Environment and Natural Resources Trust Fund

2021 Request for Proposal

General Information

Proposal ID: 2021-387

Proposal Title: Value Added Treatment of Sewage Sludge

Project Manager Information

Name: Roger Ruan

Organization: U of MN - College of Food, Agricultural and Natural Resource Sciences

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Project Basic Information

Project Summary: Develop a novel strategy to cost-effectively treat sewage sludge and simultaneously produce biofuels (biogas and bio-oil) and biochar with low emissions of pollutants

Funds Requested: $910,000

Proposed Project Completion: 2024-06-30

LCCMR Funding Category: Air Quality, Climate Change, and Renewable Energy (E)

Project Location

What is the best scale for describing where your work will take place?

Statewide

What is the best scale to describe the area impacted by your work?

Statewide

When will the work impact occur?

During the Project and In the Future

Narrative

Describe the opportunity or problem your proposal seeks to address. Include any relevant background information.

Sewage sludge is a solid waste from wastewater treatment and a growing environmental problem due to its odor and high contents of harmful substances such as heavy metals, pathogens, etc. On the other hand, sludge contains more than 70% of organic matter which can be recovered in form of energy or resources. In Minnesota, more than 185 million lb of sewage sludge (in dry basis) are produced annually, most of which are burned, and only a small amount is utilized in agriculture due to strict restrictions. In the past few decades, incineration played important role in sludge treatment for advantages in significant reduction in sludge volume, large handling capacity with minimum land occupation, and energy recovery. However, sludge incineration generates secondary pollution and is of high operation cost. An expensive flue gas cleaning system is required to control the emissions of NOx, SO2, fly ash, heavy metals, and dioxins. In the Metro Plant in St. Paul, about 45 million lb of fly ash is produced annually from sludge incineration, and safe disposal of the fly ash is required due to high content of toxic heavy metals.

What is your proposed solution to the problem or opportunity discussed above? i.e. What are you seeking funding to do? You will be asked to expand on this in Activities and Milestones.

In order to foster strengths and circumvent weaknesses of incineration, this project is designed to develop and evaluate a novel strategy to cost-effectively treat sewage sludge through microwave pyrolysis and gasification (MPG), which can not only realize significant reduction in sludge volume and energy recovery, but also has inherent advantages over incineration:

- Organic matters in sewage sludge can be recovered in forms of biofuel and biochar.
- Fly ash and heavy metals are incorporated into biochar, thus fly ash emission and heavy metals leaching of are greatly reduced.
- Formation of gaseous pollutants like NOx, SO2, and dioxins can be greatly reduced.
- Since there is no need of complex and expensive flue gas cleaning system, and no cost of fly ash disposal, the overall operation cost will be significantly lower than incineration.

MPG of sewage sludge still has many technical, economic, and environmental challenges. Briefly, the properties of biofuel and biochar are strongly dependent on MPG conditions, and profitable approaches to continuous utilization of biofuel and biochar need to be explored. These issues also impact the viability of MPG of sewage sludge and must be addressed before the technology can be commercialized.

What are the specific project outcomes as they relate to the public purpose of protection, conservation, preservation, and enhancement of the state's natural resources?

Develop and demonstrate a cost-effective sludge-to-biofuel-biochar (STBB) technology that will prevent sewage sludge from polluting Minnesota lands, waters, and airs, and at the same time produce profitable products. The efforts planned for this project are to go beyond proof of concept and develop process specifically for sewage sludge as the feedstock.

Activities and Milestones

Activity 1: Evaluate the potential economic, environmental and ecological impacts of the proposed technology

Activity Budget: $260,000

Activity Description:
We plan to conduct preliminary studies to provide big pictures of the potential economic, environmental and ecological impacts of the STBB technology. Additional data on mass and energy balance will be collected. Greenhouse gas emission during the process will be monitored. An input-output model will be used for economic analysis. The energy consumption, greenhouse gas emission, waste reduction, and biogas & biochar utilization will be considered in the assessment of environmental and ecological impacts of the technology.

Activity Milestones:

Description	Completion Date
Monitoring of greenhouse gas emission	2024-03-31
Collection of mass and energy balance data	2024-03-31
Preliminary assessment of economic, environmental, and ecological impacts	2024-06-30
Estimate of potential reduction in sewage sludge and production of valuable products	2024-06-30

Activity 2: Develop and investigate processes for converting sewage sludge to biogas and biochar

Activity Budget: $250,000

Activity Description:
We will first conduct microwave gasification of sewage sludge experiments using standard process with our lab experimental apparatus. The key processing parameters and conditions to be investigated and adjusted are heating rate, oxygen concentration, temperature, feeding rate, and catalysts. The yields of biogas and biochar fractions will be measured; the composition and energetic properties of the biogas and biochar, the textural property of biochar, and the leaching concentration of heavy metals in biochar will be determined to evaluate their quality for further utilization. These planned activities are expected to generate information that will help us understand the relationships between processing variables and product yield and quality, creating profitable approaches for continuous utilization of biogas and biochar and laying the foundation for further R&D to move the technology to commercial sectors.

Activity Milestones:

Description	Completion Date
Initial test of microwave assisted pyrolysis and gasification of sewage sludge	2021-12-31
Collection and characterization of sewage sludge	2022-06-30
Process development and investigation	2022-12-31
Evaluation of the process and product yield and quality	2023-06-30

Activity 3: Develop and demonstrate a pilot scale system

Activity Budget: $400,000

Activity Description:
With the knowledge, experience, and optimized processes obtained from Activity 1, we will develop a small pilot scale

system for comprehensive evaluation of the processes and demonstration of the technology to general public for education and outreach purpose. The system will also be used to generate data for analysis described in Activity 3.

Activity Milestones:

Description	Completion Date
Scale-up parameters will be determined for the optimized process flow	2023-03-31
System design will be completed	2023-06-30
System will be fabricated and assembled, and tested	2023-12-31
The system will be demonstrated on UMN to the stakeholders	2024-06-30

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Yanling Cheng	University of Minnesota	co-PI	No
Paul Chen	University of Minnesota	co-PI	Yes

Long-Term Implementation and Funding

Describe how the results will be implemented and how any ongoing effort will be funded. If not already addressed as part of the project, how will findings, results, and products developed be implemented after project completion? If additional work is needed, how will this be funded?

New scientific knowledge and experience on MPG of sewage sludge will be acquired through research. Processes for MPG of sewage sludge will be developed. The potential economic, environmental and ecological impacts will be presented to the stakeholders to raise their awareness and attract their support. We will seek industry partners and private, state, and federal funding to further develop and eventually commercialize the technology.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Demonstrating Innovative Technologies to Fully Utilize Wastewater Resources	M.L. 2014, Chp. 226, Sec. 2, Subd. 08c	$1,000,000
Development of Innovative Sensor Technologies for Water Monitoring	M.L. 2016, Chp. 186, Sec. 2, Subd. 04j	$509,000

Project Manager and Organization Qualifications

Project Manager Name: Roger Ruan

Job Title: Professor and Director

Provide description of the project manager's qualifications to manage the proposed project.

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 technologies, solid and liquid waste treatment and utilization, and environmental engineering. Specifically, he has conducted research and published his findings in the areas of municipal, agricultural, and industrial wastewater treatment and utilization through novel anaerobic digestion, microalgae cultivation, and hydroponic cultivation, biomass and solid wastes (including plastics) gasification and pyrolysis, airborne pathogen disinfection, catalysis, non-thermal plasma, ammonia synthesis, etc. He is a top-cited author in the area of agricultural and biological sciences with an h-index of 63, i10-index of 255, and over 15,400 citations, and has received over 180 projects totaling over $45 million in various funding for research, including major funding from USDA, DOE, DOT, DOD, LCCMR, and industries. He was the project manager of several earlier LCCMR funded projects which resulted in the issuance of a US patent and licensing of a technology. Therefore he has the technical expertise and project management experience to ensure the execution of proposed projects.

Organization: U of MN - College of Food, Agriculture and Natural Resource Sciences

Organization Description:

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.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Paul Chen		Co-PI			36.5%	0.48		$64,621
Roger Ruan		Principal Investigator			36.5%	0.12		$24,328
Post Doc		Researcher			25.4%	3		$193,799
Graduate Research Assistant		Research Assistant			45%	1.5		$301,867
							Sub Total	**$584,615**
Contracts and Services								
							Sub Total	-
Equipment, Tools, and Supplies								
	Equipment	Components for fabrication of a small pilot system including reactor vessel, insulation materials, magnetrons, power supply and control, motors, mixer, feeder, valves, etc.	To fabricate a small pilot system for extensive testing, cost and emission analysis, and demonsration					$300,000
	Tools and Supplies	Purchase of lab and miscellaneous supplies, including feedstock, catalysts, chemicals, consumable supplies for analytical instruments	For running experiments and operating conversion systems					$19,385
							Sub Total	**$319,385**
Capital Expenditures								
							Sub Total	-
Acquisitions and Stewardship								
							Sub Total	-
Travel In Minnesota								

							Sub Total	**-**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
		Repairs and Maintenence	Repairs and Maintenance of analytical instruments					$6,000
							Sub Total	**$6,000**
							Grand Total	**$910,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request

Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	**-**
Non-State				
			Non State Sub Total	**-**
			Funds Total	**-**

Attachments

Required Attachments

Visual Component

File: bf66c2cf-201.pdf

Alternate Text for Visual Component

A visual illustration of pollution caused by current sludge management practice, proposed process flow diagram, preliminary data on valuable products from pyrolysis of sludge, key parameters to be studied, expected outcomes, and existing biomass pyrolysis facility.

Optional Attachments

Support Letter or Other

Title	File
UMN authorization letter	6339f899-200.pdf
UMN financial audit report	102e5ede-f8c.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Does your project have patent, royalties, or revenue potential?

Yes,

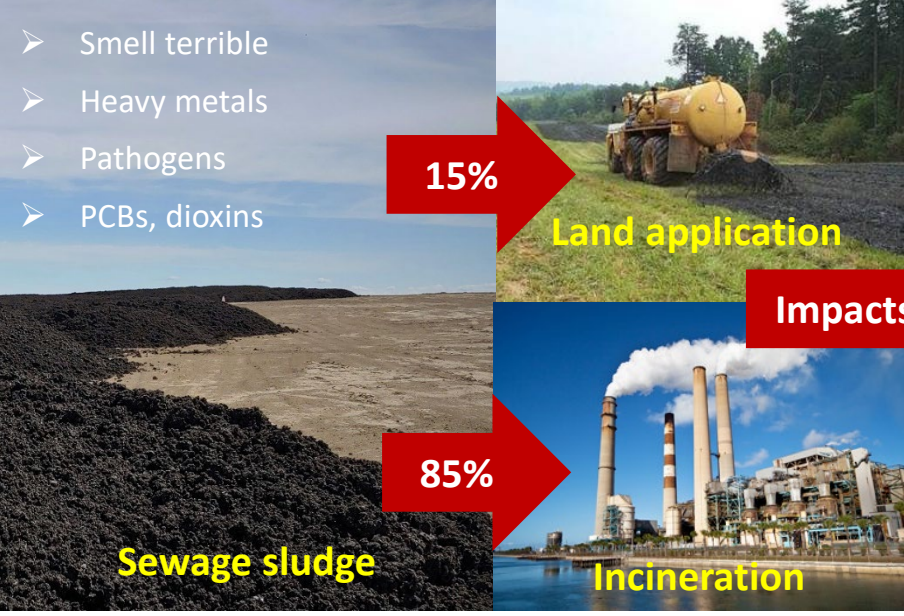
- Patent, Copyright, or Royalty Potential

Does your project include research?

Yes

Does the organization have a fiscal agent for this project?

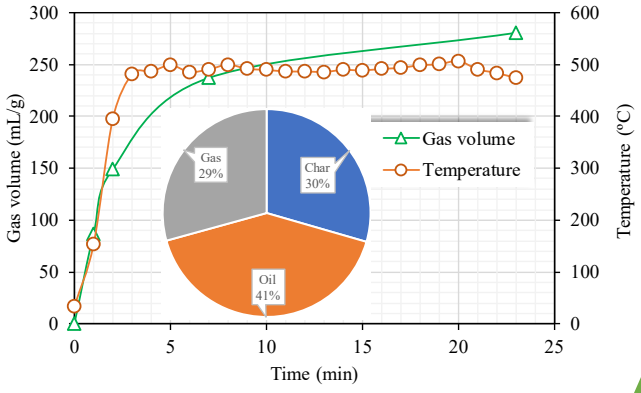
No

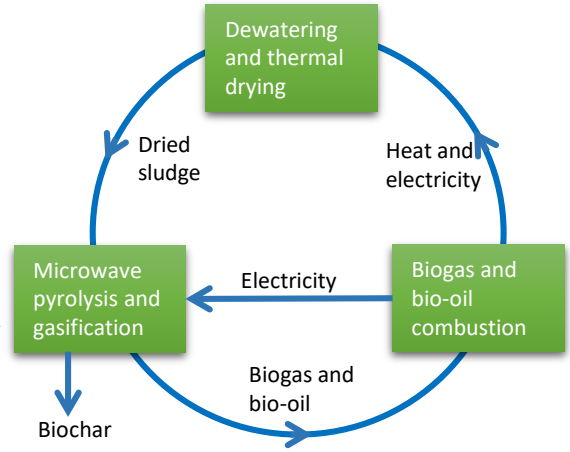


Impacts

- Potential risk of soil pollution
- Strictly restricted by pollutants content in sewage sludge, like heavy metals and pathogens.
- Secondary pollution from emissions of NO_x, SO_2, fly ash, dioxins, etc.
- Safe disposal fly ash is required
- High operation cost

A new strategy





Small pilot scale microwave assisted pyrolysis and gasification system

Key processing parameters

- Heating rate
- Temperature
- Catalysts
- Feeding rate
- Moisture content of dried sludge
- Oxygen concentration for gasification

Outcome of the Project

- Processes will be developed and investigated for conversion of sewage sludge to biofuel and biochar
- Potential economic, environmental and ecological impacts of the proposed strategy will be evaluated
- Stakeholders will be presented with the research findings and recommendations for further actions
- The research findings will be used for seeking industrial partnerships and external funds for further R & D efforts