FY 2011 Annual Report
National Program 214—Agricultural & Industrial Byproducts

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.

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

Beneficial use of nickel (Ni) hyperaccumulator plant as a nickel fertilizer. Research

by ARS pecan nutritionists in Byron, Georgia has shown that severe Ni deficiency has occurred in pecans in the U.S. Typically, Ni sulfate is marketed as a Ni fertilizer for crops such as pecans that need supplemental Ni. Previous research has shown that the plant Alyssum is a hyper accumulator of Ni from soil. Research was conducted to evaluate the use of Ni extracted from high-Ni soils by Alyssum Ni hyperaccumulator biomass as an alternative Ni fertilizer. The Alyssum extract was just as effective as the Ni sulfate chemical, and could be produced at far lower cost. Use of ground biomass to fertilize pecan and other crops which respond to fertilizer Ni could become an organic farming practice.

Midwest cropping system effects on soil quality. Cropping systems may improve or decrease soil quality depending on the specific crop rotation, nutrient amendments, and tillage practices employed. An ARS researcher in Marshfield, WI, collaborated with Univ. of Wisconsin researchers to determine the effect of six cropping systems in the Wisconsin Integrated Cropping Systems Trial on soil properties after 18 years of continuous treatments. Treatments included three grain-based systems (continuous corn and two grain rotations), two forage-based systems (organic and conventional), and a grass-legume pasture. Results showed that different Midwest long-term cropping systems have significant effects on most chemical, physical, and microbial soil properties (soil quality indicators). In particular, the intensively managed grass-legume pasture was higher in most soil quality indicators than all other corn or forage-based systems. The alfalfa-based systems had higher levels of soil carbon and nitrogen and some physical variables than did the grain-based systems but soil quality indexes were not different. There were few differences in soil quality parameters between the conventional and organic dairy cropping systems, a result explained by the fairly similar crop rotations and manure inputs. Overall, on these productive, high-organic matters, prairie-derived soils under good management, all of the cropping systems in this study maintained an acceptable level of soil quality.

User-friendly model developed to predict annual phosphorus loss in runoff. Non-point source pollution of fresh waters by agricultural phosphorus (P) can limit water use for drinking, recreation, and industry. An ARS researcher at Madison, WI developed and validated a user-friendly spreadsheet model (Annual P Loss Estimator -APLE) to predict long-term changes in soil P and P loss in runoff for a wide variety of agricultural conditions. APLE is especially designed to assess the impact of manure management, including grazing or mechanical application, surface application or incorporation, rate and timing of manure application, and manure P content as a function of animal diet. Parts of the model have been incorporated into the WI P Index, and the model is being used to help evaluate and improve predictions by other P Indexes, which are used by producers and their consultants across the US to comply with the USDA 590 nutrient management standards.

Liming marginal acidic soils may be unnecessary if using poultry litter for cotton fertilization. Soils with borderline acidity have to be limed to correct the low pH before planting cotton or other row crops. But liming may not be necessary if using poultry manure in place of conventional synthetic nitrogen fertilizers. ARS scientists in the

Genetics and Precision Agriculture Research Unit at Mississippi State, MS, studied the productivity of cotton fertilized with manure versus a commercial nitrogen fertilizer in an upland soil with marginal soil acidity. Their results showed fertilizing with ammonium nitrate, an inorganic nitrogen fertilizer, further acidified the soil, elevated leaf manganese concentration to potentially toxic levels, and reduced lint yield. Poultry manure, unlike ammonium nitrate, maintained or reduced acidity of the soil, prevented the elevation of tissue manganese concentration, and improved lint yield. Fertilizing with poultry litter makes liming unnecessary for profitable cotton production in soils with marginal soil acidity and productivity.

Poultry manure application time impact. Although spring-applied litter has the best agronomic response, this is often not practical because of typical weather patterns in the southeast, thus forcing producers to apply broiler litter in the fall. However, fall application of broiler litter before a winter fallow results in substantial leaching losses of nitrogen (N) and reduces the potential fertilizer value of the manure. ARS scientists in the Genetics and Precision Agriculture Research Unit at Mississippi State, MS, studied the impacts of a cover crop of winter rye on fall application of litter. Overseeding a cover crop to fall-applied broiler litter synchronized available N with crop needs, maximized N use efficiency, and minimized the risks of leaching losses of N. This practice helps fill critical gaps in understanding whether detrimental effect of fall-applied broiler litter can be mitigated by a combination of cover cropping strategies. The management practice positively impacts the agronomic and economic aspects to the farmers and is currently being implemented in some areas in the region. A module based on this work was selected and written into a Continuing Education (CEU) article for Crops & Soils magazine and went out to approximately 14,000 certified crop advisers and soil scientists. Url is:
http://www.magnetmail.net/actions/email_web_version.cfm?recipient_id=720941971&message_id=1354045&user_id=Soc_Agrnmy.

New application technology to band poultry litter beneath the soil surface reduced nutrient losses in runoff. Use of poultry litter as a soil amendment often results in excessive nutrients in runoff water. ARS scientists at the USDA-ARS National Soil Dynamics Laboratory (NSDL) recently developed an experimental implement to place poultry litter beneath the soil surface. Use of this implement to subsurface apply poultry litter in soil can potentially reduce the impact that nitrogen (N) and phosphorus (P) loss from poultry litter has on water quality. Rainfall simulation studies were performed to evaluate how subsurface application of poultry litter in a bermudagrass pasture would impact nutrient losses in surface water runoff at two field sites containing soil from the Piedmont and Coastal Plain regions of the southeastern U.S. Subsurface banding of poultry litter was compared to surface applied poultry litter, inorganic fertilizer, and a nonfertilized control. Subsurface banding poultry litter reduced the impact of N and P loss in surface water runoff to levels observed in the non-fertilized pasture.

Plant growth-promoting rhizobacteria improved plant uptake of nitrogen. Rhizobacteria are root-colonizing bacteria that form mutually beneficial relationships with many plants. Previous research has demonstrated that plant growth-promoting

rhizobacteria (PGPR) can potentially increase plant growth. It has been speculated that one of the mechanisms for this is stimulated nitrogen (N) uptake by plant roots exposed to PGPR. Specifically, it is believed that the increased plant N is a result of increased fertilizer N utilization efficiency. ARS scientists at the USDA-ARS National Soil Dynamics Laboratory (NSDL) conducted studies that demonstrated PGPR could enhance plant uptake of N. Results showed that the dry biomass and N uptake in plants which received 70% to 90% of recommended N fertilizer with PGPR inoculation was comparable to plants that received full rates of fertilizer without PGPR. These results indicate that application of PGPR could be used to reduce fertilizer N application needed for crop production.

Managing slurry manure based on its carbon-to-phosphorus composition. Determining the fertilizer value and optimal amount of manure to apply to a crop in phosphorus-limiting manured cropping systems requires accurate knowledge of manure composition, the phosphate content, and conversion rate of organic phosphorus forms to the soluble phosphate by microbes under the conditions existing at the site of storage before land application. ARS scientists in Beltsville, MD demonstrated the linkage between organic-mineral phosphorus conversion to the manure carbon-to-phosphorus composition. As the ratio widened, the conversion of insoluble organic phosphorus to soluble phosphate increased and phosphate accumulated in the slurry regardless of how much phosphate is already present. On-farm manure handling and storage conditions should be managed to minimize this conversion to soluble forms that are easily carried away in water by adjusting the carbon content (manure solids) in slurries manure solids to reduce the slurry's carbon-to-phosphorus ratio and lower risks of high levels of mobile and easily lost phosphate to runoff when these manures are land-applied.

Supplementation of phosphorus for developing replacement heifers: bone development. When phosphorus is fed to cattle in amounts greater than what they can utilize, the excess is excreted in the manure. If phosphorus-rich manure is later spread on farm fields to provide nutrients for growing crops, it also may cause an excess of phosphorus in runoff that can promote the undesirable growth of algae in lakes. For growing dairy heifers, phosphorus is essential for bone growth and development. The amount of dietary phosphorus needed in dairy heifer diets is very similar to that found naturally in many forages comprising typical heifer diets; this suggests that adding supplemental phosphorus to heifer diets may not always be necessary. However, no long-term studies addressing this issue exist; therefore, a study was conducted by University of Wisconsin and USDA-ARS scientists at Marshfield (WI) with dairy heifers ranging from 4 to 22 months of age. Dairy heifers were fed diets with or without supplemental phosphorus resulting in dietary phosphorus concentrations of 0.29 or 0.39%. Results show that phosphorus supplementation for developing replacement heifers had minimal effect on the extent of frame development, bone density, or bone metabolism. Potentially, this information will help dairy producers and nutritionists formulate heifer rations that contain adequate, but not excessive, amounts of phosphorus so that the growth needs of the heifers are met without adding excess phosphorus to the environment.

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

Design and use of a Salmonella vaccine strain to reduce Salmonella presence and disease in swine. The foodborne pathogen Salmonella is a leading cause of food-related disease and death in the U.S. Salmonella are often present in the gastrointestinal tracts of both wild and domesticated animals. For example, Salmonella can be isolated from over 50% of swine production facilities. However, pigs that have Salmonella usually do not show clinical disease, but because they carry the bacteria in their gastrointestinal tracts, they are a potential food safety risk for pork consumers. Agricultural Research Service researchers in Ames, Iowa, designed and evaluated a Salmonella vaccine strain in swine to determine if vaccinated pigs would have reduced disease severity and gastrointestinal colonization upon exposure to a pathogenic Salmonella strain. Disease severity, Salmonella shedding in the swine feces, and Salmonella gastrointestinal colonization were significantly reduced in the vaccinated pigs compared to the non-vaccinated pigs. This Salmonella vaccine is a promising intervention for the reduction of Salmonella in swine, resulting in enhanced pork safety and decrease potential risks for the consumer.

Mathematical model for pathogen transport and retention developed. Existing mathematical models to simulate the movement of pathogens through agricultural soils and groundwater do not provide reliable predictions even under relatively simple, well defined conditions. Researchers at the USDA-ARS US Salinity Laboratory and the University of California at Riverside have developed a mathematical model for pathogen transport and retention. The model provides a clear conceptual explanation for many incompletely understood observations of pathogen transport and retention in soils, and helps to identify areas where additional research and theory development are still needed. This information will be of interest to scientists and engineers concerned with predicting the fate of pathogens in soils and aquifers.

Animal diet affects manure-borne pathogen transport. Animal diet can affect the physical, chemical, and microbiological composition of the resulting manure. For

example, the feeding of distiller's grains as part of a finishing diet for cattle is associated with higher numbers of the pathogenic *E. coli* O157:H7. Little is known, however, about the impacts of diet on the transport of manure-borne microorganisms once manure is land-applied. ARS researchers in Lincoln, NE, investigated bacterial and parasitic bacterial virus transport in runoff from fields amended with manure from animals fed either corn or 40% wet distiller's grain. They determined that feeding 40% wet distiller's grain increased the potential for viruses that specifically infect bacteria to move into the environment. This information is being used to develop land application practices that incorporate the use of manure as a nutrient source for crop production while minimizing potential adverse environmental impacts.

Cattle feedlot pens are more than just uncomposted manure. The public and much of the food safety community tend to think of E. coli O157:H7 as being synonymous with cattle feces and the feedlot pen that collects the feces is thought of as being just packed uncomposted manure. Using DNA-based bacterial community profiling, ARS researchers in Lincoln, NE demonstrate that the bacterial communities in the feedlot pen are distinct from those of the fecal source material. Fecal microorganisms face a challenging environment on the pen surface compared to the animal gastrointestinal tract that selects for the persistence of some microorganisms over others. A better understanding these environmental challenges facing fecal pathogens like *E. coli* O157:H7 can lead to new ways of controlling them.

Microbial risk analysis: manure vs. biosolids. The presence of microbial pathogens in manure and biosolids has long been recognized as a drawback to use of these waste residuals in settings where the public could be exposed to the pathogens. Regulations and recommendations in place for 20 years have minimized exposures, but recent national and foreign outbreaks of enteric illness call into question our understanding of pathogen inactivation and risk. ARS scientists in the Genetics and Precision Agriculture Research Unit at Mississippi State, MS, conducted an in depth quantitative microbial risk analysis using current (local), historical, and national data sets for various manures and municipal Class B biosolids. Risks were analyzed for a number of situations, including occupational and public exposures (raw vegetable consumption, aerosol exposure, etc.). Using empirical data and exposure modeling, the scientists determined that specific microbial risks differed for the respective waste residuals; bacterial risks are greater for manure, while viral risks are greater for biosolids. Using these models, the scientists estimated that for public risks to approach significant levels, a 'regrowth' step must occur that increases pathogens to detectable outbreak levels after residuals are applied in the environment; so applying residuals as field crop fertilizer under conditions that preclude or minimize pathogen regrowth poses minimal public risk. This research provided a first of its kind comparison of the two residual types and highlighted the need for more microbial incidence data.

Pathogen survival after land application of manure. Enteric pathogens on soils and plants fertilized with manure can pose risks to grazing animals and humans if the pathogens survive or grow in the soil or plant environments. ARS scientists at the Genetics and Precision Agriculture Research Unit at Mississippi State, MS, studied the

survival of naturally occurring bacterial pathogens and fecal indicator bacteria in swine manure lagoon effluent during and immediately following land application in a commercial farming operation. Bacteria were monitored in aerosols, soil, and on grass leaves. Survival of most indicator bacteria and pathogens was intermittent and most bacteria were either killed within 72 hours of land application or were diluted in the application process to levels below cultural detection limits in the soil and grass environments. Aerosolized pathogens were rarely detected. This study established that bacterial pathogens known to be present in swine manure were rarely detected in environmental samples after land application of lagoon effluent suggesting that: 1) land application of lagoon effluents dilutes bacterial pathogens and mitigates potential risks; and 2) efforts to track pathogens, such as from an outbreak of enteric illness, back to manure-contaminated plants or soil will require development of more sensitive detection techniques than those currently available.

Poultry litter provides biological control of spores of plant pathogenic fungi in soil. Species of *Bipolaris*, *Curvularia*, and *Exserohilum* are plant disease-causing fungi that attack leaves and stems of many turfgrasses and cereal crops and also invade soil where they can infect roots and kill plants. The potential of poultry litter to provide biological control of spores of four species of these fungi in soil was evaluated for the first time. ARS scientists in the Genetics and Precision Agriculture Research Unit at Mississippi State, MS, placed spores into porous nylon membranes, incubated them in moist soil for two weeks with and without poultry litter added at 4% and 8% by weight, retrieved spores, and evaluated their ability to germinate. In repeated experiments, spores of all species incubated in soil without litter germinated at frequencies of 70-87% following their retrieval. When spores were incubated in soil containing 4% litter, germination was reduced to 2-42% among the four fungi, and with 8% litter, it was further reduced to 1-17% with many spores visibly fragmented or disintegrated. These results indicate that poultry litter may provide significant biological control of spores of four species of plant pathogenic fungi when incorporated into soil, but its effectiveness as a biological control material differs among the species.

Comparative die-off of *E. coli* 0157:H7 (Escherichia coli) and fecal indicator bacteria in pond water. *E. coli* 0157:H7 is the cause of bloody diarrhea in humans and has been the cause of large-scale foodborne and waterborne illnesses worldwide. Several researchers have reported on the persistence of this pathogen in surface waters of watersheds containing beef and dairy cattle, which are often the principal sources of this pathogen. Researchers at the J. Phil Campbell, Sr., Natural Resource Conservation Center in Watkinsville, GA designed experiments that demonstrated die-off rates of indicator bacteria were several times greater than the die-off rate of *E. coli* 0157:H7. Unlike the fecal indicator bacteria, the strain of *E. coli* 0157:H7 the researchers used in their experiments appeared less susceptible to the effects of solar ultra violet (UV)-radiation and predation from the natural microbial community. The greater persistence of *E. coli* 0157:H7 in environmental surface waters can result in infectious levels in waters when the levels of the indicator organisms are below the criterion of water impairment. This is important information for regulatory agencies

Concentrations, viability, and species distribution of *Cryptosporidium* in waste lagoons of swine operations in the Southern Piedmont and Coastal Plain of Georgia. Waste lagoons of large-scale swine operations have been implicated as a potential source of the protozoan parasite *Cryptosporidium* that is pathogenic to humans. Applications of lagoon effluent to cropped and hayed fields are potential sources of surface water contamination and risks to public health. Based on samples of the waste lagoons at 10 swine operations, scientists at the J. Phil Campbell, Sr., Natural Resource Conservation Center, Watkinsville, Georgia, and Cornell University, Ithaca, New York showed that *Cryptosporidium* parasites were present in all of the waste lagoons. The viability of the *Cryptosporidium* ranged between 2 and 12% of the total number of parasite eggs detected in the samples. The genetic analysis of these parasites indicated that 75% of *Cryptosporidium* parasites observed were specifically adapted to pigs. These parasites would only be pathogenic to humans with compromised immune systems. Only five of the 407 samples were identified as the species of *Cryptosporidium* that is pathogenic to healthy humans. Results of this research indicate that although swine waste lagoons are almost surely contaminated with *Cryptosporidium* parasites, the likelihood of the presence of the genetic type that is pathogenic to humans is relatively low. Thus, the human health risk associated with *Cryptosporidium* in swine waste lagoons is relatively low. This information can be used by the pork industry, agricultural extension agencies, and regulatory agencies to ensure safe application and management of swine waste effluent.

Atmospheric Emissions

Air emissions from animal production operations and land application of manure and other byproducts include particulate matter, ammonia, volatile organic compounds (that 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

Combining condensed tannins and borax can reduce production of emission and odors from swine manure. Reducing production of greenhouse gases and odorous compounds such as hydrogen sulfide is an important goal for large-scale swine production operations. Condensed tannins, which are complex phenolic compounds naturally found in plants and trees, were studied for their abilities to inhibit bacteria present in stored manure. A collaboration of Bioenergy Research Unit scientists at the National Center for Agricultural Utilization Research, Peoria, IL, and Michigan State

University have demonstrated that tannins isolated from the quebracho tree in South America, in combination with borax, will reduce overall gas and hydrogen sulfide production from manure slurries studied in the laboratory. These results can now be applied towards reducing odors and greenhouse gas emissions from large-scale swine facilities. Such reductions are of great interest to swine producers, environmental protection agencies, and local residents that live near swine facilities.

Airborne endotoxin and microorganism concentrations decrease rapidly downwind from a dairy. Airborne microorganisms could be a human health concerns near dairy farms. ARS researches at Kimberly, ID, measured bioaerosol concentrations at a freestall dairy to assess concentration changes downwind from the dairy and assess diurnal and seasonal variations in concentrations. Results showed that airborne endotoxin and bacteria concentrations 150 ft from the dairy could be several-hundred times greater than background concentrations. These concentrations decreased to near background concentrations at 600 ft downwind. Although bioaerosol concentrations did not have a seasonal trend, concentrations did correlate with meteorological factors such as temperature and solar radiation. These results suggest a reduced risk for exposure to bioaerosols as distance from dairy operations is increased, which is useful information for creating offset distances for new residential or commercial developments near dairy farms.

Determining the effect of animal diet on air emissions from feedlot surfaces. Air emissions from animal feeding operations affect the environment and pose potential nuisance concerns to downwind neighbors. Based on laboratory studies, there is evidence that animal diet impacts the types and amounts of air emissions from manure. ARS researchers at Clay Center, NE, developed a method for evaluating the spatial distribution of air emissions at the field-scale, and determined that diet had an effect on the spatial distribution, types and quantities of odorants produced by manure. Having the ability to predict the locations of elevated air emissions will allow producers to use cost-effective precision management techniques to minimize air emissions from feedlot surfaces.

Ammonia emissions from dairy farms and beef feedlots: A review. Ammonia is a gas composed of nitrogen and hydrogen; thus, ammonia emissions from cattle feedlots and dairies are a significant loss of potential fertilizer nitrogen from animal feeding operations and a source of potential environmental problems. A group of experts in the field of ammonia emissions, including scientists at the ARS Conservation and Production Research Laboratory, Bushland, TX, and other ARS and university scientists, collaborated to produce a comprehensive review that focused on ammonia chemistry, physics, animal interactions, measurement methodologies, emission sources and magnitudes, and modeling of emissions. This big-picture approach was published as an invited review article in the Canadian Journal of Animal Science and gives scientists, regulators, action agencies, and policy makers state-of-the-science knowledge to help understand the factors that control and contribute to ammonia emissions and how they may be controlled.

Methane emissions from Southern High Plains dairy wastewater lagoons in the

summer. Methane is a powerful greenhouse gas that can contribute to global climate change. A major source of methane at dairies may be wastewater lagoons; however, the contributions of methane from dairy lagoons in the southern High Plains have not been quantified. 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 at a 3,500-cow dairy that included measuring methane emission from lagoons. Daily release of methane from the lagoons averaged 402 kilograms per hectare, or 210 grams of methane released for each cow in the dairy. These results show that uncovered wastewater lagoons can be a significant source of methane at dairies and offer producers a potential management method to reduce methane losses.

Seasonal and annual ammonia emissions from southern High Plains beef cattle feedyards. Ammonia that escapes as a gas from beef cattle feedyards is a loss of valuable fertilizer nitrogen and can negatively impact sensitive ecosystems and degrade air quality. However the quantity of ammonia emitted from feedyards and the factors controlling those losses have been poorly understood. 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, continuously measured ammonia emissions from two feedyards over a two-year period. The major factors affecting ammonia emissions were ambient temperature and dietary crude protein concentration. Averaged over the two years of the study, 52% to 59% of nitrogen in the feed was lost as ammonia at the two feedyards. These results are the most extensive measures of ammonia emission from feedlots available, and they provide an important database that can be used by scientists to validate and verify process models of emissions, provide the cattle industry with accurate science-based ammonia emissions data to meet regulatory requirements, and give regulators more accurate, comprehensive data from which to build ammonia emissions inventories.

Redesigned ammonia scrubber. Ammonia, dust, odiferous compounds, and pathogens are emitted in the exhaust air from poultry and swine facilities. During the past year, ARS researchers from Fayetteville, AR, redesigned an ammonia scrubber for purifying air being exhausted from these facilities. This was accomplished with the aid of engineers and scientists brought in from Delaware, Mississippi, Oklahoma, and Tennessee. The new design allows for improved removal of ammonia from the air while increasing the airflow through the scrubber. This technology will now reduce ammonia concentrations emitted from poultry houses by 75% or more.

Novel bacteria for wastewater treatment. Investigators at Florence, SC, discovered a novel bacterium having the characteristics of oxidizing ammonia and releasing nitrogen gas under anaerobic conditions. The novel bacterial strain *Candidatus Brocadia caroliniensis* may be used for the treatment of wastewater having undesirable levels of ammonia, including agricultural, industrial, or municipal wastewaters. Compared to conventional biological nitrogen removal methods, this microbial method uses 60% of the energy normally required for aeration and does not require external carbon addition. In addition, by-products do not include greenhouse gases (methane and nitrous oxide).

This leads to a significant decrease in operational costs and provides possible environmental credit benefits for the users of this new technology.

Systems and methods for reducing ammonia emissions from liquid effluents and for recovering ammonia. ARS researchers at Florence, SC, invented new methods for the removal, recovery and use of ammonia from ammonia containing liquid effluents such as animal and municipal wastewater. The invention produces a concentrated non-volatile ammonium salt. The potential benefits are reduced ammonia emissions from liquid manure, cleaner air inside the barns with benefits to animal health, and recovery of ammonia as a concentrated liquid nitrogen reusable as a plant fertilizer.

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

Develop new, value added products from industrial byproducts (coal ash). As a result of the bombing of the Alfred P. Murrah Federal Building in downtown Oklahoma City on April 19, 1995, new regulations on licensing, sale and shipping of ammonium nitrates were developed to prevent a possible repeat of the Oklahoma bombing. Additionally, several government agencies are interested in reducing the value of ammonium nitrate as an ingredient in bombs by encapsulating ammonium nitrate in byproducts such as fly ash and flue gas desulfurization gypsum that are produced from electrical power plants. Research by an ARS scientist at Beltsville, Maryland, has demonstrated in greenhouse and field studies, that encapsulated ammonium nitrate was as effective as un-encapsulated ammonium nitrate for crop production, without increasing unwanted metals concentrations in soil and plants from the byproducts.

A better use for waste chicken feathers. Over four billion pounds of chicken feather waste is generated by the U.S. poultry industry each year. Although feathers are typically disposed of in landfills, a new use for feather fiber is as a component of biopolymers. The primary advantage of feather-based biopolymers is that they reduce the use of petroleum-based feedstocks. However, an added benefit of some biopolymers is that they degrade relatively quickly under composting conditions. Since the fate of feather-based biopolymers during composting has not been studied previously, the aim of this study

was to characterize the biodegradability of two biopolymers containing different amounts of poultry feather fiber. Results from experiments conducted by ARS scientists in Beltsville, MD showed that feather fiber was not degraded in either biopolymer after composting feather-fiber biopolymer fragments under standard conditions (60 days at 135 F). Raw feather fiber (primarily composed of the protein keratin) is itself quite resistant to microbial breakdown. However, results from other studies have shown that raw feather fiber can be degraded using special keratinase-producing fungi and bacteria. Additional studies are needed to see whether these organisms can speed the degradation of feather-fiber bioplastics.

Net energy values of wet distiller's grains. The use of wet distiller's grains, a byproduct of the grain-based bioethanol industry, in beef cattle finishing diets has increased exponentially in the past few years; however, the true net energy values have not been determined. Using a respiration calorimetry system, ARS researchers at the Conservation and Production Research Laboratory, Bushland, TX, determined that the net energy for maintenance and net energy for gain values of wet distiller's grains were similar to that of steam-flaked corn. In addition, when the diets were formulated to be equal in total fat content, feeding wet distiller's grains did not affect enteric production of the greenhouse gas methane. These net energy values can be used by nutritionists to better formulate and balance finishing diets and to better predict animal performance.

Turning wood industry waste into nursery growing media. WholeTree (WT) and Clean Chip Residual (CCR) are potential new nursery substrates that are byproducts of the forestry industry containing high wood content. Initial immobilization of nitrogen is one concern when using these new substrates; however, the addition of composted poultry litter (CPL) to substrates containing high wood content could balance initial nitrogen immobilization and provide an inexpensive fertilizer source for growers. ARS scientists at the USDA-ARS National Soil Dynamics Laboratory (NSDL) conducted experiments on these alternative substrates with poultry litter addition in nursery production. Results indicate that nitrogen immobilization can be overcome in WT and CCR substrates mixed 6:1 on a volume basis with composted poultry litter. Use of composted poultry litter in WT and CCR substrates could provide an alternative to traditional pine bark and peat based combinations in container production while providing poultry producers an environmentally sound means of waste disposal.

Biochars made from manures and crop residues improve soil carbon sequestration, water storage, fertility, and remove harmful chemicals. Investigators at the ARS Florence location produced biochars, a charcoal-like product, during carbonization of manure and plant waste materials using both thermal and hydrothermal processing. Both of these processes were optimized to produce biochars with diverse chemical and physical properties. Laboratory research showed that biochars made from nut shells were effective at increasing soil carbon sequestration while biochar made from grasses increased soil water storage. Manure biochars contained plentiful plant nutrients such as nitrogen, phosphorus, and potassium, but were blended with other plant-based biochars to produce a more nutrient balanced fertilizer-like product. Location scientists also discovered that hydrochar, the biochar made from hydrothermally processing poultry

litter, can be used as an environmental adsorbent for effectively removing harmful chemicals such as endocrine disrupting chemicals and estrogens. Production of these biochars and their blends leads to an alternative use of agricultural byproducts that can increase soil carbon sequestration and water storage, provide essential plant nutrients and reduce levels of contaminants in soils.

Risk assessment for beneficial use of flue gas desulfurization (FGD)-gypsum in agriculture. ARS researchers and others have been conducting research to evaluate the beneficial use of FGD-gypsum in agriculture. ARS is cooperating with the US-Environmental Protection Agency in conducting a full risk evaluation of this use to provide information needed to make regulatory decisions about FGD-Gypsum use as fertilizer and soil conditioner. The electrical generating industry manufactures FGD-gypsum by removing sulfur dioxide from exhaust gases. Field tests have been being conducted to assess the ability of FGD-gypsum to reduce the runoff of phosphate from soils including soils amended with poultry litter on the surface of hay fields. To date, research has shown that application of FGD-gypsum can significantly reduce runoff phosphorus and arsenic. Other studies have not found any adverse effects of amending soils with FGD-gypsum and have not shown any differences in soils amended with FGD-gypsum compared to those amended with mined gypsum.