions. This research demonstrated the importance of collecting emissions data for 24-hour periods to accurately represent the diurnal variations in emissions from open lot dairies.

Daily, monthly, seasonal, and annual ammonia emissions from Southern High Plains beef cattle feedyards. Accurate estimates of ammonia emissions from beef cattle feedyards are needed as regulatory requirements and the need for accurate emissions inventories increase. ARS researchers from the Conservation and Production Research Laboratory, Bushland, TX, in collaboration with researchers at West Texas A&M University and Texas AgriLife Research, addressed this need by measuring atmospheric ammonia concentrations and ammonia emissions for two years at two commercial feedyards. Monthly ammonia-nitrogen losses, as a fraction of fed nitrogen, ranged from 19 to 85% of fed nitrogen, with fractional loss the least during winter months and greatest during summer months. These results will provide databases that can be used by scientists to validate and verify process models of emissions, provide the cattle industry with accurate science-based emissions data to meet regulatory requirements, and give regulators more accurate, comprehensive data from which to build ammonia emissions inventories.

Subsoil Manure Injection Reduces Ammonia Losses. Ammonia emitted during manure application represents lost nutrients that could be used by crops. ARS researchers at Kimberly, ID, demonstrated that the greatest ammonia losses occurred during the first 48 hours following manure application. Injecting manure about 16 inches deep in the soil decreased ammonia emissions by 67% compared to surface application or shallow incorporation. Reducing ammonia losses 67% is equivalent to adding 50 pounds of nitrogen fertilizer per acre. This research demonstrated that subsurface injection of manure is an excellent management practice to retain nitrogen from applied manure and reduce negative impacts on air quality.

Feeding distiller's grains can increase ammonia emissions from beef cattle feedyards. The diversion of corn grain to produce ethanol more than doubled from 2003 to 2008, making available a feed byproduct called distiller's grains; however, because of its high crude protein content, adding distiller's grains to cattle finishing diets increases the potential for ammonia losses to the atmosphere \ from cattle manure. Scientists at the ARS Conservation and Production Research Laboratory, Bushland, TX used a comprehensive database of ammonia emissions collected at two feedyards--one that fed distiller's grains and one that fed only corn-based rations--to investigate the effect of distiller's grains on ammonia emissions. Ammonia emissions were similar at the two feedyards when cattle were fed similar crude protein rations without distiller's grains; however, feeding distiller's grains at one feedyard significantly increased crude protein content of the diet from 13% to 19%, and significantly increased mean monthly ammonia emissions by 44 to 144%, compared with the feedyard feeding corn-based rations. Feeding distiller's grains utilizes a valuable byproduct of the bioethanol industry; however, the increased crude protein in the diet can potentially increase ammonia emissions and complicate efforts of cattle producers to reduce ammonia emissions from cattle feedyards.

Methane emissions from a High Plains dairy lagoon. Dairies, a growing industry in the Southern High Plains, are recognized as sources of gases such as methane and ammonia that can have adverse effects on the environment. Scientists at the ARS Conservation and Production Research Laboratory, Bushland, TX, teamed with researchers at Texas AgriLife Research, West Texas A&M University, and New Mexico State University to conduct an intensive and comprehensive study to measure methane, ammonia, odor, and particulate emissions from a 3,500-cow dairy. Methane concentrations over wastewater lagoons ranged

from 3 to 12 parts per million (ppm), and averaged 5.6 ppm. Daily methane emissions from the lagoon averaged 211 grams per cow. These results demonstrate that uncovered anaerobic lagoons can be a significant source of methane emissions from Southern High Plains dairies and that modified management of lagoons could potentially decrease emissions of methane.

Evaluation of Critical Level of Litter Moisture that Reduces Generation of Ammonia in Broiler Houses. No upper limit of the moisture content that causes peak levels of ammonia generation has previously been defined. ARS scientists in the Genetics and Precision Agriculture Research Unit, Mississippi State, MS, identified the critical litter moisture level which maximizes ammonia generation during broiler meat bird production across the range of temperatures encountered from summer to winter in Mississippi. A conservative estimate shows that reducing in-house ammonia generation in only 10% of the poultry broiler houses in Mississippi increases bird growth significantly, leading to more than $26 million in additional grower revenues. This information is also of great value to poultry companies who are seeking optimum production practices.

Nutrient Management

The utilization of nutrients in manure in an environmentally sustainable manner is one of the critical management issues facing livestock producers. Movement of nutrients in excess amounts from manure and other byproducts to soil, water and air can cause significant environmental problems. Nitrogen and phosphorus from manure and other sources have been associated with algal blooms, accelerated eutrophication of lakes and streams, and development of hypoxic zones in the Gulf of Mexico. 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 and public health.

Selected Accomplishments

Recovering phosphorus from solid manure. ARS scientists in Florence, SC developed a process called ‘quick wash’ to recover phosphorus (P) and reduce the environmental impact of P in poultry litter. This technology provides an alternative poultry litter management when application onto land is not an option in areas such as Georgia, North Carolina, and the Chesapeake Bay. This technology will help the poultry producer to better manage manure and nutrient plans on their farms. It can facilitate economic P transport in concentrated form from areas where it is in excess to areas where it is needed for its effective utilization as plant fertilizer. Renewable Organics LLC applied for exclusive licensing of ARS patent rights.

Benefits of shallow subsurface band application of poultry litter. Poultry litter is typically land-applied by broadcast surface application, but this method has a high potential for undesirable transport of litter nutrients off the field into streams, rivers, lakes, and other bodies of water. An experimental litter application implement that places the litter in shallow subsurface bands in soil was used in five field experiments. When the poultry litter was applied in subsurface bands, compared to traditional broadcast surface application, phosphorus and nitrogen nutrients in water running off field plots was reduced by 80 to 95%. Use of this implement by producers and others who apply litter to fields is expected to reduce pollution of streams, rivers, lakes, and other bodies of water.

Nitrogen use efficiency in dairy production. The more efficient dairy farmers are in managing nitrogen (N), the less N will be wasted in manure. ARS researchers in Madison, WI, and University Park, PA, along with Australian colleagues, calculated N use efficiency ratings. These ratings could help dairy farmers make better use of their N in the face of escalating costs and increasing nutrient regulation. They found that only about 20-35% of the N fed to dairy cows is converted into milk. They also discovered that 16 -77% of the N in manure or fertilizer is taken up by crops and pasture plants. In addition, the study showed that between 8 and 64% of all N applied to typical commercial dairy farms is converted into farm products. The wide ranges in N use efficiency indicate that there is significant room for improved N management on the average farm, with likely benefits to farm profits and the environment.

Manure nutrient losses are reduced by stiff-stemmed grass hedges. ARS scientists in Lincoln, NE measured the effectiveness of narrow grass hedges in reducing runoff nutrient transport from sites on which beef cattle manure was applied to meet 0, 1, 2 or 4-year corn phosphorus requirements. Manure application rate significantly affected the transport of phosphorus in runoff in the treatments without a grass hedge. However, phosphorus transport in the treatments where manure was applied to plots containing a grass hedge was similar to the treatments that did not receive manure. This research indicates that stiff-stemmed grass hedges reduce the transport of nutrients in runoff occurring soon after manure application, and an adoption of grass hedges would decrease phosphorous runoff into streams and enhance water quality.

Nitrogen and phosphorus losses from beef cattle feedyards. Losses of nitrogen and phosphorus from animal feeding operations can potentially have adverse effects on the environment; however, the utilization and losses of these nutrients from beef cattle feedyards need to be better understood. Scientists at the ARS Conservation and Production Research Laboratory, Bushland, TX\, conducted a nitrogen and phosphorus balance study at two large (greater than 20,000 head capacity) beef cattle feedyards in the Southern Great Plains. On average, approximately 31% of fed nitrogen was excreted in feces and 55% was excreted in urine. Over time, 48% of the excreted nitrogen was retained in the manure pack and 52% was apparently lost to the atmosphere via volatilization. However the values were greatly affected by diet and season. These data will be useful for nutrient management planners in preparing nutrient management plans for beef cattle feedyards and also in evaluating nutrient losses from feedyards.

Invented and Developed a Second-Generation Treatment System for Management of Livestock Manure. ARS Scientists at Florence, SC and business cooperators have developed a streamlined second-generation swine manure management process that delivers healthier pigs, healthier profits, and a healthier environment. A U.S. Patent 7,674,379 was issued in 2010. The system used solid-liquid separation and nitrogen and phosphorus removal processes that replaced traditional anaerobic lagoons with a system that produces a clean, deodorized, and disinfected effluent. It was certified by the State of North Carolina as an Environmentally Superior Technology (EST) due to its efficacy in reducing problems of ammonia emissions, excess nitrogen and phosphorus, pathogens, odors, and heavy metals. North Carolina and USDA NRCS's Environmental Quality Incentives Program started a statewide Lagoon Conversion Program (LCP) that provides financial support to livestock farmers installing an EST for manure management. The revamped system met EST standards at one-third the cost of the previous version. The new system also cut emissions of methane and nitrous oxide—powerful greenhouse gases—by 97 percent. Animal health and production also benefited: Swine daily weight gain increased, feed conversion improved, and animal mortality decreased. Using the second-generation system instead of the lagoon system, the farmer sold 61,400 pounds more hogs –a 5.8% increase- per growing cycle. This technology was featured as an example of five carbon-reducing technologies that can quickly create green jobs in America in the report "Manufacturing Climate Solutions: Carbon-Reducing Technologies and U.S. Jobs," that was presented at the first Middle Class Task Force meeting organized by the White House. The new technology is being commercialized by Terra Blue Inc., of Clinton, NC. The scientists received the 2010 Federal Laboratory Consortium (FLC) for Excellence in Technology Transfer.

Pathogens and Pharmaceutically Active Compounds

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. Livestock and poultry can also be re-infected not only via water and air, but from other vectors such as birds, rodents and insects. 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*. Pharmaceutically active compounds such as hormones and antibiotics may also be present in animal waste and disseminated in the environment. The potential for serious health effects both on and off the farm, the lack of knowledge about pathogen survival in manure during collection, storage, treatment and application, and uncertainty about fate and transport of pathogens in soil, water and air from the animal production site or manure application area, clearly point to the need for research on these issues.

Selected Accomplishments

Troughs as a hidden source of Johne's Disease. *Mycobacterium avium* subsp. *paratuberculosis* (*M. paratuberculosis*) causes Johne's disease, a chronic intestinal infection that affects ruminants such as dairy cows. This disease can cause losses of as much as $200,000 per year in a herd of 1,000 dairy cows. A continued increase in the number of cases of Johne's disease among dairy cattle suggests that there may be uncharacterized sources of contamination on farms. Scientists from the ARS Laboratory in Bowling Green, KY evaluated differences in the ability of the bacteria to adhere to and persist on the surfaces of different livestock watering trough materials. Researchers found high concentrations of *M. paratuberculosis* on all trough materials within three days of inoculating trough water with the bacteria and they persisted for more than 149 days. Persistence of *M. paratuberculosis* was lowest on stainless steel, followed by plastic, galvanized steel and concrete. To reduce exposure of susceptible animals to *M. paratuberculosis* on infested farms, best management practices aimed at reducing slime build-up on trough surfaces should be included in any Johne's control plan.

Association of *Enterococcus* species and antibiotic resistance with specific pollutant sources. Enterococci are widely used as indicator of fecal contamination of waterways in most urban areas throughout the United States. Repeated exposure of these bacteria to antibiotics may result in antibiotic resistance and become a serious public health threat. This research was conducted at the ARS Salinity laboratory in Riverside, CA to investigate the influence of the apparent source of *Enterococcus* in waterways on their resistance to a number of antibiotics. *Enterococcus* species showed multiple resistances to ciprofloxacin, erythromycin, and tetracycline. Resistance to tetracycline was most prevalent in samples collected from sediments that were impacted by agricultural activities, while ciprofloxacin and erythromycin resistance were prevalent in samples impacted by urban runoff. This information will provide useful information for water utilities on microbiological pollutant types and sources affecting the Santa Ana River and can help the development of best management practices for water quality improvements.

Presence of intestinal tract bacteria opportunistic pathogens in dairy lagoons. Lagoon wastewater at dairies is a potential source of water that can be recycled for flushing cattle alleys or other uses; however, it is also a potential source of pathogens and bacterial toxins (endotoxins). Scientists at the ARS Conservation and Production Research Laboratory, Bushland, Texas, conducted studies to estimate the presence of pathogens and endotoxins in dairy lagoons and other dairy water sources. Dairy lagoon water contained endotoxins, *Salmonella* and *Escherichia coli* pathogens, as well as fungi. *Salmonella ssp*. were also recovered from the milking barn, ditch effluent, settling basin, feed alley flush water, and center pivots used for irrigation. Because dairy lagoon wastewater is a potential source of opportunistic pathogens and endotoxins, care is needed in the use of this resource; however, catabolic fungi present in wastewater may decrease pathogen loads.

Aerosolized Antibiotic Resistant Poultry Bacteria. Antibiotic resistant bacteria may shuttle in a resurgence of long controlled diseases. The presence of resistant bacteria in colonizing poultry concentrated animal feeding operations (CAFO's) has long been known and can be a nuisance not only to human workers but the poultry occupants as well. The presence of these bacteria in poultry litter has been documented; however, their presence in poultry house aerosols has not been demonstrated. ARS scientists in the Genetics and Precision Agriculture Research Unit at Mississippi State, MS, have completed a study in a commercial broiler house in which they measured the antibiotic resistance patterns of aerosolized *Staphylococcus*, *Escherichia coli*, and *Enterococcus*. Resistance increased in the litter and aerosols as the flock cycle progressed through the sell-off period. Resistance in aerosols dropped to baseline levels between flocks; however, litter levels remained elevated. This type of data demonstrates there may be a need for worker protection and better control of aerosols to limit potential house-to-house contamination by resistant bacteria.

Byproducts

Each year millions of tons of agricultural, municipal and industrial byproducts are generated in the United States. These materials are frequently considered to be wastes and are often disposed in landfills. However, many of these materials have characteristics that make them potentially useful to improve soil properties

for enhanced crop production, to prevent movement of contaminants to critical bodies of water, and to lower energy inputs in agricultural systems. Research is being conducted to determine benefits and risks of the materials, to develop and evaluate the effectiveness and economic benefits of byproduct-based management practices and control technologies, to document the environmental benefits of using these materials, and to develop guidelines for specific uses.

Selected Accomplishments

Feather pots produce larger and healthier plants. U.S. poultry producers generate yearly as much as five billion pounds of feathers, which are exclusively made of keratins. Unlike non-biodegradable petroleum-based polymers and plastics, these biopolymers contain nitrogen and other unique chemistries that can be exploited for specific uses. ARS scientists at Beltsville, MD have developed new biopolymer resins from waste feathers that were used to make pots for growing nursery crops. In greenhouse studies, begonias and lilies planted in these feather pots showed significantly enhanced growth and heartier root formation versus those in grown in traditional plastic pots. These new biodegradable pots are currently being tested for large scale use in the nursery and greenhouse industry.

Carbonization of swine solids. High temperature pyrolysis of swine manure and manure blends generates energy co-products similar to low grade coals and natural gas. Pyrolysis is the well known process of heating organic material in the absence of oxygen. It is currently the subject of a new study as a method for producing bioenergy and useful byproducts from agricultural biomass. ARS scientists in Florence, SC and an industry cooperator tested high temperature pyrolysis of swine manure and a blend of swine manure and ryegrass. In addition to the pyrolysis oil, the process generated a solid char product with an energy equivalent to that of some coals, and a combustible gas with an energy density slightly less than that for natural gas (methane).

Production of biochar from poultry manure. Because of high fossil fuel costs and limited disposal options, utilization of poultry litter as an energy source and suitability of the biochar byproduct as a soil fertilizer/amendment were determined through pyrolysis reactions and laboratory studies. Energy content measurements revealed that poultry litter had a heating value as high as 60% of coal's higher heating value. Biochar produced from poultry litter had a phosphorus content from 2 to and 4%, suggesting its potential use as a soil fertilizer.

Drinking water treatment residuals reduce selenium. Selenium is a naturally occurring trace element commonly found in soils in the western U.S. Selenium can cause reproduction failure, deformities, and die-off of migratory waterfowl, fish, insects, and plants. Drinking water treatment residuals are a solid byproduct, composed primarily of alum that is used to remove very small solid particles from the water supply. Collaborative research involving scientists from ARS in Kimberly, ID, Colorado State University, EPA National Risk Management Research Laboratory, and Argonne National Laboratory tested the ability of drinking water treatment residuals to reduce selenium in water. In this laboratory study, drinking water treatment residuals were added to selenium solutions. Results indicate that water treatment residuals can reduce waterborne selenium concentrations, and the adsorbed selenium is stable and not likely to be released back into the environment. Drinking water treatment residuals, which are a normal byproduct of drinking water treatment, can potentially be used to remove soluble selenium from areas impacted by selenium such as Kesterson Reservoir and the Salton Sea in California.

Non-composted municipal solid waste (MSW) processing byproduct improves U.S. Army training land reclamation. The costs to the U.S. Army for handling, management, and disposal of non-hazardous solid waste are significant and are expected to increase. A new MSW processing technology has been developed that sterilizes and separates the MSW and produces a light cellulose pulp called Fluff®. The U.S. Army has large areas that have been damaged due to extensive training activities. These areas often lack sufficient topsoil, organic matter, and nutrients necessary for successful revegetation. A study was conducted at Fort Campbell, KY, to evaluate Fluff® as a soil amendment for improving soil quality, plant growth, and revegetation success on training lands. The highest Fluff® rate improved native grass establishment. Plant phosphorus accumulation also increased significantly with increasing Fluff®

application. Because no adverse environmental effects were detected and Fluff® improved perennial grass establishment, MSW processing followed by land application of the resulting Fluff® should be considered to be a viable and beneficial alternative to current waste management and revegetation practices.

Future Research

National Program 206, Manure and Byproduct Utilization, ended in 2010. It has been replaced by National Program 214, Agricultural and Industrial Byproducts. The new projects in NP 214 were approved in 2010 and will be fully operational in 2011. The components of NP 214 are:

1. Management, Enhancement, and Utilization of Manure Nutrients and Resources
2. Manure Pathogens and Pharmaceutically Active Compounds (PACs)
3. Atmospheric Emissions
4. Developing Beneficial Uses of Agricultural, Industrial, and Municipal Byproducts.