Environment and Natural Resources Trust Fund
2018 Request for Proposals (RFP)

Project Title: **ENRTF ID: 059-B**

Developing Nutrient Separation Systems for Livestock Environmental Sustainability

Category: B. Water Resources

Total Project Budget: $ 304,000

Proposed Project Time Period for the Funding Requested: 3 years, July 2018 to June 2021

Summary:

This project will develop an economical manure nutrient separation system. The separation system will produce environmentally sustainable fertilizers and ameliorate the water environmental impact of Minnesota livestock operations.

Name: Hongjian Lin

Sponsoring Organization: U of MN

Address: 1390 Eckles Ave.
St Paul MN 55108

Telephone Number: (612) 624-4915

Email linxx867@umn.edu

Web Address

Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

This project will develop an economical manure nutrient separation system that will ameliorate the water environmental impact of Minnesota livestock operations.

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency
_____ Capacity Readiness	_____ Leverage	_____ TOTAL	_____%

PROJECT TITLE: Developing nutrient separation systems for livestock environmental sustainability

I. PROJECT STATEMENT

This project will develop an economical manure nutrient separation system that will ameliorate the water environmental impact of Minnesota livestock operations. This system will generate additional revenue for farmers, and will stimulate their willingness for environmental protection. The overall goal will be achieved by:

- Developing a manure management system that generates phosphorus and nitrogen fertilizers,
- Evaluating the technical and economic feasibility of the system by on-farm experiments, and
- Conducting an environmental life-cycle assessment of the system installation.

Minnesota is a leading agricultural producing state (the fifth in 2015) in the US, and the livestock industry accounts for about half of the state's farm income. However, this industry has a disproportionally high impact in rural water and air environment. The impact is increasingly perceived as a challenge by the general public, and is reflected in several court cases over the years. The impact is recently augmented by the adoption of concentrated animal feeding operations and the business expansion in MN. An important environmental concern associated with the livestock industry is the land application of swine and dairy manure. The nitrogen (N) to phosphorus (P) ratio in manure is too low as a fertilizer, and surplus phosphorus may gradually accumulate in soils and release to water bodies. The adverse environmental consequences like eutrophication are commonly seen. Unfortunately, the phosphorus overloading issue is not tackled by best management practices (BMPs) for manure, which are developed based on crops' N desirability. The Natural Resources Conservation Service (NRCS) 590 standards and the Minnesota Pollution Control Agency (MPCA) 7020 rules set manure application restrictions based on phosphorus index of soil and other environmental conditions, as a supplement to BMPs. The solution is not yet achievable as those restrictions result in long-distance and uneconomical transportation of manure.

It is a fact in MN that the local cropland is in short compared with the local manure generation, but state-widely, manure itself is in short. The overall issue can be solved if manure is effectively and economically separated to a phosphorus-rich dry stream for long-distance transportation, and the other stream enriched with nitrogen for direct land application. The technical difficulty lies in the efficient separation of phosphorus -rich particles from liquid manure, because those particles are stabilized during the year-long storage and display low settling capability. Our research group at University of Minnesota innovatively proposed a consolidated processing module to combine the chemical precipitation and electrocoagulation and we want to integrate this module with current swine and dairy manure management systems. The implementation of the technology separates animal manure into manure solids, phosphorus fertilizer and nitrogen fertilizer for different targeted applications.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Lab study of phosphorus separation from animal manure **Budget: $107,000**

Activity 1 aims to develop a novel phosphorus separation technology in 1-L scale bench experiment. A lime dosing (Ca/Mg) will be performed with electrocoagulation (EC) treatment, considering 1) eastern MN soils generally require lime for pH adjustment; 2) lime serves a coagulant; and 3) lime decreases iron dosage in electrocoagulation. The process combination of lime dosing and EC will be optimized for three types of manure, including undigested liquid dairy manure, digested liquid dairy manure and liquid portion of swine manure. We will study the process optimization to determine the best operating conditions for nutrient separation.

Outcome	Completion Date
1. Optimization of the process combination mode of lime dosing and electrocoagulation	*09/30/2018*
2. Optimization of the combined nutrient separation process	*06/30/2019*

Activity 2: Pilot-scale production of phosphorus and nitrogen fertilizers **Budget: $97,000**

Activity 2 aims to determine the technical and economic feasibility of the nutrient separation system through a pilot-scale study. A 20-gal nutrient separation reactor will be built and on-farm tested at a manure treatment capacity of 100 gal/day for one week. On-farm operation will be set up at two sites, one at UMN research swine barn in Waseca, MN, and the other at Haubenschild Dairy Farm in Princeton, MN. Haubenschild Dairy Farm houses around 1000 cows and operates a plug-flow anaerobic digester. Liquid manure from the barns will be fed into the separation module to produce P and N fertilizers. For the dairy operation, the heat from biogas combustion will be used to dry P fertilizer. Both the liquid and the dried sludge will be determined for P and N contents to evaluate the fertilizer value on the market. The economic analysis will estimate the net present value (NPV) and return on investment (ROI) of system installation based on the results from the pilot-scale study, including the expected costs to construct a commercial facility, lifetime of the separation system, operations and maintenance costs including labor requirements, and revenue by P fertilizer sales.

Outcome	Completion Date
1. Prototype construction for pilot-scale study	*09/30/2019*
2. Pilot-scale study for a swine operation	*03/31/2020*
3. Pilot-scale study for a dairy operation	*06/30/2020*
4. Economic analysis for swine and dairy operations	*12/31/2020*

Activity 3: Determination of the environmental impacts of the technology **Budget: $100,000**

Activity 3 aims to determine the environmental impacts on MN water and air of installing the nutrient separation systems by using life-cycle assessment (LCA) tools. The attributional LCA, defined by International Organization for Standardization (ISO) in 14040:2006, will be applied to the analysis by using the LCA modeling software SimaPro (PRé Consultants, Netherlands). Pig Production Environmental Footprint Calculator developed at the University of Arkansas and recent research results will be used to generate life cycle inventories for assessment. The environmental assessment will evaluate the impacts of the technology on the energy efficiency, gas emissions, and water consumption and quality of the MN livestock industry.

Outcome	Completion Date
1. Building life cycle inventory datasets	*03/31/2021*
2. Environmental impacts of the technology installation on MN water and air	*06/30/2021*

III. PROJECT STRATEGY

A. Project Team/Partners: The research team includes Dr. Hongjian Lin, Researcher in the Department of Bioproducts & Biosystems Engineering (BBE) at UMN, and Dr. Bo Hu, Associate Professor in BBE Department of UMN. The team was recently awarded as one of the four winners at the Nutrient Recycling Challenge initiated by the EPA and USDA, and this project will be a demonstration and adaptation of that solution to the real livestock operations. Our EQIP demonstration partner Haubenschild's Dairy Farm (supporting letter attached) received the award of Innovative Dairy Farmer of the year during a ceremony at the International Dairy Foods Association's Dairy Forum 2010 and has the ideal facility settings for on-farm test.

B. Project Impact and Long-Term Strategy: The installation of the new nutrient separation system will promote Minnesota environmental sustainability. The separation system will solve the local phosphorus overloading issue, and will stimulate the technology users by generating additional revenue to them. Successful separation of manure components and recovery of phosphorus fertilizer from liquid manure will benefit nutrient management and irrigation water conservation. The systematic change of nutrients management practices by this proposed technology to livestock industry will be one of the ultimate solutions to achieve the environmental, social, and economic sustainability of livestock industry in terms of nutrients and water, two of the most demanding elements in agricultural practices.

C. Timeline Requirements: We are planning to finish lab study, field study, and environmental impact analysis within three years.

2018 Detailed Project Budget

Project Title: Developing nutrient separation systems for livestock environmental sustainability

IV. TOTAL ENRTF REQUEST BUDGET *3* **years**

BUDGET ITEM	AMOUNT	
Personnel:	**$**	**251,000**
Hongjian Lin, PI, Research Associate (68% Salary, 32% Benefits), 100% FTE for years 1-3	$ 209,000	
Bo Hu, Co-PI (68% Salary, 32% Benefits), 8.3% FTE each year for year 1-3	$ 42,000	
Professional/Technical/Service Contracts		
Equipment/Tools/Supplies:	**$**	**40,000**
Supplies for the lab experiments, including electrodes, chemicals, test kits, regular lab consumables.	$ 25,000	
We will build a pilot-scale demonstration device for use at the UMN swine and dairy barns	$ 15,000	
Acquisition (Fee Title or Permanent Easements): N/A	$	-
Travel:	**$**	**3,000**
In-state travel (Mileage, lodging, and meals)	$ 3,000	
Additional Budget Items:	**$**	**10,000**
Professional analysis service for the chemical analysis at other UMN labs	$ 7,000	
Publication costs for two -three publications	$ 3,000	
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	**$**	**304,000**

V. OTHER FUNDS

SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ To Be Applied To Project During Project Period:	$ -	
Other State $ To Be Applied To Project During Project Period:	$ -	
In-kind Services To Be Applied To Project During Project Period (Unrecovered F&A)	$ 156,060	*UM F&A*
Past and Current ENRTF Appropriation	$ -	
Other Funding History:	$ -	

Project Title: Developing nutrient separation systems for livestock environmental sustainability

Summary: *This project will develop an economical manure nutrient separation system that will ameliorate the water environmental impact of Minnesota livestock operations.*

- Expanding livestock industry in Minnesota
- More concentrated animal housing and operations
- Imbalanced nitrogen and phosphorus ratio

→ ~~•~~ Local phosphorus over-loading
~~•~~ Water and air pollutions

Animal barns

Manure

Land application of manure
(http://www.extension.umn.edu)

Novel nutrient separation system

Nitrogen fertilizer and water: for local land application

Dry phosphorus fertilizer: for sale & transportation

07/29/2017

Project Manager Qualifications

The research team will include Dr. Hongjian Lin, and Dr. Bo Hu from the Department of Bioproducts and Biosystems Engineering.

Dr. Lin is a researcher at Department of Bioproducts and Biosystems Engineering, University of Minnesota. He has more than seven years of research experience on wastewater nutrient removal and recovery from various waste streams through bioprocessing, electrochemical-based crystallization and electrocoagulation, adsorption and precipitation. During his PhD study at University of Minnesota, he participated in projects of ammonia capture from gas phase and of energy recovery via microbial fuel cells. During his postdoc training, Dr. Lin has assisted to secure several research grants and research gifts from agencies including USEPA, National Pork Board, MAES Rapid Agricultural Response Fund, and Emerson Commercial & Residential Solutions. Dr. Lin successfully participated in project management for several water and wastewater study sponsored by ENRTF and UMN. Dr. Lin was recognized for his research capability by American Society of Agricultural and Biological Engineers for his nutrient and energy recovery study using microbial fuel cells, and by USEPA Nutrient Recycling Challenge for his innovative reactor design for nutrient separation.

Dr. Bo Hu is a junior Associate Professor at Department of Bioproducts and Biosystems Engineering, University of Minnesota. With more than 10 years of active research experience specifically in biomass utilization, fermentative conversion, and waste management, he is leading projects to remove phosphorus from manure and from wastewater in the septic tank systems, projects to reveal the myth of recent swine manure foaming in Midwestern states, projects on synthetic ecology in lichen biofilm formation by co-culturing mixotrophic microalgae and filamentous fungi. He has finished projects to develop a co-digestion system in Jer-Lindy dairy farm in Minnesota and a modified anaerobic digestion system for biohydrogen production. Dr. Hu's team at UMN has set up several standard procedures such as 16s rDNA based microbial analysis by using high-throughout pyrosequencing methods to study the microbial species in the waste treatment processes, ITS sequences to identify fungal species. His team is also developing several conversion platforms, such as lichen biofilm co-cultivation of fungi and microalgae, pelletized fungal fermentation, and solid and hemi-SolidSF of filamentous fungi, to produce bioprducts and biofuel from agricultural waste and residue, and to remove nutrients and pollutant from contaminated water. As the PI of the project, Dr. Hu will design and coordinate the research; the Post-Doc researcher will assist in design and experimentation; and the graduate student will assist in data collection and dissertation.

Our laboratory has all the necessary equipment and facilities for this project, including: Bio-Rod MJ Mini 48-Well Personal Thermal Cycler, Bio-Rod electrophoresis, New Brunswick refrigerated incubation shaker INNOVA 42R, New Brunswick shaker Excella E-24, Beckman Allegra X-15R Refrigerated Centrifuge, VWR refrigerated water heater circulator, Bioreactor/fermentor, Agilent 7820 A GC-FID-TCD [gas-chromatography analysis–flame-ionization detector–thermal conductivity detector] , Agilent Micro-GC, Agilent 1260 HPLC (Diode Array detector, Refractive Index Detector and autosampler), and Dionex ICS 2100/ ICS 1100 bundle ThermoFisher Scientific. Other basic equipment within the lab includes Biosafety cabinet, Autoclave, -20 freezer and 4 degree refrigerator, balances, pH meter, etc.. The lab is also equipped with two incubation rooms with full range of temperature control, a walk-in refrigeration room and a walk-in cold room.

Organization Description

As the core department of UMN to tackle Agricultural engineering and environmental engineering issues, Bioproducts and Biosystems Engineering Department has very dynamic research activities and numerous excellent scientific researchers have received grant supports from LCCMR program. UMN Sponsored Projects Administration (SPA) will be the entity authorized by the Board of Regents to manage the project agreements with LCCMR program.