National Program 214 Agricultural and Industrial Byproducts
National Program Annual Report: FY2014

Introduction

The U.S. Department of Agriculture's Agricultural Research Service (USDA-ARS) National Program for Agricultural and Industrial Byproducts (NP 214) had another productive and dynamic year in FY 2014. Scientists in NP 214 continue to make extraordinary impact in diverse areas of research that address management and use of manure nutrients and resources, manure pathogens and pharmaceutically active compounds (PACs), atmospheric ammonia and greenhouse gas emissions from agriculture, and developing beneficial uses of agricultural, industrial, and municipal byproducts.

The overarching goal of NP 214 is:

> *To effectively and safely manage and use manure and other agricultural and industrial byproducts in ways that maximizes their potential benefits while protecting the environment and human and animal health.*

The total amount of manure, biosolids, and industrial and municipal wastes generated annually in the U.S. exceeds 1 billion tons. Most animal manure and biosolids, along with significant amounts of other agriculture and industrial byproducts, are applied to agricultural land because of the benefits they can provide, including nutrients for crop production and organic matter to improve soil properties. However, improperly managed manure and other byproducts can be a source of pollution when their constituents move offsite, posing a threat to soil, water, and air quality, and to human and animal health.

Farm sales of meat and milk in the U.S. in 2012 were valued at more than $128 billion annually. For animal production, new technology and economies of scale have driven a structural shift from small to large animal feeding operations (AFOs). The development of AFOs has often separated animal production from crop production. Consequently, less land is available for on-farm recycling of manure-derived nutrients to crops, despite the U.S. having more than enough agricultural land to use all manure nutrients. Because transportation costs inhibit its distribution, most manure is land-applied locally around animal facilities, often exceeding local need and demand for use as fertilizer. AFOs are now typically subject to regulations designed to prevent negative environmental impacts of manure generation, storage, and use. There is thus an increasing challenge to using manure on agricultural lands while protecting the environment, and a great demand exists for scientific research and information about effective management of manure to guide management, policy, and regulation.

In addition to manure, millions of tons of industrial and municipal byproducts are produced annually in the U.S. They are often considered to have little value and are frequently either disposed of in landfills or incinerated, at considerable expense. However, many of these byproducts are potentially useful on agricultural land or in horticulture, either individually or through blending, mixing, or treating with other byproducts. Byproducts have many characteristics that may make them useful for direct land application, soil reclamation and remediation, as components of manufactured soils and composts, or as animal feedstuffs. Research and development is needed, however, to determine the composition and bioactivity of these products and to determine potential hazards and appropriate uses. At this time, state and federal regulatory agencies lack analytical tools to make reasonable policy decisions regarding the beneficial use of byproducts in agriculture or horticulture. Protocols and methodology standards are needed to enable regulatory authorities to examine and approve byproducts use. Treatment

technologies and management practices to make these products usable will reduce potential environmental hazards, reduce disposal costs, and increase the cost-effectiveness of agriculture.

USDA-ARS recognizes the value of manure and other agriculture and industrial byproducts and established NP214 as a primary area of research and as a link between the research community, agriculture and industry stakeholders, and the broader public. During FY 2014, 41 full-time scientists working at 14 locations across the U.S. actively engaged in 15 ARS-led and 43 cooperative research projects. Research conducted under NP 214 occurs at locations and scales ranging from a laboratory bench top or growth chamber to 10,000-head dairies. The gross fiscal year 2014 funding for NP214 was $20 million.

New additions to the NP214 team in 2014 are:

- **Heidi Waldrip** joined the Livestock Nutrient Management Research Unit in Bushland, TX, as a Research Chemist after serving as a post-doc at the location. She has a Ph.D. in soil science from the University of Maine and is now focused on characterizing the fertilizer value of open-lot feedyard and dairy manures, and in developing mechanistic models to estimate greenhouse gas and ammonia emissions from beef cattle feedyards and open-lot dairies.

The following scientists retired from the ranks in NP214:

- **Patrick G. Hunt** of the Coastal Plains Soil, Water, and Plant Research Center, Florence, SC.

NP 214 lost the following scientist in 2014:

- **Cherie Ziemer,** of the Agroecosystems Management Research Unit, Ames IA, passed away in 2014.

The distinguished record of service of these scientists is recognized world-wide, and they will be missed in NP214.

The following scientists in NP 214 received prominent awards in FY 2014:

- **Scott Bradford** of the Contaminant Fate and Transport Research Unit, Riverside, CA was named a Fellow of the American Society of Agronomy and a Fellow of the Soil Science Society of America
- **Ariel Szogi,** of the Coastal Plains Soil, Water, and Plant Research Center, Florence, SC, was recognized as Fellow of the American Society of Agronomy.
- **Ariel Szogi, Matias Vanotti,** and **Patrick Hunt**, of the Coastal Plains Soil, Water, and Plant Research Center, Florence, SC, received from the Federal Laboratory Consortium the Award for Excellence in Technology Transfer for the "Quick Wash Process for Removing and Recovering Phosphorus from Wastes."

The quality and impact of NP 214 research was further evidenced in FY 2014 by the following:

- Over 85 refereed journal articles
- 1 new invention disclosure
- 1 current cooperative research and development agreement and 5 material transfer agreements with stakeholders
- 27 new technologies developed, and
- Administration or development of 3 web sites for academia or stakeholders.

In 2014 NP 214 scientists participated in research collaborations with scientists in Australia, Brazil, Colombia, Japan, Mexico, South Korea, Spain, Turkey, and Uruguay.

This section summarizes significant and high impact research results that address specific components of the FY2009 – 2014 action plan for the NP 214. Many of the programs summarized for FY 2014 include significant domestic and international collaborations with both industry and academia. These collaborations provide extraordinary opportunities to leverage funding and scientific expertise for USDA-ARS research by rapidly disseminating technology, which enhances the impact of ARS research programs. Accomplishments address 4 categories of research:

1. Management and use of manure resources
2. Manure pathogens and pharmaceutical compounds
3. Atmospheric gas emissions
4. Beneficial use of byproducts

Component 1. Management, Enhancement and Utilization of Manure Nutrients and Resources

Efficient treatment of ammonia, odor, pathogens and phosphorus in 3rd generation manure treatment technology. New or expanding swine operations in North Carolina are required to meet some of the strictest environmental standards in the world. These standards include emissions of ammonia and odor; the release of pathogens; and nutrient and heavy metal contamination of soil and groundwater. Scientists at ARS in Florence, South Carolina, together with industry and university cooperators, demonstrated and verified a 3rd generation wastewater treatment system for swine manure (U.S. Pat. 7,674,379) that could meet the environmental standards at reduced cost. The technology was demonstrated full-scale on a farrow-to-finish swine farm that generates 75,000 gallons of manure per day. This treatment process meets the referenced performance standards and significantly reduces the potential for emissions of odor and ammonia, and the transfer of nutrients and pathogenic bacteria to surface and groundwater. The treatment process also provides a mechanism and market for the separated solids.

Early warning of unintended discharge from holding ponds. Unintentional discharge from feedlot runoff holding ponds can potentially contaminate soil and groundwater. Working with the Nebraska Cattlemen's Association, Nebraska Department of Environmental Quality, and AgraTek LLC, ARS scientists in Clay Center, Nebraska, developed an automated resistivity array that can be used as an early warning system for this discharge. The technology allows sub-surface observations and greatly expands the surface area monitored compared with traditional monitoring. The system notifies land managers via modem or cell phone when a spill occurs. This early notification allows for much faster response and clean-up times, improving the safety and environmental sustainability of the feedlot operation.

Ammonia volatilization from surface-applied poultry litter can account for one-fourth to one-half of the litter's ammonia nitrogen. ARS scientists in Beltsville, MD conducted a series of wind tunnel studies that evaluated methods to reduce ammonia loss, yet retain high surface residue cover for erosion control. The data showed that compared to surface-applied litter, ammonia volatilization decreased an average of 67% by light disking, and decreased 88% when litter was applied below the soil surface using a prototype applicator developed by ARS collaborators in Arkansas. These results demonstrate that subsurface injection of dry poultry litter can minimize ammonia loss, thus conserving nitrogen for row crops and reducing potential nitrogen losses to the environment.

New data improves computer model for estimating whole-farm phosphorus (P) loss from dairy farms. Nutrient loss in runoff from dairy farms can pollute local waters, but there is little

information in the U.S. about how much nutrient loss comes from pastures grazed by beef and dairy cattle. ARS scientists in Madison, Wisconsin, in collaboration with the University of Wisconsin, monitored runoff and nutrient loss from eight beef and dairy pastures for two years to develop accurate parameters for use in modeling. Annual precipitation runoff from the pastures varied from 3 to 10%, but sediment loss was very low due to well-established vegetation. Annual nutrient loss in runoff was also low, averaging less than 1 pound per acre of P and 2.5 pounds per acre of nitrogen. The scientists used the runoff data to update and validate the Annual Phosphorus Loss Estimator (APLE) computer model, which predicts annual phosphorus loss in runoff from cropland and pastures. The increased accuracy of the APLE model to estimate whole-farm phosphorus loss from dairy production systems will help producers identify the most effective and economical on-farm practices to reduce phosphorus loss from grazed pastures.

Phosphorus recovery from manure solids and municipal biosolids. Over-application of manure or municipal biosolids can result in excess soil leaching or runoff of P, which can lead to degradation of ground or surface water. A process called 'quick wash' developed by researchers at ARS in Florence, South Carolina, and patented by USDA (U.S. Pat. 8,673,046) can recover 80% of P from livestock manure solids or municipal biosolids. The quick wash process generates two products: 1) washed solid residue, and 2) concentrated recovered P material. The process selectively removes P from manure solid while leaving the nitrogen in the washed solid residue. The washed solid residue can be safely applied to crop land while the recovered P can be transported off-site in concentrated form to provide a recycled P source for use as crop fertilizer while minimizing P losses into the environment. USDA granted an exclusive license of the invention to a private company in Pinehurst, North Carolina. The quick wash process is commercially available for use in the recovery of P from poultry litter, solid animal manure, and municipal biosolids in the Mid-Atlantic region including the Chesapeake Bay.

Component 2. Manure Pathogens and Pharmaceutically Active Compounds (PACs)

Vaccine trials to reduce risk of *Salmonella* in swine. *Salmonella* is a leading cause of bacterial foodborne disease. In the U.S., more than 50 percent of swine farms experience *Salmonella* contamination; on-farm interventions are needed to reduce *Salmonella* in swine production and limit the potential risk of foodborne disease in humans. A *Salmonella typhimurium* vaccine has been developed by ARS researchers in Ames, Iowa, and is currently undergoing efficacy trials. To date, vaccine trial analysis indicates that swine vaccination reduces disease severity and gastrointestinal colonization. One advantage of the vaccine is that it allows the use of an industrial test, *Salmonella* lipopolysaccharide, which is used in Europe to monitor *Salmonella* status at the herd level. Swine producers will be able to use the new vaccine to differentiate infected from vaccinated animals.

Identifying sources of Shiga toxin *E. coli* in outbreak investigations. While most shiga-toxigenic *E. coli* outbreaks in humans are associated with food, some are associated with direct or indirect animal contact, such as at fairs or petting zoos. The methods that public health laboratories use to find these microbes are effective for human samples, but not for animal or environmental samples. As experts in isolating these microbes from complex environmental sources, ARS scientists in Lincoln, Nebraska consulted with public health officials in nine states in over a dozen outbreaks, to aid in identifying their sources. In ten investigations, ARS scientists were able to rapidly isolate the outbreak strain, providing laboratory confirmation of the outbreak, and facilitating the implementation of corrective measures so that similar outbreaks could be avoided in the future.

Component 3. Atmospheric Emissions

Better computer tools to estimate ammonia emissions from beef cattle feed-yards. Ammonia losses from cattle feed-yards represent both an air pollutant and a loss of nitrogen that could be recycled as a soil amendment. Ammonia emissions will be regulated by the U.S. Environmental Protection Agency in the near future; however, the EPA currently lacks an effective model to determine ammonia emissions or estimate effects of management strategies on ammonia fluxes from agricultural operations. ARS scientists in Bushland, Texas, and State College, Pennsylvania, have improved the Integrated Farm Systems Model to estimate feed-yard ammonia emissions. This model is more accurate than current EPA emission models and has the potential to be adapted by regulators, consultants, and producers to better estimate ammonia emissions and determine the effectiveness of different ammonia management strategies in minimizing ammonia losses in feed-yards.

Component 4. Developing Beneficial Uses of Agricultural, Industrial, and Municipal Byproducts

Gypsum application reduces soluble Phosphorus (P) losses to the environment from poultry litter applications. There are growing concerns regarding the fate of nutrients, especially P, from land application of animal waste. One approach to reduce runoff losses of P is to treat manure or the soil receiving manure with chemical amendments such as gypsum. A study using rainfall simulations to examine the impact of flue gas desulfurization (FGD) gypsum application on runoff nutrient losses was conducted on a Coastal Plains soil. Four rates of FGD gypsum were applied to plots of coastal bermudagrass, which had received application of poultry litter. Plots with FGD gypsum but no poultry litter and plots with no litter or FGD gypsum were also utilized. Rainfall simulation was used to generate water runoff and samples were analyzed for soluble reactive P (SRP) and other total and soluble elements. Heavy metals were also analyzed. Results indicated a 51% reduction in total SRP load with the application of the highest rate of FGD gypsum. Measurements of heavy metals in runoff were all found to be below detection limits. The results indicate that use of FGD gypsum on pastures receiving poultry litter in the Coastal Plains would be an effective method of reducing SRP losses to the environment. Results from this work resulted in gypsum use with poultry litter application being adopted as a Best Management Practice in Alabama.

Phosphate amendment to lead (Pb)-contaminated soils continues to reduce the bioavailability and bioaccessibility of soil Pb. Field test plots using phosphate, biosolids compost and iron oxides combinations were installed in 1997. In 2013, the soils were re-sampled to obtain longer equilibrated soils for both chemical (bioaccessibility) and mouse feeding (bioavailability) tests to examine the effect of soil treatments on Pb bioavailability. In addition, some Joplin, Missouri, soils were fed to quail to test whether soil treatments could reduce bioavailability to birds. Studies confirmed the persistent reduction in soil Pb bioavailability and bioaccessibility due to both phosphate and biosolids compost treatments. These *in situ* treatments can strongly reduce the risk from Pb in ingested soil at low cost compared to soil removal and replacement.