Environment and Natural Resources Trust Fund
2020 Request for Proposals (RFP)

Project Title: **ENRTF ID: 094-B**

Full Utilization of Concentrated Livestock Wastewaters

Category: B. Water Resources

Sub-Category:

Total Project Budget: $ 545,000

Proposed Project Time Period for the Funding Requested: June 30, 2023 (3 yrs)

Summary:

To develop and demonstrate a system for complete treatment and utilization of concentrated animal wastewater, reducing/preventing pollutants from escaping to air and leaching to groundwater, producing bioenergy, feeds, and foods

Name: Roger Ruan

Sponsoring Organization: U of MN

Job Title: Professor

Department: College of Food, Agricultural and Natural Resource Sciences

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St. Paul MN 55108

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Web Address:

Location:

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

Process flow diagram, taking wastewater from animal production source through numerous biological and physical treatment and utilization processes, and discharging clean water to the environment.

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

PROJECT TITLE: Full utilization of concentrated livestock wastewaters

I. PROJECT STATEMENT

Each year, Minnesota agricultural activities generate a huge amount of wastewaters, especially in the livestock production sector. There were about 24,000 registered feedlots in Minnesota. Take swine manure for example, on March 1, 2019, there are 8.7 million hogs/pigs on Minnesota farms, generating more than 5 million gallons of wastewater each day. Land applications and improper storage of livestock manure can contaminate surface water and groundwater. Animal manure is a valuable resource only if managed properly. This project is intended to address ***Priority B*** *titled "Water Resources, 2II. Preventing or reducing levels of contaminants in ground and surface waters"* by taking a systems approach and assembling a suite of practical technologies being developed at the UMN Center for Biorefining to deliver ***multiple benefits*** including:

- Treating and utilizing concentrated wastewater for production of bioenergy, fertilizer, feeds, & foods;
- preventing nutrients and antibiotics from contaminating ground and surface waters
- reducing impacts of livestock farming on public health and quality of life
- bringing extra revenue to MN farmers

Direct discharges of wastewater from large concentrated animal feeding operations into the water way ***are regulated*** under the Clean Water Act. ***Land application*** of raw or digested concentrated animal wastewater ***is inefficient due to nutrient runoff*** to the atmosphere, surface water, and groundwater, ***creating significant and urgent water and air pollution issues***.

This project is aimed to develop and demonstrate a system for complete treatment and utilization of concentrated animal wastewater. The proposed work is built on the promising preliminary results obtained from the previous scaled back LCCMR funded project. With the preliminary data from small scale systems, we are now ready to optimize, integrate, and demonstrate the processes and systems in pilot scale. The R&D work will overcome several ***technical challenges*** *in order to move the technology to the pilot demonstration stage*:

- Concentrated animal wastewater must be diluted 10-200 times for algae and vegetable cultivation. Adding so much fresh water to a wastewater treatment process does not seem intuitive and sustainable.
- Plant mostly absorb ions and not molecules. Therefore, molecules must be broken down.
- Use of animal manure for hydroponic cultivation raises concerns about pathogenic microorganisms that can cause diseases to vegetables and post safety risk to consumers.
- after hydroponic cultivation, the water may not be clean enough for discharge or for on-farm uses.

The impacts of the project are broad and extendable. The technology, if adopted by 20% of the swine capacity, can effectively reduce the potential of 380 million gallons of wastewater polluting our surface and ground water and use 19 million lbs, 13 million lbs, and 9.5 million lbs of nitrogen, phosphorus, and potassium fertilizers, respectively, for hydroponic production annually. The knowledge acquired and technology developed during the project will be disseminated through multiple channels and their application can go beyond swine manure to other animal wastes and municipal wastewaters.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: *Develop and optimize processes to reduce chemical oxygen demand and ammonia to desirable levels*

In this project, we will design and demonstrate a system consisting of ***novel and scientifically sound processes*** including vacuum assisted thermophilic anaerobic digestion, biofilm based aerobic digestion, microalgae cultivation, biochar filtration, and hydroponic cultivation (*See a schematic diagram in visual presentation*). These processes have the potential to solve key issues in current anaerobic digestion and hydronic cultivation operations. The vacuum assisted thermophilic anaerobic digestion is designed to break down large organics, remove most ammonia and hydrogen sulfide (converted to solid fertilizers), inactivate pathogens, and generate biogas (converted to electricity). The biofilm aerobic digestion is designed to further break down molecules to ions, remove contaminants such as anti-biotics, and further reduce pathogens. The microalgae cultivation is included to further reduce remaining ammonia and nutrient concentration to levels suitable for hydroponic

cultivation. The biochar filtration steps are designed to remove fine particles and bacteria and prepare the water for efficient algae and/or hydroponic cultivation. After hydroponic cultivation, water is filtered through biochar and recycled back to hydroponic system. Excess water can be discharged or used for farm operations such as animal house cleaning.

ENRTF BUDGET: $275,000

Outcome	Completion Date
1. Develop and optimize vacuum assisted thermophilic anaerobic digestion and bio-film aerobic digestion processes	*06/30/2021*
2. Evaluate microalgae growth on vacuum assisted thermophilic anaerobic digestion and bio-film aerobic digestion treated water	*12/31/2021*
3. Develop and optimize photocatalytic materials coupled with aerobic bacteria *for antibiotics removal and biochar filtration for particle removal*	*12/31/2022*
4. Study hydroponic cultivation on the treated water	*12/31/2023*

Activity 2: *Develop a demonstration system*

With the knowledge, experience, and optimized processes obtained from Activity 1, we will develop a small pilot scale system consisting of *vacuum assisted thermophilic anaerobic digestion, bio-film aerobic digestion*, photocatalytic materials coupled with aerobic bacteria, biochar filtration and hydroponic tray for comprehensive evaluation of the processes and demonstration of the technology to general public for education and outreach purpose. Stakeholders will be brought to the greenhouse facility at UMN where a demonstration of the technology will be conducted.

ENRTF BUDGET: $270,000

Outcome	Completion Date
1. Scale-up parameters will be determined for the optimized process flow	*03/31/2022*
2. System design will be completed	*06/30/2022*
3. Individual units will be fabricated and assembled, and tested	*12/31/2022*
4. The system will be demonstrated on UMN outreach center or a farm setting to the stakeholders	*06/30/2023*

III. PROJECT PARTNERS:

A. Project team:

Roger Ruan (BBE, UMN), Paul Chen (BBE, UMN)

B. Partners NOT receiving ENRTF funding

Name	Title	Affiliation	Role
Peter Forsman	Owner	Forsman Farms	Help withfield test and demonstration
John Snyder	President	Minnesga	Coordinate raw material and field test

IV. LONG-TERM- IMPLEMENTATION AND FUNDING:

New scientific knowledge and experience on complete wastewater utilization process will be acquired through research, and the demonstration will raise significant interests from the public. We will seek industry partners and private, state, and federal funding to further develop and eventually commercialize the technology.

V. TIME LINE REQUIREMENTS:

This project is planned for 3 years beginning July 1, 2020 and ending June 30, 2023. Most of the first 24 months will be focused on process improvement and parameter optimization, and full understanding of the proposed process, and much of the second 12 months will be focused on development, evaluation, and demonstration of the proposed demonstration system.

Attachment A: Project Budget Spreadsheet
Environment and Natural Resources Trust Fund
M.L. 2020 Budget Spreadsheet
Legal Citation:
Project Manager: Roger Ruan
Project Title: Full Utilization of Concentrated Animal Wastewaters
Organization: University of Minnesota
Project Budget: $545,000
Project Length and Completion Date: 3 Years - June 30, 2023
Today's Date: 4/11/19

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits)	$ 435,000	$ -	$ 435,000
Roger Ruan, PI, 0.08 FTE, 3 years,$67,00, 73.5% salary/26.5% fringe - leading and managing lab and field testing project, leading demonstration, supervising graduate student			
Paul Chen, Co-PI, 0.08 FTE, 3 years, $64,000, 73.5% salary/26.5% fringe -leading and managing lab and field testing project, leading demonstration, supervising graduate student			
Grad RA, 0.5 FTE, 3 years, $148,000, 57.5% salary/42.5% fringe - conducting R&D, operations, demonstration, data analysis			
Post-doc associate, 1 FTE, 3 years, $156,000, 80.5% salary/16.5% fringe - conducting R&D, operations, demonstration, data analysis			
Professional/Technical/Service Contracts			
	$ -	$ -	$ -
Equipment/Tools/Supplies			
Lab supplies, instruents, minor equipment for setting up lab and field experiments and testring and demonstration system	$ 95,000	$ -	$ 95,000
Capital Expenditures Over $5,000			
	$ -	$ -	$ -
Fee Title Acquisition			
	$ -	$ -	$ -
Easement Acquisition			
	$ -	$ -	$ -
Professional Services for Acquisition			
	$ -	$ -	$ -
Printing			
	$ -	$ -	$ -
Travel expenses in Minnesota			
Travel to collect samples in fields and demonstration site over the 3yrs project period	$ 5,000	$ -	$ 5,000
Other			
Laboratory analysis, equipment calibration, repairs and maintenance	$ 10,000	$ -	$ 10,000
COLUMN TOTAL	$ 545,000	$ -	$ 545,000

SOURCE AND USE OF OTHER FUNDS CONTRIBUTED TO THE PROJECT	Status (secured or pending)	Budget	Spent	Balance
Non-State:		$ -	$ -	$ -
State:		$ -	$ -	$ -
In kind: Unrecovered F&A	Secured	$ 294,000	$ -	$ 294,000

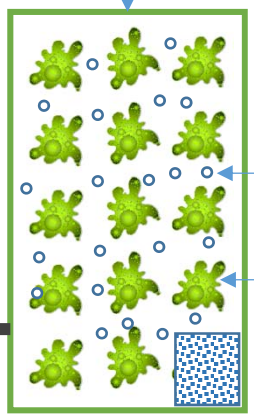
Other ENRTF APPROPRIATIONS AWARDED IN THE LAST SIX YEARS	Amount legally obligated but not yet spent	Budget	Spent	Balance
M.L. 2014, Chp. 226, Sec. 2, Subd. 08c	$ -	$ 1,000,000	$ 1,000,000	$ -

Complete treatment & utilization of concentrated wastewaters

Concentrated Wastewater
(High in COD, total nitrogen, ammonia, total phosphorus, antibiotics)

Methane

Vacuum assisted thermophilic anaerobic digestion (VA-TAD)
(Reduce COD, ammonia, hydrogen sulfide, total nitrogen and total phosphorus)



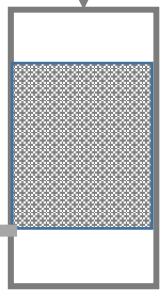
Aerator

Biofilm aerobic digestion (BFAD)
(Reduce COD and nitrogen to appropriate levels)

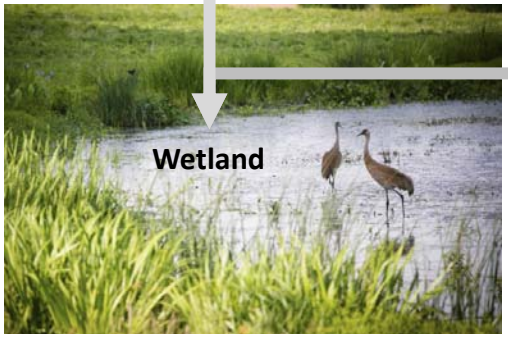
Photocatalytic materials coupled with aerobic bacteria (PMCAB)
(Reduce antibiotics)

Algal & bacterial biomass

Microalgae and bacteria cultivation (MAC)
Reduce COD, nitrogen, phosphorus, and antibiotics



Biochar filtration (BF)
Remove fine particles, etc.



Project Manager Qualifications and Organization Description

Dr. Roger Ruan, Professor and Director, Center for Biorefining and Department of Bioproducts and Biosystems Engineering, University of Minnesota, Fellow of ASABE and Fellow of IFT, is the project manager of the proposed project. Dr. Ruan's research focuses on renewable energy and the environment as well as food safety and quality. Professor Ruan has published over 450 papers in refereed journals, has co-authored two books, and many book chapters, over 300 meeting papers and reports, and holds 17 US patents. He is also a top cited author in the area of agricultural and biological sciences. He has supervised over 65 graduate students, 110 post-doctors, research fellows, and other engineers and scientists, and 13 of his Ph.D. students and 8 other post-doctors hold university faculty positions. He has received over 170 projects totaling over $40 million in various funding for research, including major funding from USDA, DOE, DOT, DOD, LCCMR, and industries. He was the project manager of earlier LCCMR funded projects which resulted in issuance of a US patent and licensing of a technology.

Dr. Ruan has very active ongoing research programs in the areas of environmental and renewable energy engineering. Specifically, his research group has been investigating processes for wastewater treatment and utilization including thermophilic anaerobic digestion, microalgae cultivation, and aquaponics systems. They have accumulated good collections of wastewater sludge, aerobic bacteria, and microalgae strains. His team has experience in building bench and small pilot systems for testing and systems analysis. They are well published in these areas.

The Center for Biorefining is a University of Minnesota research center and help coordinate the University efforts and resources to conduct exploratory fundamental and applied research; provide education on bioenergy, biochemicals and biomaterials; stimulate collaboration among the University researchers, other public sector investigators, and private investigators involved in biobased production technology development; promote technology transfer to industries; and foster economic development in rural areas. The Center's research programs are founded by DOE, USDA, DOT, DOD, LCCMR, IREE, Xcel Energy, and other federal and state agencies, NGOs, and private companies. The Center is equipped with state of the arts analytical instruments, and processing facilities ranging from bench to pilot scale. In particular, they have the capability to develop various bioreactors for different purpose and the means to evaluate related processes.