Action Plan: National Program 214
Utilization of Manure and Other Agricultural and Industrial Byproducts
February 2009

Goal

The goal of the Utilization of Manure and Other Agricultural and Industrial Byproducts National Program is to effectively and safely manage and use manure and other agricultural and industrial byproducts in ways that maximize their potential benefits while protecting the environment and human and animal health.

Relationship of This National Program to the ARS Strategic Plan: Outputs of NP 214 research support the "Actionable Strategies" associated with the performance measures shown below from the ARS Strategic Plan for FY2006 – 2011, Strategic Goal 2.0 Enhance the Competitiveness and Sustainability of Rural and Farm Economies, and Strategic Goal 6.0 Protect and Enhance the Nation's Natural Resource Base and Environment.

Actionable Strategies/Activities for Objective 2.1

- Develop technologies for the sustainable production and collection of biomass feedstocks, including on-farm methods to harvest, handle, transport, and store biomaterial such as energy crops, plant residue, and animal manure.
- Design on-farm systems to supply energy needs for on-farm use as well as for distributed energy generation of liquid fuels and electricity.
- Develop technologies that improve the energy efficiency and reduce the cost of converting biomaterials via biological or thermochemical processes into fuels and coproducts.
- Convert low value agricultural byproducts or their components into higher value food or biobased products.
- Develop improved and new techniques and technologies to convert agricultural products into value-added food or biobased products.
- Develop commercially viable biobased substitutes for petroleum-derived products.

Actionable Strategies/Activities for Objective 2.2

- Integrate new science-based knowledge, management practices, technologies, or decision support tools to optimize efficient, economical, and environmentally sustainable production systems that are size- and scale appropriate for a variety of farms and ranches.
- Create effective nutritional programs for food animal production systems that efficiently capture and utilize byproducts of biofuels production.

Actionable Strategies/Activities for Objective 6.1

- Develop measurement techniques to quantify the fate and transport of agricultural pollutants.

Actionable Strategies/Activities for Objective 6.2

- Develop and evaluate practices, technologies, and decision tools to measure, predict, and control emissions of particulate matter and gases from agricultural operations to enhance air quality and limit greenhouse gas emissions.

- Develop management practices, control technologies, and decision tools to reduce or eliminate atmospheric emissions, loss of nutrients, and offsite transport of pathogens and pharmaceutically active compounds from animal production operations.
- Develop guidelines for safe and effective agricultural uses of manure and selected municipal and industrial byproducts to lower production costs, improve soil properties, and reduce use of energy and petroleum-based products.

Relationship of this National Program to other related National Programs: There are projects that complement NP214 research conducted under other ARS programs including:
- NP101 Food Animal Production
- NP211 Water Availability and Watershed Management
- NP212 Climate Change, Soils and Emissions Research
- NP215 Pasture, Forages and Rangeland Systems
- NP213 Agricultural System Competitiveness and Sustainability
- NP305 Crop Production
- NP306 Quality and Utilization of Agricultural Products
- NP307 Bioenergy and Energy Alternatives

Research Components
The Utilization of Manure and Other Agricultural and Industrial Byproducts National Program is organized into four components:
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

Component 1. Management, Enhancement and Utilization of Manure Nutrients and Resources
Manure, biosolids, and other agricultural and industrial byproducts often contain components [e.g., nitrogen (N), phosphorus (P), potassium (K), carbon (C)] that can be used to improve plant growth or as a potential bio-energy source. The quantity of nutrients and energy in manure is primarily determined by the animal species and diet, and the post-excretion management and treatment of the manure. Because the quantity of readily available fertilizer nutrients is frequently limited or high in cost, recycling of these nutrients in manure and byproducts back into production agriculture is highly desirable. Therefore, land application is frequently the preferred method of utilizing animal manure, biosolids, and many other byproducts. In addition to their value as nutrients, manure, biosolids and other byproducts can enhance carbon storage, improve soil tilth, increase water holding capacity and root growth, as well as improve other soil biological and chemical properties. Electrical energy and transportation fuels such as ethanol, hydrogen, butanol and bio-diesel can also be recovered from the organic matter in manure and other byproducts via a variety of microbial and chemical methods.

Strategies to take advantage of the opportunities and resources identified above involve managing animal diets, manure, and other byproducts in order to maximize the quantity of nutrients that are beneficial in agriculture. These strategies are the basis for the four problem areas identified for this component. The problem areas identified are: (1) animal nutrition and management; (2) collection, storage, treatment and utilization of manure; (3) utilization of manure in integrated farming systems, and (4) energy recovery from manure and other agricultural byproducts.

Problem Statement 1A: Improving the Usability of Manure Nutrients through More Effective Animal Nutrition and Management.

Major factors controlling the type, quantity and form of nutrients in animal manures are composition and quantity of diet consumed, nutrient retention in the animal or in animal products, and, in some cases, the route of excretion by the animal. Retention of nutrients in livestock or their marketable products is typically less than 30% of total dietary intake. As a consequence, excretion of nutrients into urine and feces (manure) can be relatively high. For example, in cattle and swine, 70% or more of N, P, K, and S intake are subsequently excreted in the manure. Optimal formulation of animal diets is complicated by numerous factors such as variation in nutrient content and price of feed ingredients, variation in the nutrient requirements of animals, and other management factors. However, improvements in the diets of livestock and poultry can not only affect the retention of nutrients within the animal, but can also affect manure quantity, manure nutrient content, and ultimately, gaseous and runoff losses from livestock production facilities and subsequent field application of manure. Thus, it may be possible, through diet modification, to improve nutrient utilization efficiency, decrease nutrient excretion, alter the phytoavailability of nutrients in the manure, and thereby reduce the impact of animal production on the environment.

Because of the rapid growth of the bio-ethanol industry there has been a significant decrease in the availability of feed grains and a simultaneous increase in the quantity of distiller's grains (spent grain from ethanol production), and other milling byproducts available as a feed resource for livestock and poultry. However, the utilization of these byproducts as a feed resource can frequently be limited because of their high N, P, S, and moisture content. Feeding high levels of many byproducts can potentially result in a significant increase in the quantity of nutrients excreted in manure, alter the balance of nutrients in the manure, and thus alter the optimal utilization of that manure.

Research Needs

Animal production efficiency needs to be balanced with environmental impacts. Revising the nutrient content of diets can have dual benefits: 1) production efficiency can be increased and 2) nutrient losses to the environment can be decreased. Improvements are needed in animal feeding and management regimens in order to increase the proportion of dietary nutrients retained in the animal or animal products while decreasing the quantity of dietary nutrients excreted and lost to the environment. Information is also needed concerning the impact of diet manipulation and animal management on nutrient retention, the quantity and route of nutrient excretion, animal production, health and reproduction, manure composition, the bio-availability of manure nutrients to plants, and potential nutrient losses to the environment. Furthermore, research is needed to evaluate the nutrient availability of co-products from the biofuels industry and other alternative feed ingredients available to poultry and livestock producers and to develop feed processing, diet formulation, and feed additive recommendations that balance animal production and environmental outcomes.

In addition, potential interactive effects among feed components (i.e., fiber and protein) as they relate to nutrient retention and excretion are needed. A better understanding of the impact of feed processing (grinding, extrusion, steam flaking, etc.), feed additives (enzymes, microbial cultures, etc.), and feed formulations (i.e., feedstuff combinations) on nutrient retention and excretion is also needed. Studies are necessary to evaluate the impact of feed formulation on gastrointestinal microbial ecology, the ability of microbial metabolism to impact host nutrient utilization, and on host gene expression and the effects of host gene expression on nutrient utilization.

Anticipated Products

- Improved understanding of the effects of dietary carbon, nitrogen, phosphorus, potassium and sulfur concentrations and sources, and diet formulation on subsequent retention, and excretion of these nutrients, potential carbon, nitrogen and sulfur emissions, and phosphorus runoff losses from cattle, swine, and poultry feeding operations.
- Diet formulation, feed processing, and dietary management recommendations that improve carbon, nitrogen, phosphorus, potassium, and sulfur capture by cattle, swine and poultry, thereby decreasing manure nutrient loads and reducing the effects of animal production on the environment.
- Microbial-based and host gene-based technologies to improve nitrogen and phosphorus utilization in the animal, and thereby reduce nitrogen and phosphorus excretion, and reduce the impact of animal production on the environment.
- Feeding practices that optimize the utilization of agricultural byproducts such as distiller's grain as beef and dairy cattle, swine, and poultry feedstuffs while minimizing negative environmental impacts.
- Models that can be used by animal nutritionists and nutrient management planners to predict the effects of feeding strategies on animal production, carbon, nitrogen, phosphorus, potassium, and sulfur excretion, and manure nutrient composition.

Potential Benefits

- Enhanced farm profits through greater conversion of feed nutrients into marketable products.
- Decreased excretion of nitrogen, phosphorus, potassium, and sulfur in beef, dairy, swine, and poultry manure.
- Decreased losses of feed nitrogen, phosphorus, potassium, sulfur and carbon to the air or ground and surface waters.
- Increased conversion of feed nitrogen into dairy products, beef, pork, and poultry production.
- Increased nitrogen: phosphorus ratio in manure collected from beef, dairy, swine, and poultry feeding operations, thereby increasing its value as a crop amendment.

Problem Statement 1B: Maximizing the Value of Manure through Improved Collection, Storage, and Treatment Options.

Significant losses of nutrients can occur from manure in animal facilities or on pastures, during collection or storage, or soon after land application. For example, N in manure is especially susceptible to loss through ammonia volatilization, denitrification, leaching, and runoff. Because of ammonia volatilization losses, the ratio of N to P in manure often differs from that required by many crops. Thus, applying manure based on meeting crop N needs generally results in over-application of P; whereas, applying manure to meet crop P needs significantly decreases manure application rate, increases land requirements and manure transportation costs, and may require application of supplemental commercial N fertilizer to meet plant needs. Ratios of other nutrients in manure also frequently do not match the needs of plants. In addition, many nutrients such as C, N, and P are subject to chemical and biological transformations that alter their chemistry, plant availability, and environmental behavior following land application. Similar issues often occur with other agricultural byproducts. Pharmacologically active compounds (PAC) and endocrine disrupting compounds (EDC) from human and livestock waste are detectable in waste streams and can end up in the environment; however, their subsequent impact on humans, animals, and other organisms in the environment are largely unknown.

Most livestock and poultry feeding operations are required to control and capture animal manure and runoff in order to prevent manure from entering surface waters such as lakes and streams. The design and form of runoff containment facilities and methods of manure treatment and handling vary with location, climate, animal species, and other factors.

Research Needs

New practices and technologies are needed to efficiently collect and utilize runoff and manure from animal feeding operations while protecting soil, water and air quality. In dry-manure handling systems such as beef feedyards, alternative technologies need to be developed to control runoff and improve water reuse. In addition, tools need to be developed to locate manure build up within beef feedlots and in manure amended fields to mitigate excessive accumulation of nutrients, pathogens, PACs, and EDCs. Different manure management schemes can also influence ammonia concentrations inside animal houses. A better understanding of how these management schemes affect ammonia levels inside animal houses is needed. In liquid manure handling systems, improved separation technologies that concentrate and recover manure P and N need to be developed. Improved methods for lagoon clean-out and restoration are also needed.

Improved manure treatment and handling technologies need to be developed to manage nutrients, conserve water, mitigate PACs and EDCs, and reduce emissions of odors, pathogens, fine particulates (PM_{fine}), ammonia, and greenhouse gases (GHG). These treatment technologies need to be enhanced with the combined use of biological, chemical, and physical methodologies, as part of holistic systems.

Better methods to assess environmental credits from implementation of alternative manure treatment technologies need to be developed. Improved technologies to use constructed wetlands also need to be developed to prevent off-farm release of manure nutrients. A better understanding of nutrient release and utilization of co-digestion residuals from bio-energy production systems is also needed.

Anticipated Products

- Techniques that improve the recovery of runoff water and nutrients from open-lot animal feeding operations (AFOs) to produce value-added-products such as animal feed, wild-life habitat, and feedstock for energy recovery.

- Improved control and treatment technologies to better manage manure from swine, beef, dairy, and poultry AFOs to reduce odors, pathogens, PM_{fine}, EDC, PAC, ammonia, and GHG releases to the environment.
- Improved herd and management systems that enhance the collection of manure, especially urinary nitrogen, on dairy farms.
- Concentrated phosphorus and nitrogen fertilizers and soil amendments derived from manures produced on the farm using new technologies that extract, capture, and concentrate those nutrients.
- Improved methods for lagoon cleanup that extend design life and improve site remediation for facility closures.
- Improved procedures and guidelines to accurately quantify the foot-print of carbon and other nutrients from manure management procedures for credit trading and marketing.
- On-farm nutrient sensing tools and precision management techniques for controlling nitrogen and phosphorus imbalances, pathogens, PACs, and EDCs.
- Best management practices to reduce ammonia emissions and nutrient losses to both air and water from AFOs and manure storage and handling facilities.

Potential Benefits
- Decreased losses of nutrients such as nitrogen from manure between excretion and land application.
- Development of livestock manure-based soil amendments with improved nutrient balance for crop production or land reclamation.
- Decreased loading of deleterious concentrations of nutrients, pathogens, EDC and PAC to soil, surface and ground water from AFOs.
- Improved control of losses of nutrients, pathogens and EDC from AFO.
- Decreased manure nutrient build-up and spatial variability in soils receiving manure as an amendment.
- Improved animal house air quality and decreased animal mortality due to reduction of ammonia and other injurious gases and particulates from manure storage and handling systems within animal housing facilities.

Problem Statement 1C: Utilizing Manure in Integrated Farming Systems to Improve Profitability and Protect Soil, Water, and Air Quality

Increased complexity in agricultural production systems requires development of integrated farming systems in order to efficiently utilize manure resources and protect soil, water, and air quality. Land application of manure as a soil amendment and nutrient source is generally the most viable method of recycling animal wastes. Land application, however, does carry risk. Manure and other byproducts must be carefully managed if they are to be used beneficially in production agriculture. These materials are frequently bulky and their nutrients are usually less concentrated and released more slowly and less predictably than those in commercial fertilizers, so a greater quantity must be applied to meet plant nutrient requirements. However, the slow release property of many organic amendments can be a positive attribute if the material is appropriately managed. Over-application or mismanagement of manure can potentially result in excess leaching or runoff of N and/or P which can lead to degradation of ground or surface water quality. The risk of over-application of manures can be especially great in areas with high concentrations of animal production or when high-P byproducts constitute a significant portion of the diet. Trace elements (e.g., copper, selenium, etc.) and salts are also potential environmental contaminants in many manures and byproducts. Nutrients (e.g., N as ammonia, C as carbon dioxide or methane) can also be lost to the atmosphere from animal production areas, during handling and storage, and during land application.

Developing improved manure management practices that conserve nutrients and reduce detrimental impacts on the environment require basic knowledge of the fate and transport of specific nutrients for major soils and hydrologic conditions, for various cropping systems, and for various manure management schemes. For example, manure application method can have environmental effects because its effects on nutrient availability, ammonia and carbon dioxide emissions, nutrient leaching, and mineralization.

In addition to traditional grain agrosystems, silage, and newer bioenergy-based cropping systems provide an avenue for utilization of manure and byproducts. Insufficient return of nutrients and organic matter to these systems can lead to degradation of soil quality; whereas, manure application can provide organic matter and nutrients. Bioenergy-based systems represent a significant change to cultural systems and the agricultural landscape. They may have altered nutrient requirements and require different field-level and regional-level P and N management strategies. Depending on the crop species, harvest timing, and biomass production, bioenergy-based systems can result in increased utilization of manure and increased P removal from the farm soils.

Process-based numerical models are efficient tools for integrating site-specific data with current knowledge of the physical, chemical, and biological processes governing nutrient dynamics. Model results can expand assessment of the environmental impacts of wastewater pollutants and improve understanding of watershed-scale nutrient and manure-borne contaminant transport.

Research Needs

The fundamentals of nutrient transformations and transport must be understood in order to improve nutrient use efficiency and enhance manure nutrient assimilation by crops. Basic research is needed to evaluate the fate and transport of manure nutrients in the major soil-crop systems common to animal agriculture. This is the foundation for developing Best Management Practices (BMP). Nutrient concentrations and forms must be known in order to properly and efficiently utilize the nutrients present in animal manures. Nutrient transformations and their interactions with other manure-borne contaminants must be evaluated to optimize nutrient use efficiencies, the efficacy of treatment technologies, or the development of practical discharge mitigation methods. Improved understanding of the basic processes of the soil P- and N-cycles can be used to develop practical management practices to attain an optimal balance between production and potential environmental risks associated with nutrients in manure and other bio-nutrients.

New manure application methods and associated equipment need to be developed and evaluated. Application methods are needed that can improve nutrient use efficiency and incorporate manure to conserve N while maintaining adequate crop residue to protect the soil from erosion and runoff. These practices, and their associated nutrient management plans, must be based on sound understanding of the fate and transport of specific nutrients for major soils, hydrologic conditions, and cropping systems. These practices should be economically viable and environmentally sound, and should be evaluated at field, farm, and watershed as well as conventional plot scales. Cropping and pasture systems that integrate improved manure management with environmentally beneficial practices such as cover crops and conservation tillage are needed. Nutrient management strategies, soil nutrient speciation and transformations, and the approach to protecting the land resource in bioenergy cropping systems need to be evaluated and developed.

Land application management tools such as the widely-used P Index need to be improved to accommodate temporal and spatial variability in soils, landscape positions, and variability in P availability and transport arising from P speciation and transformations. The P Index needs to be validated in many areas in which it is being used, and a similar strategy for evaluating risks associated with various N management scenarios is needed to determine the potential impacts of manure application on N transport to air, rivers, lakes, and groundwater. There is a continuing need for improved understanding of P accumulation capacity, transport, and impact of alternative practices at scales from farm- to watershed.

New on-farm and real-time analytical and soil and crop-sensing tools and biological methods are also needed to evaluate manure nutrient availability, particularly for plant-available N and bioactive P. The impact of soil properties, climatic variables, and manure composition on manure N and P availability must be quantified so that manure N and P availability to crops can be accurately predicted. Expanded knowledge is needed that quantifies the linkages among C, N, and P cycling processes and incorporates this information into process-based models. Decision support tools are needed that incorporate all this information.

Alternative systems of manure utilization are also needed where land application is not a viable practice. To be adopted, these practices (both land and non-land based) should be effective, efficient, profitable, and fit into crop and pasture production systems used by the producer. On-farm treatments are needed to recover nutrients in a cost effective and, possibly, value-added form for sale and eventual transport and reuse away from nutrient–enriched regions.

Anticipated Products

- Expanded knowledge of the fate and transport of organic matter, N, P, and metals derived from manure in major animal production areas of the US.
- Improved manure application equipment and practices for solid and liquid manures that increase nutrient use efficiency and decrease losses of N and P via runoff, leaching and/or gaseous pathways.
- Decision aids for determining application rates, timing, and other management practices for various manure types.
- Integrated crop-soil-tillage practices to minimize leaching and runoff losses of manure nutrients applied in traditional food/feed and emerging bioenergy cropping systems.
- Best Management Practices such as buffer strips, grass hedges, and riparian filter strips that minimize off-site impacts of manure application to crops and pastures.
- Real-time tools for rapid nutrient detection in manure and soil and precision management of nutrient inputs.

Potential Benefits

- Adoption of management practices by farmers and livestock producers that minimize the loss or accumulation of animal manure nutrients at field, farm, and watershed scales.
- Improved crop nutrient uptake from manure and decreased field nutrient losses through runoff, leaching, and volatilization.
- Adoption of science based regulations and recommendations for agricultural production practices.
- Assimilation of data used in research for national program access to enhance research opportunities.
- Control points that can be used to evaluate potential strategies to reduce emissions and discharges to focus future manure and bio-nutrient fate research.
- Improved collaboration between locations, national programs, and institutions that will increase impact of process research for integrating research outputs into decision-aid tools for sustainable bio-nutrient management.
- Agricultural practices that will contribute to greater plant nutrient assimilation and reduced environmental footprints.

Problem Statement 1D: Using Manure and Other Agricultural Byproducts as a Renewable Energy Resource.

The US and world citizenry face a fundamental challenge in meeting future energy needs in an environmentally sustainable way. World energy consumption is projected to increase by 71% from 2003 to 2030. These issues are compounded by the increased release of carbon dioxide and other combustion byproducts that can potentially affect local air quality and global climate. In addition, energy generation must be balanced against the loss of N and organic matter which can be used in other manure utilization systems.

Animal feeding operations (AFO) generate large quantities of nutrients in manure that can potentially strain the nutrient utilization capacity of adjacent farm- and pasture-lands. Frequently, because of these environmental limitations associated with high livestock densities, sufficient land is not available near AFO to economically use animal manure as a soil amendment for on-farm nutrient recycling. Thus, alternative uses for manure and other byproducts are of interest.

Development of renewable energy from manure and other byproducts has received much attention due to diminishing availability and higher costs of conventional fossil fuels, especially transportation fuels. Because agriculture may be uniquely positioned to address some of these renewable energy issues, there has been increased interest in developing waste treatment technologies to produce energy from manure and other agricultural byproducts. Some energy recovery methods have the added environmental benefits of decreasing pathogens, controlling odor, and mitigating the introduction of PAC into the environment.

There are at least three basic pathways of extracting renewable energy from animal manure – biochemical, thermochemical, and thermal conversion. Biochemical pathways utilize microorganisms and/or enzymes to convert biomass into useful energy forms. Microbes are metabolically diverse and capable of bio-converting a wide variety of biomass into useful products such as ethanol, hydrogen, methane, lipids (used in biofuels such as diesel), and butanol in carbon neutral processes. Consortia of microbes, or individual strains may also be used to generate electricity in microbial fuel cells. Although relatively simple, optimal methane production systems have not been adequately explored. Co-digestion of animal manures with other biomass, such as food waste, may result in improved digester performance and biogas quality compared to digestion of manure alone.

Thermochemical pathways utilize heat and pressure under limited oxygen conditions to thermally decompose and convert biomass into gaseous (hydrogen, methane, carbon monoxide, etc.), liquid (bio-oil), and solid (char) biofuels; the type produced is dependent upon how the biomass is heated and pressurized. Thermochemical conversion efficiency is very high and normally requires only minutes or hours. Biofuels produced from thermochemical conversion of biomass can be directly used as feedstocks for other processes such as internal combustion engines. Char can be applied to land to improve soil fertility, reduce nutrient leaching, and sequester carbon.

Thermal conversion utilizes the energy contained in the volatile components of animal manure to produce heat. This heat can be used directly or to produce steam for turning turbines or heating biological reaction vessels. Fluidized bed combustion is one method that has received considerable attention, however, for optimal energy generation; the manure must be high in volatile solids but low in moisture and ash. Unfortunately, obtaining manures with these optimal characteristics has been difficult because of inconsistencies associated with manure collection and harvesting. Thus instrumentation that can estimate the energy content of animal manure before or during harvesting would improve the quality of the fuel for combustion.

Although microbial fuel cells, thermochemical conversion, anaerobic digestion of manures, co-digestion of manures with other biomass, and thermal conversion are potential technologies for on-farm production of biofuels and thermal or electrical power, the systems represent a major capital expense and the technologies are not yet fully developed. These technologies can also potentially provide new sources of farm revenue through electricity generation, collection of tipping fees, and carbon credits. Therefore, research is needed to investigate the efficacy of recovering energy from manure and other waste streams.

Research Needs

New technologies and feedstocks will need to be developed to improve the economics, efficiencies, and applicability of on-farm anaerobic digestion. Anaerobic digestion performance must be evaluated for digesters utilizing a range of feedstocks - manures, biomass sources, or blends of these resources. Optimal blending ratios of these resources also need to be determined. In addition, new digester technologies need to be developed using ‘dry’ high solids (>30%) feed stocks comprised of mixtures of manure and biomass crops or crop residues. Research evaluations of these new designs are needed to validate the economics and process effectiveness upon scale-up for both large and small agricultural operations.

In order to make butanol production from agricultural biomass commercially viable, butanol resistant microbial strains that both produce butanol more efficiently and produce fewer undesirable co-products must be developed. Because there is good potential to produce hydrogen and electricity from biomass, microbial fuel cells designed for manures, need to be developed. In order to more efficiently recover energy from manures by thermochemical conversion technologies, direct combustion or co-combustion systems, methods need to be developed to improve the energy value (i.e. BTU) and consistency of the product.

Most existing full-scale thermochemical conversion facilities utilize mostly woody biomass as a primary feedstock. Development of thermochemical conversion technologies are needed that can accept wide varieties of biomass feedstocks including animal manure and forage crops. In addition, economical down-scaling of thermochemical technologies to farm-scale is needed. The impact of applying biochar into soil must be better characterized and the potential for obtaining carbon credit for sequestering carbon into soil needs further investigation.

Anticipated Products

- Microbial fuel cells that generate electricity from manures.
- Bioreactors for hydrogen production from manures.
- More economical anaerobic digestion systems for combined heat and power production from manure.
- On site farm-scale pyrolysis/gasification systems to produce heat, power, and biofuels from manure.
- Collaborations with thermo-chemical conversion technology companies for implementing farm-scale energy production system.
- Protocols to quantify carbon credit via utilizing manures as feedstock for biological and thermochemical conversion systems.
- Feedlot surface manure mapping procedures and improved manure harvesting methods to maximize the energy value of harvested manure.

Potential Benefits

- Alternative fuels, electricity and value-added products will be economically produced from manure and other agricultural biomass using a variety of microbial technologies.
- Decreased carbon footprint for livestock production facilities.
- Manure and biomass feedstocks characterized for their suitability to be used in existing and emerging wastes-to-energy conversion systems.
- Bioenergy co-products suitable as soil amendments for enhanced production and carbon credits.
- Development of potentially profitable markets of carbon credit.

Component 1 Resources

ARS projects that are coded to National Program 214 address the research problems identified under Component "Management, Enhancement and Utilization of Manure Resources**."** ARS locations and scientists who are assigned to these projects include the following:

Ames, IA	Brian Kerr, Thomas Moorman
Auburn, AL	Allan Torbert
Beltsville, MD	Matt Smith, Thanh Dao, Jack Meisinger
Bowling Green, KY	Karamat Sistani, Carl Bolster
Bushland, TX	Andy Cole

Clay Center, NE	Bryan Woodbury
Fayetteville, AR	Philip Moore
Florence, SC	Matias Vanotti, Patrick Hunt
Kimberly, IA	April Leytem
Lincoln, NE	D. Miller, John Gilley, Brian Wienhold
Madison, WI	Bill Jokela
Mississippi, State, MS	Johnny Jenkins, John Read
Riverside, CA	Abasiofiok Ibekwe
Tifton, GA	Robert Hubbard

Component 2. Manure Pathogens and Pharmaceutically Active Compounds (PACs)
Animal and zoonotic pathogens, antibiotic resistant bacteria (ARB) and PACs may be found in manure, waste storage systems, soils where manure slurries are applied or in contaminated waters. Pathogens, ARB and PACs are a public health concern because they may be transmitted to animals and humans via contact with contaminated manure, soil, air or water, or from other colonized or infected animals. Farmers and regulatory agencies (EPA, CDC) cite the critical need for research to address issues surrounding these chemical and biological contaminants. Data are needed to better understand mechanisms for the shedding (deposition), survival and transport of potentially harmful microorganisms and PACs in livestock wastes, the adequacy of manure management techniques for reducing their levels in agricultural wastes, and to determine the fate of these contaminants in the environment after land application of livestock manure and wastewater. Therefore, the focus of this component will be to evaluate the occurrence, fate and transport of manure pathogens, ARB and PACs in agricultural systems.

Problem Statement 2A: Identifying Factors that Control the Fate and Transport of Pathogens from Animal Agriculture.
Daily exposure to pathogens in manure and other byproducts necessitates greater knowledge of their deposition, fate and transport, and identification of non-point sources of fecal contamination to protect human and animal health. Limiting exposure to pathogens is a major concern of public health officials throughout the world. An expanded understanding of the fate and transport of pathogens through watersheds and agricultural landscapes is required. For example, there is a need for better knowledge of the inactivation rates for pathogens relative to environmental conditions (e.g., temperature, moisture, etc.), the determination of their transport characteristics across variable soils and vegetative covers, and the application of effective tools for identifying non-point sources of fecal contamination. Data that fill these gaps will improve decision support tools, development of on-the-farm best management practices (BMPs) and the predictability of mathematical models.

Research Needs
Information is needed on pathogen inactivation and die-off as well as their potential for re-growth as functions of environmental conditions (e.g., temperature, moisture, etc.) during all stages of waste management. These stages include deposition, collection, storage, handling, treatment, utilization and application of manure. Knowledge concerning pathogen colonization of agricultural animals is needed to develop effective intervention strategies to reduce pathogen colonization and shedding into manure. The influence of soil types, vegetative covers, animal

management practices and impoundments on the transport of pathogens needs to be quantified. In addition, atmospheric and hydrologic transport characteristics need to be determined. Regulations on discharges from animal feeding operations and watershed total daily maximum loads (TMDLs) are based on concentrations of fecal indicator bacteria, but the relation between the indicator bacteria and pathogens in environments impacted by animal husbandry needs to be better understood. Improved and more extensive data sets on the survival of particular pathogens are needed. Pathogens such as *E. coli* 0157:H7, *Salmonella* spp., *Campylobacter*, the protozoan parasite *Cryptosporidium parvum* and viruses will have different die-off rates under similar environmental conditions. These measured die-off rates need to be determined and compared with those of new and existing indicator organisms that will be used to monitor the presence of pathogens from animal agriculture. Rates of die-off for pathogens need to be determined under controlled laboratory conditions as well as under variable field conditions in soil, water, and sediments. In addition to survival studies, transport studies need to be designed. Small scale plot studies that involve rain simulation in conjunction with small watershed scale studies need to be undertaken in which both particular pathogens and indicator organisms are measured. Related to pathogen transport are non-point agricultural sources of fecal bacteria in surface waters. To curtail agriculture-associated fecal contamination, sources need to be identified. In addition to better understanding fate and transport of manure bacteria, ARS scientists are in the position to validate the applicability of the molecular tools of microbial source tracking that USEPA (and collaborators) have been developing for identifying fecal sources of microbial contamination.

Anticipated Products

- Peer-reviewed datasets describing the inactivation and transport of livestock pathogens (i.e., *Mycobacterium avium* subsp *paratuberculosis*), zoonotic pathogens (*Salmonella*, *Escherichia coli*, *Campylobacter*, *Listeria*) and fecal indicator bacteria in soil, water, and in waste treatment systems.
- Data sets on transport and sorption parameters for pathogens *(Salmonella*, *E. coli* O157:H7, *Campylobacter*, *Listeria*) relative to new and existing fecal indicator bacteria (i.e., *E. coli*, *Bacteroides* sp.).
- Increased knowledge of *Salmonella* colonization mechanisms in animals and survival responses of *Salmonella* in manures and bedding.
- Peer-reviewed information on transport characteristics of the fecal indicator *E. coli* and pathogens *Salmonella*, *E. coli* 0157:H7 and *Campylobacter* from poultry litter and applications under pasture management with industrial byproduct additions.
- Determine whether the application of industrial byproducts (e.g. gypsum from coal-fired power plants) or other chemical treatments (e.g. lime and alum) to dairy manure reduces the release of *Mycobacterium avium* subsp. *paratuberculosis* into the environment.
- Data on transport and sorption parameters for common indicator organisms (e.g. *E. coli*, enterococci, and bacteriodes) and bacterial pathogens (e.g. *Campylobacter*, *Salmonella*) in both leaching and runoff experiments for a variety of different soil textures.
- Data on the ability of various pathogens to contaminate or infect crops.
- Recommendations for the effective application of microbial source tracking tools.
- Application of microbial source tracking results to the development and compliance with TMDLs under various land use.

Potential Benefits

- Pathogen persistence, inactivation rates, and transport parameters that will be useful to producers, managers of watersheds, regulators, decision makers, and developers of predictive models.
- Intervention strategies to reduce *Salmonella* colonization of swine and shedding into manure.
- A model for estimating transport and sorption parameters for pathogens based on measured parameters obtained from indicator organisms. This, in turn, will lead to improved predictions for the fate and transport of pathogenic microorganisms in the environment.
- Development of BMPs for minimizing the release of *Mycobacterium avium* subsp. *paratuberculosis* from infected manures into the environment.
- Intervention strategies to reduce pathogen colonization of animals and shedding into manure.
- Reduced transport of pathogens and PACs to water bodies.
- Producers and industry will have more science-based information for improved, cost-effective management practices.

Problem Statement 2B: Minimizing the Release of Veterinary Pharmaceuticals and Hormones.

Animal drugs and feed additives are routinely used in concentrated animal feeding operations (CAFOs) to improve health and production. Some veterinary drugs are specifically used to stimulate endocrine function/activity while others have a wide range of therapeutic functions. Many of these compounds are excreted by the animals along with several natural hormones. The impacts of the discharges of these compounds (hormones and veterinary pharmaceuticals) on the ecosystem are poorly understood. Evidence is available that several of these compounds, including the natural hormones, can persist in the environment and may affect the ecology of downstream areas and perhaps even humans. It is documented that large volumes of hormones and veterinary pharmaceuticals are present in animal wastes (wastewater and manure). Dissemination of these agents in the environment occurs as a result of natural deposition, application of animal manure and contaminated water (wash water and storm runoff) to agricultural lands, and partitioning of manure components to flowing water (irrigation or precipitation) and possibly through particle adsorption and aerosol dispersal. The potential public health and environmental effects from environmental exposures to veterinary PACs are largely unknown.

Research Needs

Knowledge of the processes that control the transport and persistence of pharmaceuticals and hormones in livestock manure and wastewater is needed to accurately assess the risk and vulnerability of water resources to contamination. To date, limited studies have been conducted on the environmental persistence, sorption, and transport of natural animal hormones, and veterinary pharmaceuticals and the degradation byproducts of these compounds. In addition, manure-borne antibiotics may adversely influence indigenous bacterial populations in soil and water thus affecting ecosystem functions. A better understanding of fate and transport processes of these compounds in association with manure collection and during storage and subsequent handling is important for deriving better management strategies.

Anticipated Products

- Data sets on transport parameters for hormones in manure after land application.
- Data and analyses that identify veterinary pharmaceuticals that are environmentally persistent and prone to transport by leaching or runoff.
- Data sets on the concentration, persistence and fate of veterinary pharmaceuticals in tile drainage systems and evidence for the beneficial effects of using wood chip bioreactors to manage their release to the environment.
- Comparison of different reactors (bio and non-bio) for inactivation of veterinary pharmaceuticals and natural hormones.
- Demonstration of the benefit of use of industrial byproducts (gypsum, coal ash etc) as inactivators of hormones and veterinary pharmaceuticals in environmental settings.
- Knowledge of persistence, and transport parameters that will be useful to producers, managers of watersheds, regulators, decision makers, and developers of predictive models.

Potential Benefits

- Minimal management criteria for attainment of different exposure reductions scenarios for several classes of veterinary pharmaceuticals and natural hormones that result from manures.
- Inclusion of criteria for reduction of pharmaceutically active compounds and hormones in nutrient management plans.
- A scientific basis for establishing total maximum daily loads (TMDLs) for hormones and veterinary pharmaceuticals.

Problem Statement 2C: Reducing Antibiotic Resistant Bacteria in Agricultural Manures and Wastes.

Public health can be compromised by overuse of antibiotics, as has been recently demonstrated with outbreaks of community acquired methicillin-resistant *Staphylococcus aureus* (MRSA) and *Clostridium dificile* in the U.S. and Europe. Non-judicious antibiotic use has brought forth and helped establish multi-agency antibiotic resistance monitoring programs in North America (National Antibiotic Resistance Monitoring System) and Europe. In Europe, these concerns and pressures have precipitated the banning of sub-therapeutic (i.e. growth promoting) antibiotic use in CAFOs, while domestically, industries such as the poultry industry have made strong commitments to reducing antibiotic use, though the length of time required for these mitigation approaches to become effective is unknown. The extent to which agricultural industries influence antibiotic resistant infections in humans is largely unknown. The issue is particularly complex due to the realization that any bacterium exposed to antibiotics can potentially harbor resistance.

The concern with antibiotic resistance can be centered amongst the pathogenic strains of well known genera such as *Staphylococcus*, *Escherichia*, *Clostridium*, *Campylobacter*, and *Salmonella*. These genera are known for their pathogenic species, made more notorious by their antibiotic resistant brethren. However, of equal concern is the presence of non-pathogenic (commensal) bacteria which can harbor antibiotic resistance determinants, making them a reservoir for resistance in the environment. Commensals often outnumber pathogens by orders of magnitude and therefore, may survive physical and chemical treatments aimed at pathogens. When livestock are administered antibiotics, whether for therapeutic or non-therapeutic purposes, the entire microbial population is exposed to the antibiotics, not just the intended target. Therefore, survival of antibiotic resistant commensal bacteria may create a reservoir for antibiotic resistance genes.

Research Needs
Very little research and information is available on the presence of antibiotic resistant bacteria originating in manure and manure-impacted environments. Thus, little is known about the fate and transport of pathogenic and non-pathogenic ARBs and likewise their associated resistance genes in soil, water, crops, and agronomic systems. A large percentage of antibiotic efficacy is retained while passing through the intestine and into feces. Thus, research is needed to determine if the continual application of manure can impact a seemingly pristine environment and increase antibiotic resistance. Preservation of bacterial antibiotic resistance genes, once removed from constant antibiotic pressures such as in the intestine or manure lagoon is also not understood. In addition, if land-applied areas are seemingly devoid of pathogens and suitable for crop growth, will the presence of non-pathogenic ARBs be a confounding factor for public health? Very little evidence, anecdotal or otherwise, exists to link agriculture use or disuse of an antibiotic on public health. Knowledge in these crucial areas will aid implementation of BMPs which can simultaneously address nutrients, pathogens, and ARB.

Anticipated Products
- Data sets on the presence of ARB with regard to commonly applied agricultural antibiotics such as tetracycline, penicillin, and aminoglycoside classes and related resistance genes and cassettes in manure.
- Identification of ARB and reservoirs of ARB genes in stored swine manure.
- Identify new AR genes in animal waste.
- Data on the potential for survival and maintenance of ARB related to tetracycline, penicillin, and aminoglycoside class resistance and resistance genes in poultry, dairy, and swine manure land-applied sites and on food and forage crops grown on these sites.
- Data on the potential horizontal and vertical transfer and selection of ARB genes via plasmid or resistance cassettes to indigenous soil environmental bacteria and elucidation of the mechanisms of transfer of ARB genes into pathogens.
- Data necessary to assess agricultural antibiotic use in comparison to anthropogenic antibiotic use and disposal in wastes in terms of increased antibiotic resistance in the environment and subsequent increases in antibiotic resistance in public health.
- Routes of transmission of resistance and what drive the resistant rates from sources to non-point sources
- Peer-reviewed information on the base level distribution and frequency of antibiotic resistant bacteria and antibiotic resistance genes in manure from cattle and poultry and environments where this manure is applied or accumulates.

Potential Benefits
- Provide environmentally-based scientific evidence to assist in decision making on the use of antibiotics in agriculture.
- Manure management practices in conjunction with other nutrient-based BMPs aimed at reducing ARB presence and their potential future implication on crops and public health.
- Provide scientific evidence of a link or no link between agriculture and public health antibiotic resistant bacteria.

- Expanded knowledge of the distribution and frequency of antibiotic resistance genes associated with agriculture will improve our understanding of the connection of antibiotic resistant bacteria, sub-therapeutic administration of antibiotics, and public health issues.
- Reduction in the availability of antimicrobials in the environment and cost reduction.

Problem Statement 2D: Minimizing Risk with Best Management Practices and Treatment Technologies.
Traditional and alternative livestock manure, runoff and wastewater treatment systems are primarily designed for the control of nutrients. Best management practices (BMPs) focusing on comprehensive nutrient management plan development, precision nutrition and waste handling, storage and recycling are supported by the EPA and other regulatory agencies, however, little data are available to determine how these policies effect fecal contaminants such as pathogens, ARB, and PACs. The fate of manure-borne contaminants in treatment systems optimized for manure reduction or nutrient control has not been fully characterized. Since these contaminants pose a risk to human, animal, and environmental health, the reduction of pathogens, ARB and PACs should be considered as a part of any sanctioned BMP or treatment technology. Information obtained as part of this problem area should provide farmers, regulators and researchers with information important for production of risk management models and for development of new or improved BMP and treatment technologies that optimize manure-borne contaminant control.

Research Needs
A better understanding of how currently implemented BMPs and treatment technologies affect the immobilization and inactivation of pathogens, ARB and PACs is required. Further studies are needed to determine optimum conditions for BMP and treatment technologies that are effective for pathogen, PAC and nutrient control. BMPs for livestock waste management including nutrient management plans, waste handling and manure application recommendations need to be evaluated for effectiveness in controlling chemical and biological contaminants. A comprehensive best management practice should consider potential methods to reduce or prevent the excretion or shedding of livestock and zoonotic pathogens, ARB and PACs from agricultural animals into manure. Research has been undertaken to evaluate pathogen reduction in traditional treatment technologies such as composting, lagoon systems, anaerobic digesters, wetlands, and buffer strips, however, more work should be done to evaluate the effectiveness of these system for removal/control of ARB and PACs. Inactivation rates for specific pathogens should also be developed so that they can be applied to risk assessment models. Newly developed technologies designed to prevent off-farm release of nutrients and to reduce odors need to be validated for pathogen, ARB and PAC control.

Anticipated Products
- Addition of a pathogen and PAC components to nutrient management plans resulting in recommendations on implementing BMPs and treatment technologies for pathogen, ARB and PAC control.
- Design, improve, and test new and existing animal BMPs and treatment technologies (i.e., effect of land application method on transport, relationship of nutrient transport to pathogen transport, effect of soil amendments on survival (i.e., lime, alum)) to obtain data sets on reduction of manure-associated pathogens, ARB and PAC.

- Investigate alternative manure collection, treatment, and storage technologies and new uses for manure (i.e., trough designs to reduce biofilm formation, effect of value-added processes (e.g., methane digestion) on pathogen survival) to optimize pathogen, ARB and PAC inactivation in manure, soils and water sources.
- Provide data sets (through scientific and white papers, conferences and lectures) on inactivation rates of these contaminants under current and improved treatment technology and BMP regimes to regulatory agencies (EPA, FDA, USDA) and universities for development of improved risk management models.

Potential Benefits

- Improved BMPs for waste management systems that are effective for controlling pathogens and PACs as well as nutrients.
- Development of BMPs for minimizing the release of *Mycobacterium avium* subsp. *paratuberculosis* from infected manures into the environment.
- Identification of critical control points in waste management processes that may help reduce treatment costs while protecting water quality.
- Treatment system design modifications that better control transmission of pathogens, ARB and PACs to plant and soil, water systems, and animals.
- Waste treatment systems that are economically and environmentally sustainable.

Component 2 Resources

Thirteen (13) ARS CRIS projects that are coded to National Program 214 address the research problems identified under Component 2. ARS locations and lead scientists who are assigned to these projects include:

Ames, IA	Tom Moorman; Brad Bearson
Beltsville, MD	Matt Smith; Clifford Rice; Walter Mulbry
Bowling Green, KY	Carl Bolster; Kimberly Cook
Bushland, TX	Bill Rice
Clay Center, NE	Bryan Woodbury
Fayetteville, AR	Philip Moore
Florence, SC	Pat Hunt
Kimberly, ID	Robert Dungan
Lincoln, NE	Dan Miller
Marshfield, WI	Bill Jokela
Mississippi State, MS	John Brooks; Mike McLaughlin
Peoria, IL	Terry Whitehead; Mike Cotta
Riverside, CA	Mark Ibekwe; Scott Bradford
Watkinsville, GA	Mike Jenkins

<u>Component 3. Atmospheric Emissions</u>

Concentrated animal production systems and the manure they produce are sources for ammonia (NH_3), hydrogen sulfide (H_2S), volatile organic compounds (VOCs), odor, greenhouse gases [methane (CH_4), nitrous oxide (N_2O), and carbon dioxide (CO_2)], particulates (2.5 and 10 µm and total suspended particulates), and bioaerosols. Emissions may come from multiple sources, including the site of animal production, manure storage, and manure application sites. Understanding the production, emission, and transport of gases and particulates from livestock manures is critical to identifying and implementing management practices that will reduce these emissions. Practices implemented to control a single type of atmospheric emission will not only need to be specific to sources, but can also impact other types of atmospheric emissions and manure-related environmental issues (nutrients, pathogens, or pharmaceutically active compounds) when the production system is viewed as a whole. Concerns and questions raised by stakeholders, including livestock producers, air quality regulators, and rural residents, can be grouped into four major themes: the need for scientifically sound assessment of emission rates and emission factors for air quality constituents; development and assessment of technologies that will reduce emissions from agricultural operations; the need for process-based models that incorporate biological, chemical, and physical factors to describe the emission of gases, particulates, and bioaerosols; and fate and transport of atmospheric constituents to receptors through which human health assessments could be conducted. Research in these themes was initiated in this program during the previous 5-year cycle, and although substantial progress has been made, important questions remain. The possibility of air quality regulations increases the need for answers to questions posed in these themes and for tools that help livestock producers better manage facilities to solve air quality problems, with benefits to livestock producers and rural residents. The research program described in this component will build upon progress to date and apply results to management systems within the next 5-year cycle. Air quality is comprised of many constituents, and the variation among these constituents in the overall scope of emission, nutrient, and pathogen control associated with animal production increases the complexity in addressing these problem areas. The research is conducted at multiple ARS locations.

Problem Statement 3A: Quantifying the Extent of Agricultural Emissions of Air Pollutants.

Animal production facilities, manure handling and storage systems, and land application of manure releases constituents which are a concern for local, regional, and global air quality and from a human health perspective. Accurate measurement of these constituents from animal production systems is necessary in order to quantify the emissions produced from these systems per measure of animal production over time. Development of these emission factors will provide bench-mark values for evaluating efficacy of emission reduction practices and technologies. Emission factors will also allow decision makers to evaluate the contribution of constituents from animal agriculture with other sectors such as transportation or industrial sources, which will assist in long-term planning efforts aimed at improving air quality and reducing emissions.

Research Needs

Knowledge on the type and amount of constituents released into the air from animal production sites, manure handling and storage systems, and land application of manures is needed to determine baseline emissions rates for animal species and production practices across a continuum of geographic regions and climates. Current technologies available for measuring constituents in air have been developed specifically for industrial sites; hence adoption of these technologies to animal agricultural settings and constituents will require validation. In some cases, new methods will need to be developed for quantifying agricultural air constituents. In

addition to measurement techniques, sampling methods and protocols will need to be developed in order to obtain accurate and reliable results.
Once reliable measurement techniques have been developed, information related to production of these air quality constituents from animal production systems will need to be collected and compiled to develop emission factors that represent the main animal production scenarios across the country (animal species, facility management, geographic regions and climatic conditions). Particular attention needs to be paid to the diurnal and seasonal variations in emissions rates to accurately assign emissions factors. Currently applied emission factors are often based on information limited by a lack of directly relevant research, and are non-representative of many U.S. production practices and facilities. Therefore, the development of these emissions factors will need to be based on on-farm research representing the variety of animal production facilities currently utilized in the U.S. animal agricultural sector. Whether derived from empirical studies, or based on either mechanistic or process-based models, emission factors will continue to play a critical role in understanding animal agriculture as a source of air quality constituents. Comprehensive, relevant, science-based emission factors are needed to provide the best information to develop national emission inventories and to evaluate the contribution of animal agriculture to air quality.

Anticipated Products
- Methods to measure air emissions from poultry and livestock farms.
- Ammonia emission factors representing broiler houses in the southeastern U.S.
- Measurements of bioaerosol (including endotoxins and bacterial pathogens) and gaseous (ammonia, carbon dioxide, methane, nitrous oxide) emissions from concentrated dairy operations in the Pacific Northwest.
- Benchmark ammonia, methane, nitrous oxide and VOC emission factors from barn, manure storage, and land application components of dairy production systems in the Midwestern region of the U.S.
- Quantification of spatial and temporal variations in emissions (ammonia, hydrogen sulfide, VOC, etc.) from swine buildings and beef feedlots in the Midwest with identification of high emission areas for targeted management.
- Measurements of atmospheric ammonia and methane concentrations at beef cattle feedyards and dairies in the southern Great Plains on seasonal and annual timescales using integrative, noninvasive methods.
- Estimates of ammonia and methane emissions from beef cattle feedyards and dairies in the southern Great Plains on seasonal and annual timescales using measured concentrations and meteorological variables and dispersion modeling.

Potential Benefits
- Reduced emission of gasses from livestock and poultry farms in the U.S. that will result in enhanced air quality on farms and in surrounding and distant communities
- Provide stakeholders with emission estimates from large scale dairy operations in the Pacific Northwest that can be used to develop/modify emission regulations or to set goals for reduction of ammonia and greenhouse gases.
- Provide stakeholders with emission estimates from large scale beef and dairy cattle operations in the southern Great Plains that can be used to develop/modify emission regulations or to set goals for reduction of ammonia and greenhouse gases.

- Defined methods and protocols for measuring air quality constituents (odors, greenhouse gases, PM) from cattle and swine production facilities from which science-based regulations can be developed.

Problem Statement 3B: Characterize the Physical, Chemical, and Biological Processes Essential for the Development and Evaluation of Emissions Models.

Emission factors are currently used to develop emissions inventories or assess emissions for regulatory purposes. However, this paradigm is limited by the relatively small amount of research used to develop emission factors, the great diversity of animal production systems, and the spatial and temporal variability inherent in a given production system. A better approach is to employ process models. Process models are mathematical representations, with mass balance constraints, of the physical, chemical and biological processes that contribute to the emission of a constituent of interest. Our knowledge of physical and chemical processes affecting emissions is developing, but incomplete. Gaps in our understanding of the biological (namely microbial) component are even larger. Microbial activity is responsible for the generation of volatile compounds in the animal's digestive tract as well as in waste storage and treatment areas and is ultimately largely responsible for their degradation or transformation as well. Yet we have considerable gaps in our understanding how microbial communities and their activities govern the formation and fate of volatile compounds affecting air quality. Nitrogenous compounds, methane and hydrogen sulfide are amenable to process modeling, while emissions of odorous compounds and particulates may be potentially described by process models that can be utilized across the diversity of animal production systems.

Research Needs

Process models of emissions require as inputs an array of relevant variables, process coefficients and parameters. These must be identified and the state of the science for each evaluated. Quantification of emission of a constituent of interest is required to verify the accuracy of process models. Inputs must be identified, measured and collected in accessible databases. Better understanding of the microbial populations responsible for the generation of volatile compounds as well as those populations capable of metabolizing these compounds is required. Process models, either currently existing or newly developed, must be tested for accuracy by comparing predicted emissions with measured emissions.

Anticipated Products

- Information describing microbial populations and their biochemical activities responsible for odor compound production and consumption (odor control) in swine and beef cattle production areas.
- Databases of ammonia, greenhouse gases and PM, and relevant input variables (temperature, moisture, relative humidity, pH, EC) from cattle feedlot and confined swine feeding operations
- Identification of interactive effects between nutrient supply (source, quantity, and composition) and manure microbial ecology responsible for emission and consumption of gaseous (odors, ammonia, hydrogen sulfide, VOC, etc.).
- Mathematical expressions that describe critical physical, chemical and biological processes that control ammonia emissions in beef cattle feedyards in the southern Great Plains.

- Databases of emissions and relevant input variables from beef cattle feedyards that can be used for inputs and verification of process models of ammonia emissions.

Potential Benefits
- Development of conceptual models relating the emission of odorous compounds to the action of specific groups of microorganisms and environmental factors.
- Development of nutrient flow models to the proliferation or reduction of specific microbes involved in emission and consumption of gaseous produced from livestock production facilities.
- Refined process models that accurately quantify ammonia emissions from beef cattle feedyards in the southern Great Plains

Problem Statement 3C: Develop and Test Technologies and Improved Management Practices to Reduce Emissions.
Reduction of atmospheric emissions from animal agriculture is necessary because of concerns with global air quality, climate change, and human health. The use of control technologies and improved manure management practices will protect the air quality environment of animals, farm workers, and neighboring communities and mitigate impacts of emissions on climate. Stakeholders will benefit from the development of cost effective emission control technologies with the potential to generate additional income through production of valuable manure byproducts and environmental offset credits.

Research Needs
Strategies for effective and reliable control of gaseous and particulate matter emissions from animal agriculture operations are needed to protect air quality and mitigate impacts on the environment. These control strategies can be grouped in the following four research areas: (1) diet modification; (2) animal and facilities management; (3) methods for manure handling, storage and treatment; and (4) manure land application. Managing or changing the components of animal diets can widely influence the amounts of manure and emissions. Evaluation of new dietary strategies is needed to assist with lowering emissions from fresh and stored manure. Management of manure is highly variable across animal species and products with further variation among geographical regions, structures, operation size, integrators, and individual growers. Characterization of these management practices is needed to provide a source tracking origination point to help determine effective emissions control technologies. A better understanding of chemical, physical and biological processes that control emissions is needed as a scientific basis for development and evaluation of improved manure treatment technologies. This scientific basis is also needed to support approaches to assess environmental offset credits (carbon and nutrients). As a result of both the expansion of animal production and the increasing cost of commercial fertilizers, land application of manure will continue being an important source of fertilizer nutrients for crop production. Yet, research is needed to accurately determine how selected best management practices for manure land application impact crop productivity and soil and air quality.

Anticipated Products

- Define dietary strategies equating a reduction in carbon, nitrogen, and sulfur excretion on manure composition and subsequent reduction of ammonia, hydrogen sulfide, odor, and greenhouse emissions from animal manure.
- Manure amendment formulations utilizing natural products (tannins and plant oils) to reduce volatile emissions from stored cattle and swine manure.
- Improved solids-liquid separation technologies that reduce water strength and enhance reduction of ammonia and GHG emissions from liquid swine manure slurries.
- Aerobic treatment technologies to reduce ammonia and malodor emissions from swine and dairy lagoon slurry.
- Improved procedures and guidelines to quantify carbon and nitrogen environmental credits from implementation of manure management practices in AFOs for environmental offsets trading and marketing.
- Generation of peer-reviewed data sets determining the sources and sinks of particulate and gaseous emissions as affected by animal and manure management practices.
- Improved dairy manure application methods to reduce ammonia emissions and increase utilization of manure N in corn and perennial forage cropping systems.

Potential Benefits

- Development of nutrient retention strategies and manure management practices for improved utilization of manure nutrients for crop production resulting in a reduced impact of animal production on environment and human health.
- Reduction of odors, particulate matter, ammonia and GHG releases from AFOs into the environment by the implementation of improved emission control technologies.
- Improvement of air quality in animal production environments resulting from the adoption of improved management practices that reduce particulate and gaseous emissions.

Component 3 Resources

Thirteen (13) ARS CRIS projects that are coded to National Program 214 address the research problems identified under Component 1. ARS locations and lead scientists who are assigned to these projects include:

Ames, IA	Brian Kerr
Auburn, AL	Allen Torbert
Beltsville, MD	Thanh Dao
Bowling Green, KY	Karamat Sistani
Bushland, TX	Andy Cole
Clay Center, NE	Bryan Woodbury
Fayetteville, AR	Philip Moore
Florence, SC	Ariel Szogi
Kimberly, ID	April Leytem
Lincoln, NE	Dan Miller
Madison, WI	William Jokela
Mississippi State, MS	Johnie Jenkins
Peoria, IL	Terry Whitehead

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

Each year millions of tons of agricultural, industrial, and municipal byproducts are generated that have been considered to have little value, are classified as wastes, and often disposed in landfills. Alternative uses for these byproducts are needed to promote sustainable agriculture, as well as to reduce landfill requirements, greenhouse gas emissions, and disposal/remediation costs. This research component examines these byproducts to determine their potential value to agriculture and horticulture either individually or through blending, mixing, or treatment. Many of these byproducts have characteristics that make them prospectively useful for direct land application, soil reclamation and remediation, production of manufactured soils and composts, or feedstuffs for value-added products.

The utilization of these byproducts in agriculture and horticulture requires careful analysis and management. Research and development is needed to determine the composition and potential bioactivity of these products. At this time, state regulatory agencies lack analytical tools to make reasonable policy decisions regarding the beneficial use of these byproducts. The USDA-ARS will develop protocols and methodology standards that regulatory authorities can adopt to examine and approve byproducts for agricultural use. Treatment technologies and management practices to make these products usable will reduce potential environmental hazards, reduce disposal cost, and increase cost-effectiveness of agriculture.

Problem Statement 4A: Enhance the Value of Agricultural, Industrial, and Municipal Byproducts by Developing Beneficial Uses.

Agricultural, municipal, and industrial processes result in a wide array of byproducts. Many of these byproducts, if properly processed and used, may have specific benefits to water quality, soil quality, plant health, plant and animal production systems, and to reduce undesirable air emissions. In order to achieve these benefits, the byproducts need to be utilized in an environmentally sound manner that reduces the cost of disposal or converts them into marketable assets. While previous ARS research has resulted in acceptance of byproducts (i.e. foundry sand), there are many materials and applications for which little scientific information exists or potential benefits have yet to be identified. Currently, ARS is conducting research on the beneficial use of flue gas desulfurization (FGD) gypsum derived from power generating coal-fired boiler units. In 1996, 24 million tons of FGD gypsum was generated annually.

Research Needs

Technologically sound methods are needed for utilizing byproducts that will be characterized as beneficial and can result in products that are commercially sustainable. This includes blending, composting, and amending byproducts as well as developing land application and management techniques that will improve soil, water, and air quality in addition to improved plant growth. In addition, improved formulations of agriculture byproducts feed stock for use in industrial as well as agricultural applications are needed. Specific sub-areas of research include creating and testing prototype byproducts for application into existing processes and technologies, measurement of fate and transport of byproduct components, measurement of treatment efficacy and controlling processes, identification of beneficial properties, development of innovative processes, and applying real time cost-benefit evaluations of the research. The overall objective is to utilize agricultural, municipal, and industrial byproducts in a cost-effective and environmentally sound manner.

Anticipated Products

- New and improved systems to capture, concentrate, and reuse nutrients (i.e. N, P, K, S, and micro plant nutrient) from manures and other byproducts.
- Guidelines for using byproducts to stabilize or sequester nutrients in manures and soils (for example, FGD gypsum to stabilize P in manure).
- Procedures to use manure, compost, and byproducts to remediate and improve soils and to formulate manufactured soils.
- Newly identified pool of agricultural byproducts for use in industrial applications.

Potential Benefits

- Byproducts will be used for improvement of soil and the environment, remediation of degraded or contaminated soils, such as strip mine reclamation.
- Byproducts will be used as components of manufactured soils such as potting material in the horticulture industry.
- Innovative products and processes that make agricultural economics more efficient and which add quality and value and/or lower costs of feed stocks for industrial processes.
- Procedures to evaluate, process, and apply byproducts for long-term benefit.

Problem Statement 4B: Increase Understanding of the Risks and Benefits of Using Byproducts in Agriculture and Horticulture.

Each year in the U.S., millions of tons of agricultural, industrial and municipal byproducts are generated. Alternative uses for these byproducts are needed to promote sustainable agriculture as well as to reduce landfill space requirements, greenhouse gas emissions, and disposal/remediation costs. Many of these byproducts have plant nutrients or characteristics that make them prospectively useful as soil amendments or conditioners whether for direct land application, soil reclamation and remediation, or as components of manufactured soils and composts. US-EPA is actively encouraging Industrial Materials Recycling, with regulations adopted at the state level. At this time, state regulatory agencies lack evaluation tools for environmental acceptability of beneficial use of these byproducts in agriculture or horticulture. The ARS will conduct research to provide critical information about constituent phyto- and bio-availability in byproduct amendments to state regulatory agencies, and how to use these data to conduct pathway risk assessments to support use decisions.

Research Needs

Many regulators are reluctant to approve land application, soil manufacturing and other agricultural and horticultural uses of byproducts because of a lack of knowledge of interactions with soil, nutrient bioavailability, groundwater impacts, and impacts on other soil-related functions and processes. The development of methods to examine and approve byproducts based on sound science will simultaneously ensure environmental protection, improve soil, water and air quality, and derive economic benefits to both byproduct generators and the agricultural community. Accurate and cost-effective methods of byproduct evaluation must be established. The specific research goals are to (1) identify agricultural, municipal, and industrial byproducts amenable to beneficial use in agriculture and horticulture; (2) develop a generic framework by which risks of byproducts of different origin and constituents can be evaluated; (3) identify analytical methods that can accurately identify and quantify byproduct risks from constituents using proper QA/QC; (4) develop a Decision Tree to help stakeholders determine which evaluation methodologies are appropriate for matching byproducts with intended uses--then develop a "branching" evaluation protocol that proposes analyses that could ultimately be carried out in independent laboratories and universities; and (5) characterize a number of different byproducts (including variability) using the generic framework to demonstrate to stakeholders that the proposed framework yields comparable and reproducible data.

Anticipated Products

- Generic test models or analyses, for example FGD gypsum and other coal byproducts, water treatment residuals, and composted food waste.
- Decision trees for state, city, or local agencies, for example FGD gypsum and other coal byproducts, water treatment residuals, and composted food waste
- Guidelines on beneficial uses of agriculture, industrial and municipal byproducts.

Potential Benefits

- An established sampling, analysis, and assessment protocols for agriculture, industrial and municipal byproducts will provide accurate and reliable data for risk assessment.
- A model process by which different types of byproducts can be evaluated for use in agriculture and horticulture.
- Development of generic evaluation methods for potential land applications for agriculture, industrial and municipal byproducts.

Component 4 Resources

The following locations have research projects addressing the problem statement identified under problem area 4.

Auburn, AL	Allen Torbert
Beltsville, MD	Walter Schmidt
Bowling Green, KY	
Clay Center, NE	
Florence, SC	
Madison, WI	
Mississippi State, MS	Philip Moore
Oxford, MS	
Watkinsville, GA	
West Lafayette, IN	

Cooperators

Horticultural Research Institute (HRI), Foundry Industry Recycling Starts Today (FIRST), EPRI, USEPA, US-FDA, State Regulatory agencies, universities, farming community, ASTM, National Council on Air and Stream Improvement, GLBMA, American Coal Ash Assn.