Environment and Natural Resources Trust Fund

2025 Request for Proposal

General Information

Proposal ID: 2025-204

Proposal Title: Nonthermal Plasma and Microwave Technology for Virus Control

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: The project aims to develop pilot-scale non-thermal plasma and microwave air filtration modules for virus, aerosol, chemical gas, and odor removals with effectiveness surpassing HEPA filters.

ENRTF Funds Requested: $959,000

Proposed Project Completion: June 30, 2028

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.

Minnesota is a leading agricultural state, ranking 1st in turkey production and 12th in poultry production nationwide (Su Ye, 2022). However, the intensive indoor farming practices prevalent in the state raise significant concerns regarding air quality. Airborne pathogens pose serious risks to both human and animal health. The Highly Pathogenic Avian Influenza (HPAI) outbreak in 2015 resulted in an estimated economic loss of $647.2 million and affected over 2,500 jobs in Minnesota. Additionally, pollutants such as NH3 and H2S in production facilities pose health risks such as eye and respiratory irritation, and generate community complaints due to unpleasant odors.

Traditional animal houses often lack proper biosecurity, operating under negative pressure and relying on HEPA filters. While HEPA filters effectively capture large particles, they struggle with viruses, aerosols, and harmful gases. This necessitates the development of new air filtration systems to protect both animal and human health from airborne hazards and disease outbreaks.

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

This project aligns with Priority E: Air Quality, Climate Change, and Renewable Energy. This project will be focused on the development and evaluation of innovative non-thermal plasma (NTP) and microwave (MW) processes for reducing or eliminating airborne biological and chemical contaminants in animal production facilities. Our research involves evaluating the effectiveness of these technologies in inactivating avian influenza virus (AIV), decomposing NH3 and H2S, and removing odors, complemented by configuration modeling, airflow simulation, and economic analysis.

NTP involves the generation of a partially ionized gas through a strong electric field, leading to rapid breakdown of air into reactive species such as UV photons, high-energy electrons, and reactive oxygen species. Our previous research has demonstrated its efficacy in inactivating airborne viruses, bacteria, and fungal spores.

Microwave (MW) systems represent another emerging antimicrobial technology. Microwaves are a form of electromagnetic radiation, in the frequency range of 300MHz to 300GHz. MW-absorbing foam filters made of SiC are incorporated into the system. Their sponge-like structures featuring interconnecting macroscopic pores enable efficient removal of impurities and viruses with minimal pressure drop and superior heat and mass transfer capabilities.

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 proposed technology is expected to overcome the technological limitations of conventional air filtration systems, effectively eliminating fine particles such as viruses, chemical gases, and odors. Furthermore, the understanding gained from scale-up modeling and airflow simulations will be used to optimize product design and use, extending its application beyond the poultry industry. Given Minnesota's 18,000 registered feedlots, the successful development of this technology will play a significant role in safeguarding human and animal health within animal facilities, ensuring a sustainable and revenue-generating solution for animal welfare and environmental conservation.

Activities and Milestones

Activity 1: Develop and test the performance of MW and NTP module prototypes

Activity Budget: $120,000

Activity Description:

In the MW system, SiC foam serves as the foundational structure in the microwave based reactor. SiC's high microwave absorption facilitates rapid heating and disinfects pathogens in the incoming air. The temperature of the exhaust air will be maintained below 60°C through heat sink. Additional coatings on the SiC foam, like zeolite, enhance virus trapping efficiency by absorbing moisture from aerosols. Virucidal catalytic materials such as TiO2 and CuO exhibit enhanced disinfection efficiency under MW and can be loaded onto zeolites to enhance AVI disinfection.

Our NTP module incorporates a compact, dielectric-barrier discharge (DBD) reactor for plasma generation. Air enters through one end of the DBD reactor, passing through the plasma discharge region where it is ionized to generate energetic particles that disinfect airborne pathogens or transform chemicals into harmless forms . Treated gas exits the DBD vessel without hazardous compounds . Various parameters, including applied voltage, discharge gap, air flow rate, and electrode materials, can significantly impact the treatment efficiency of the DBD reactor. As a result, we will conduct experiments testing different configurations of the DBD reactor under varying conditions to optimize its performance.

Activity Milestones:

Description	Approximate Completion Date
Develop the foundational MW module and test the disinfection ability	October 31, 2025
Test on different MW configurations with incorporated Zeolite and catalysts	January 31, 2026
Develop the DBD reaction vessel and test the disinfection ability	April 30, 2026
Test on DBD configurations with different electrochemical features	July 31, 2026

Activity 2: Model and scale up the NTP and MW processes

Activity Budget: $550,000

Activity Description:

We will use the data from testing the prototypes to model the NTP and MW modules for larger scale application. Parameters such as dimension, air flow rate, contaminant concentrations, temperature and power output will be included in this model. Various test conditions and responses such as outlet air temperature, contaminant concentrations, flow rate, and energy consumption will be used as the training set to i) investigate the correlation between parameters, ii) to find the principal and minor components influencing the disinfection ability, and iii) to validate the feasibility for larger scale applications. An optimal configuration, a set of optimized processing parameters, and scale-up parameters will be determined to guide the development of a prototype treatment unit that will fit the requirements of a demonstration farm facility.

Activity Milestones:

Description	Approximate Completion Date
Data collection and modeling for MW reactors completed	October 31, 2026
Scale-up parameters will be determined for the optimized MW configuration	January 31, 2027
Data collection and modeling for NTP reactors completed	April 30, 2027
Scale-up parameters will be determined for the optimized NTP configuration	July 31, 2027

Activity 3: Pilot-scale experiments with air dynamic modeling

Activity Budget: $289,000

Activity Description:

The pilot-scale units developed will be taken to a poultry barn in Rosemount Research and Outreach Center for pilot-scale testing and demonstration. Prototype units will be mounted at different places, and data on the destruction and removal of airborne contaminants and air flow profiles will be constantly monitored at different spots in the farmhouse. For this activity, the strategy to place prototype units according to the internal configuration of the barn will be thoroughly investigated. Computational fluid dynamics (CFD) tools such as Ansys will be used to simulate the ventilation and hazard removal performance within the barn. The final decision will consider criteria including air distribution, treatment capacity, energy consumption, and operation costs to optimize the compatibility between MW and NTP modules and other facilities such as the air filtration units. Stakeholders will be brought to the demo site to view the system and operation.

Activity Milestones:

Description	Approximate Completion Date
Pilot-scale test/demonstration system design completed	August 31, 2027
Pilot-scale test/demonstration system fabricated and tested	January 31, 2028
Simulation of the pilot scale test condition completed	April 30, 2028
The field test/demonstration system will be demonstrated in WCROC to the stakeholders	June 30, 2028

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 work be funded?

Results will be implemented in bench scale and pilot scale. Data will be collected by manual measurement and supported by the additional simulation. Fundings will be assigned to materials, facilities, data acquisition and labor. For any extension of our technologies from this project, we will seek industry partners and private, state, and federal funding to further develop and eventually commercialize the technology. Streamlined collaboration ensures the project's real-world feasibility and accuracy, revolutionizing current practices and facilitating commercialization, promoting scalability, and real-world impact in mitigating airborne contaminants in animal production facilities.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Methods to Destroy PFAS in Landfill Leachates	M.L. 2022, , Chp. 94, Art. , Sec. 2, Subd. 04a	$200,000

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 is a Fellow of the National Academy of Inventors, the American Society of Agricultural and Biological Engineers, the Institute of Food Technologists, the International Association of Advanced Materials, and Vebleo, and have received many other awards, including International Bioprocessing Association's Pandey Award, CAFS Professional Achievement, Scientist of IAAM, etc. Dr. Ruan's research areas include renewable energy and environment technologies for sustainable development and circular economy. His research has focused on biomass and solid wastes such as plastic wastes pyrolysis and gasification for chemicals, materials, fuels, and energy production; wastewater treatment and utilization through novel anaerobic digestion, microalgae cultivation; airborne and other pathogen disinfection and pollutant control; innovative catalytic non-thermal plasma, low temperature microwave and pulse microwave, photocatalytic intensive pulse light, and NMR/MRI technologies development and applications in nitrogen fixation, food safety assurance, and food quality improvement; and food engineering and various value-added processing. Dr. Ruan has published over 600 papers in refereed journals, two books, and 28 book chapters, and holds 19 US patents. He is also a top-cited author in engineering and technologies, with an h-index of 96, i10-index of 480, and over 37,000 citations. He has received over 200 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 US patents and licensing of technologies. He has the technical expertise and project management experience to ensure the execution of proposed project.

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

Organization Description:

The Center for Biorefining is a University of Minnesota research center and help coordinate 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 in biobased production technology development; promote technology transfer to industries; and foster economic development in rural areas. The Center's research programs have been 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.

The Department of Bioproducts and Biosystems Engineering, in CFANS, discovers and teaches solutions for the sustainable use of renewable resources and the enhancement of the environment. We discover innovative solutions to address challenges in the sustainable production and consumption of food, feed, fiber, materials, and chemicals by integrating engineering, science, technology, and management into all degree programs.

https://bbe.umn.edu/biobrief

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Roger Ruan		Principal Investigator			37.1%	0.3		$83,916
Part time Researcher		Manage lab, conduct research and analysis			37.1%	1.5		$134,266
Graduate Research Assistant		Research Assistant			46%	3		$173,637
Post doctoral student		Conduct research and analysis and prepare manuscripts/reports			27.1%	3		$233,386
							Sub Total	**$625,205**
Contracts and Services								
							Sub Total	**-**
Equipment, Tools, and Supplies								
	Tools and Supplies	Purchase of lab and miscellaneous supplies, including virus culture medium, catalysts, chemicals reagents, consumable supplies for analytical instruments, PPEs, and etc.	For running experiments and operating conversion systems					$31,795
	Equipment	Components including mirowave-assisted reactor vessel, plasma generators, insulation materials, magnetrons, control, motors, mixer, feeder, valves, etc.	To fabricate a pilot system for pilot-scale demonstration system for catalytic NTP air filtration modules					$250,000
	Tools and Supplies	Up to 2 units computer hardware	Data storage, run analytics, interface with manufactured equipment					$3,000
	Tools and Supplies	components of lab system	For testing and development of lab system					$45,000
							Sub Total	**$329,795**
Capital Expenditures								
							Sub Total	**-**

Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	Mileage, per diem for trips for up to the whole team	Demonstration of air filtration modules and outreach to local communities					$4,000
							Sub Total	**$4,000**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$959,000**

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	**-**

Total Project Cost: $959,000

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: 6f978091-042.pdf

Alternate Text for Visual Component

The visual abstract shows the proposed air sanitation units, which employ catalytic non-thermal plasma or low-temperature microwave treatments. These innovative systems effectively eliminate airborne pathogens, viruses, chemical gases, and odors as air passes through the sanitation units. The treated air can then be recirculated inside the facility or exhausted....

Supplemental Attachments

Capital Project Questionnaire, Budget Supplements, Support Letter, Photos, Media, Other

Title	File
Preliminary result	33f2e6ed-1a8.pdf
SPA Cover Letter - Virus Control	2c885da0-ac9.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Does your project have potential for royalties, copyrights, patents, sale of products and assets, or revenue generation?

No

Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?

N/A

Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?

N/A

Does your project include original, hypothesis-driven research?

Yes

Does the organization have a fiscal agent for this project?

No

Does your project include the pre-design, design, construction, or renovation of a building, trail, campground, or other fixed capital asset costing $10,000 or more or large-scale stream or wetland restoration?

No

Do you propose using an appropriation from the Environment and Natural Resources Trust Fund to conduct a project that provides children's services (as defined in Minnesota Statutes section 299C.61 Subd.7 as "the provision of care, treatment, education, training, instruction, or recreation to children")?

No

Provide the name(s) and organization(s) of additional individuals assisting in the completion of this proposal: