Environment and Natural Resources Trust Fund

2021 Request for Proposal

General Information

Proposal ID: 2021-345

Proposal Title: Treatment of Organic Medical and COVID-19 Contaminated Wastes

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 technology for on-site treatment and conversion of organic medical wastes contaminated by COVID-19 and other pathogens to energy and materials.

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.

Medical wastes, if not treated properly, can potentially contaminate our waters and air, causing public health hazards. U.S. hospitals produce more than 5.9 million tons of medical waste each year. It was estimated that approximately 20% of medical waste are hazardous induced by infectious, toxic, and radioactive substances. Before 1997, more than 90 percent of potentially infectious medical waste was incinerated. Medical wastes contain nitrogen, chloride, and sulfur compounds which may be converted to dangerous air pollutants, such as toxins, NOx, N2O, and SOx, and the greenhouse gas emission has been a growing concern also. EPA promulgated regulations setting stringent emission standards for medical waste incinerators due to major concerns over detrimental air quality affecting human health. EPA's Office of Air Quality Planning and Standards continues to review and revise the Hospital Medical Infectious Waste Incinerator (HMIWI) standards as required most recently in May of 2013. Hence, other alternative treatment technology for medical waste should be developed. By on-site treating and converting medical waste to energy, waste can be cost effectively intercepted and re-used, limiting pathogens and virus spread and protecting the environment.

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.

Gasification and pyrolysis, which convert organics to syngas, liquid fuels, and chars, are usually carried out at temperature above 600 ºC, meaning that no microorganisms in the medical waste can survive the process. Yet, attempts to scale up and commercialize this technology have seen no fruition so far as most existing studies remain in the bench scale and struggle with yield and quality issues of the products. Several challenges, including reactor design, operating conditions optimization, and catalyst application, have to be overcome in order to scale up the technology and make the process economically viable. With LCCMR's past support, our technology has evolve into mobile fast microwave assisted pyrolysis/gasification with continuous operation and enhanced heating rate. Our preliminary research indicated that this system can effectively convert plastic wastes into hydrocarbon-rich liquid oil or high quality syngas featuring high C1-C4 light hydrocarbons and hydrogen content. We are ready to tweak the pyrolysis/gasification system for medical waste treatment and utilization. Due to high contents of plastics in medical waste, the recovery of hydrocarbon-rich liquid oil can also be achieved by pyrolysis at relatively low temperature if desirable.

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?

The key outcome of the project is the development of microwave-assisted gasification (MAG) technology for safely treating and converting medical waste into energy and simultaneously killing coronavirus and other pathogens. Thus the project helps reduce pollution by medical waste and protect the environment, and also eliminate health hazards.

Activities and Milestones

Activity 1: 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

Activity 2: Develop and investigate processes for converting medical wastes to high quality and clean syngas and then generate electricity

Activity Budget: $300,000

Activity Description:
Medical wastes mainly contain plastics, cotton fabric, woodware, and pharmaceutical waste. We will first test different representative feedstocks using standard process with our lab experimental apparatus. The issue to be addressed in this project is poor syngas quality and tar formation from the mixed feedstocks. We will use very high heating rate and temperature enabled by the microwave absorbent induced heating and proper catalysts to increase the CO and H2 concentration and inhibit tar formation. The results from the initial tests will guide our further research and optimization of the processes and controls in the pilot scale system development. The key features of the new system will include automatic waste sizing and feeding mechanism, a motor-driven mixer to ensure uniform mixing of MW absorbent and the raw material, and temperature distribution, catalytic tar conversion, multiple-point temperature sensing and temperature control. Syngas cleaning mechanism will be incorporated as needed. These planned activities are expected to generate information that will help us understand the relationships among mixed medical wastes, gasification processing variables and product yield and quality, laying the foundation for further R&D to move the technology to commercial sectors.

Activity Milestones:

Description	Completion Date
Initial test of microwave assisted gasification of medical wastes	2021-12-31
Process development and investigation	2022-12-31
Evaluation and optimization of the process and product yield and quality	2022-12-31

Activity 3: Evaluate the potential economic, environmental and ecological impacts of the proposed technology

Activity Budget: $210,000

Activity Description:

The proposed R&D, optimization and demonstration efforts are designed to conduct system analysis to provide big pictures of the potential economic, environmental and ecological impacts of the medical waste-to-electricity technology and help streamline and design the process for site-specific applications. A preliminary techno-economic analysis of the technology will be conducted using some baseline assumptions together with data collected from the project. Revenue creation from medical waste producers as a result of the commercialization of the technology will be considered in the analysis. The energy consumption, virus inactivation, greenhouse gas/pollutants emission, and waste reduction will be considered in the assessment of environmental and ecological impacts of the technology.

Activity Milestones:

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

A novel, safe, and reliable mobile on-site medical waste disposal technology will be developed and evaluated. New scientific knowledge and experience in microwave assisted gasification of medical wastes will be acquired through research and development. The potential economic, environmental and ecological impacts will be estimated to the stakeholders to raise their awareness and attract their supports. We will seek industry partners and private, state, and federal fundings 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 $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								
Roger Ruan		Principal Investigator			36.5%	0.12		$24,328
Paul Chen		Co-Prinicpal Investigator			36.5%	0.48		$64,621
Post Doc		Researcher			25.4%	3		$193,799
Graduate Research Assistant		Research Assistant			45%	1.5		$150,933
Graduate Research Assistant		Research Assistant			45%	1.5		$150,933
							Sub Total	**$584,614**
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					$19,386
							Sub Total	**$319,386**
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 Maintenance	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: 3b2071be-9fb.pdf

Alternate Text for Visual Component

1) Disadvantages of current processes and advantages of the proposed technology
2) Our past accomplishments in the related areas
3) Expected outcomes of the project

Optional Attachments

Support Letter or Other

Title	File
UMN authorization letter	85a7d21d-cb4.pdf
UMN financial audit report	146a89db-5b7.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

Disadvantages

- Low energy efficiency
- PM2.5
- Toxins, SO_x, NO_x
- Transportation issue and cost

Incineration

Advantages

- Mobile on-site treatment
- High effeciency
- Automatic waste sizing and feeding
- Scalability and portability
- Environmental friendly

Gasification

Electricity

Our microwave pyrolysis/gasification technology development

Highlights

- Fast heating
- Easily-controlling
- Using a negligible amound of carrier gas
- Energy-saving
- Nearly 100% chemical recyclables
- Mature R&D plans

Using SiC bed

Improving heating rate

Further improving system design

Transfer it to company

Outcome of the Project

- An advanced microwave gasification technology will be developed for cost effectively and safely converting medical wastes to electricity
- Potential economic, environmental and ecological impacts of the proposed strategy will be evaluated
- The research findings will be used for seeking industrial partnerships and external funds for further R & D efforts