



# Environment and Natural Resources Trust Fund

2023 Request for Proposal

## General Information

**Proposal ID:** 2023-202

**Proposal Title:** Virus, Bacteria and Odorous Air Pollutant 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:** Development and demonstration of the feasibility of using low temperature microwave and nonthermal plasma (NTP) with catalysis enhancement for effective air sanitation for livestock and poultry facilities.

**Funds Requested:** \$499,000

**Proposed Project Completion:** June 30, 2026

**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 remains one of the country's top agricultural states. However, a major concern with livestock farming - airborne pollutants including pathogenic microorganisms, e.g., avian influenza virus (AIV), and odorous chemicals, e.g., ammonia and hydrogen sulfide, which pose great threats to animal and human health, economy, and environment, especially during Covid19. Bird flu caused by AIV is incredibly disruptive to the regional poultry industry due to massive culling of infected birds, and restrictions placed on poultry meat exports. In 2015 a regional outbreak in Minnesota resulted in an economic loss of estimated \$647.2 million and affected over 2,500 jobs. This year the first cases of H5N1 in Minnesota were confirmed on March 25, 2022 soon after USDA Animal and Plant Health Inspection Service (APHIS) confirmed several findings of the presence of highly pathogenic avian influenza (HPAI) in wild waterfowl in the Atlantic flyways in January 2022. Other airborne pathogens in poultry barns and hog farms, which have potential to harm humans, include Salmonella, Staphylococcus, Streptococcus, and others may be harmful to humans. Odor-related issues range from mild complaints from neighboring communities to lawsuits resulting in costly stoppages in farming operations.

### **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 will be focused on the development and evaluation of innovative low temperature microwave (MW) and non-thermal plasma (NTP) processes and their use in reducing or eliminating airborne biological and chemical contaminants from animal production facilities. NTP is a partially ionized gas. When air is exposed to a strong electric field, it rapidly decomposes into a variety of reactive species including UV photons, high-energy electrons, reactive oxygen species, and others, and have successfully inactivated airborne viruses, bacteria, and fungal spores in our previous research. Low temperature microwave (MW) systems represent another emerging effective antimicrobial technology. Microwaves are a form of electromagnetic radiation, in the frequency range of 300MHz to 300GHz. MW-absorbing ceramic foam filters made of silicon carbide are incorporated into the system where viruses can be captured and disinfected more effectively and efficiently. In this project, we will develop a hurdled treatment unit for air sanitization and odor control in poultry facilities. The effect of the treatment on AIV viability, decomposition of ammonia, H<sub>2</sub>S, and removal of small particles will be evaluated. Furthermore, the economic, environmental, and health impacts will be analyzed.

### **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 successful development of the proposed technology is expected to help protect human and animal health by removing hazardous airborne biological and chemical contaminants from poultry facilities. The knowledge acquired and technology developed may be extended beyond the poultry industry. With more than 18,000 registered feedlots in Minnesota, the proposed technology has a great potential to make a huge impact on controlling and reducing airborne pollutants in Minnesota livestock farms, as mentioned before, this would also be a great tool to relieve the public concern of the pandemic.

## Activities and Milestones

### Activity 1: Develop, optimize and evaluate a MW system aided with catalysts

**Activity Budget:** \$190,000

#### Activity Description:

The optimization of the low temperature MW system will be based on our current system. Application of a bifunctional coating onto the ceramic foam support for the MW system will be tested. The coating is composed of zeolite material of high specific surface area, which can absorb moisture from the aerosol and therefore potentially improves the effect of trapping viruses onto the foam support. Then different types and doses of virucidal materials including TiO<sub>2</sub> and CuO will be loaded onto the zeolites to further enhance the disinfection efficiency on AVI. Plus, design a heat recovery system so that the thermal energy in the exhaust air can be recycled to preheat untreated incoming air. Two additional ceramic foam sections will be added to both sides of the original foam reactor. While the microwave only heats the central section, the exhaust hot air enters into the opposite section and heats up the cold ceramic foam material, so the final temperature of the exhaust air can be reduced. When steady state is reached, the flow direction is reversed so that the residue heat will be used to preheat. Therefore, heat recovery is achieved and energy efficiency can be significantly increased.

#### Activity Milestones:

Description	Completion Date
Different catalysts will be prepared and characterized	December 31, 2023
The heat recovery system will be designed and incorporated to the system	December 31, 2023
The performance of the modified MW system will be investigated	June 30, 2024
Energy efficiency will be evaluated	June 30, 2024

### Activity 2: Design, fabricate, and test the NTP and MW treatment unit for destruction and removal of airborne contaminants in animal production facilities

**Activity Budget:** \$220,000

#### Activity Description:

We will first use our current lab NTP apparatus to develop and optimize the process. Additional promising reactor configurations will be tested. For instance, the feasibility of enhancing airborne contaminant removal using electrostatic precipitation will be examined. Also investigated is the incorporation of photocatalysis, such as using modified TiO<sub>2</sub>, which could be promoted under NTP conditions and therefore improve the effectiveness of the overall process. An optimal configuration, a set of optimized processing parameters, and preliminary scale-up parameters will be determined to guide the development of a prototype treatment unit that will fit the requirement of a small demonstration farm facility. The destruction and removal of key airborne contaminants, i.e., selected pathogens (AI virus, Salmonella) and odorous compounds (ammonia, H<sub>2</sub>S) will be evaluated when the unit is initially tested in labs.

#### Activity Milestones:

Description	Completion Date
NTP system will be modified	June 30, 2024
Removal efficiency, air quality data, and energy efficiency will be evaluated	June 30, 2025
An optimized system and process flow diagram will be delivered alongside with the comparison with the MW system	December 31, 2025

### Activity 3: Assess potential positive environmental, health, and economic impacts of the strategy

**Activity Budget:** \$89,000

#### **Activity Description:**

After testing and study of the prototype unit in a lab setting, the units will be taken to a small poultry barn in University of Minnesota Rosemount Research and Outreach Center for field testing and demonstration. Data on destruction and removal of airborne contaminants, treatment capacity, energy consumption, and operation costs will be collected and analyzed. The environmental, health, and economic impacts of the strategy will be assessed under different scenarios. Stakeholders will be brought to the demo site to view the system and operation.

#### **Activity Milestones:**

Description	Completion Date
Scale-up parameters will be determined for the optimized process flow	December 31, 2025
Field test/demonstration system design will be completed	December 31, 2025
Field test/demonstration system will be fabricated and tested in lab and on fields	June 30, 2026
The field test/demonstration system will be demonstrated in WCROC to the stakeholders	June 30, 2026

## Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Paul Chen	University of Minnesota	Co-PI	No

## 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?**

New scientific knowledge and experience on NTP and MW based processes for removal of airborne contaminants from poultry barns will be acquired. The operation and demonstration on farms will raise significant interests from the stakeholders. 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. Ruan, Professor and Director of Graduate Studies of Bioproducts and Biosystems Engineering Department, and Director of Center for Biorefining at University of Minnesota, is a Fellow of ASABE, IFT, Vebleo, and IAAM, and has received many other awards, including CAFS Professional Achievement and Scientist of IAAM, etc. He is a top cited author in engineering and technology with an h-index of 80, i10-index of 392, and has over 25,000 citations. Dr. Ruan's research include renewable energy and environment technologies for sustainable development. He has published over 500 referred journal articles, two books, 24 book chapters, and holds 20 US patents in the areas of municipal, agricultural, and industrial liquid and solid waste including biomass and waste plastics treatment and utilization through novel anaerobic digestion, microalgae and hydroponic cultivation, pyrolysis and gasification, airborne and other pathogen disinfection and pollutant control, catalysis, non-thermal plasma, and nitrogen fixation, etc. He has received over 200 grants totaling over \$45 million in various funding for research, including major grants from USDA, DOE, DOT, DOD, LCCMR, and industries. He has served as guest editor or editorial board member of Bioresource Technology, Renewable Energy, Engineering, Applied Catalysis and Chemical Engineering, Journal of Food Process Engineering, The Open Plasma Physics Journal, and Associate Editor of Transactions of ASABE, Engineering Applications in Agriculture, and Transactions of CSAE, and Chairman of Editorial Board and Editor-in-Chief of International Journal of Agricultural and Biological Engineering, etc. He has supervised over 75 graduate students, 140 post-doctors, research fellows, and other engineers and scientists. He has given over 300 keynote lectures, invited symposium presentations, and short courses. His earlier LCCMR funded projects have resulted in several patented technologies which have been successfully licensed to the industry. He has the technical expertise and project management experience to ensure the execution of proposed projects.

**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 affiliated with the College of Food, Agricultural and Natural Sciences and help coordinate the University efforts and resources to conduct exploratory fundamental and applied research and provide education on science and technology for environment protection and circular economy; 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
<b>Personnel</b>								
Professor/faculty		Primary Investigator - project lead, advises researchers, plans and directs research, oversees budget, monitors and reports progress			33.5%	0.06		\$15,940
Professor/faculty		Co-Primary Investigator - advises researchers, designs and directs experiments, conducts data analysis, writes reports and publications			33.5%	0.15		\$69,062
1 Graduate Research Assistant		carries out experiments, collects and analyzes data, prepares reports and manuscripts			45%	1.5		\$160,139
Post Doctoral Reseracher		designs and carries out experiments, collects and analyzes data, prepares reports and manuscripts			20.9%	3		\$185,001
							<b>Sub Total</b>	<b>\$430,142</b>
<b>Contracts and Services</b>								
equipment manufacturer	Professional or Technical Service Contract	Maintenance and repair, including callibration				0		\$9,000
							<b>Sub Total</b>	<b>\$9,000</b>
<b>Equipment, Tools, and Supplies</b>								
	Equipment	Components for fabrication of a small pilot system including reactor vessel, high voltage power supply, catalysts, pumps, membrane separator	To fabricate a small pilot system for extensive testing, cost analysis, and demonstration					\$25,000
	Tools and Supplies	Purchase of lab and miscellaneous supplies, including catalysts, chemicals, consumable supplies for analytical instruments	For running experiments and operating conversion systems					\$31,858
							<b>Sub Total</b>	<b>\$56,858</b>
<b>Capital Expenditures</b>								
							<b>Sub Total</b>	<b>-</b>

<b>Acquisitions and Stewardship</b>								
							<b>Sub Total</b>	-
<b>Travel In Minnesota</b>								
	Miles/ Meals/ Lodging	12 one-day 3-person trips, ~100 miles each round trip (\$0.585/mile), meals @\$49/person	Visits to farms, conduct experiments on farms and industry collaborators sites					\$3,000
							<b>Sub Total</b>	<b>\$3,000</b>
<b>Travel Outside Minnesota</b>								
							<b>Sub Total</b>	-
<b>Printing and Publication</b>								
							<b>Sub Total</b>	-
<b>Other Expenses</b>								
							<b>Sub Total</b>	-
							<b>Grand Total</b>	<b>\$499,000</b>



Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
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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: [79fe8407-907.pdf](#)

#### *Alternate Text for Visual Component*

Showing the process flow diagram, sources of biohazards, key technical approaches, and outcomes and benefits of the project...

### Optional Attachments

#### *Support Letter or Other*

Title	File
Financial audit	<a href="#">c0bec3bb-235.pdf</a>
Institutional Approval to Submit	<a href="#">2c1346e3-4e2.pdf</a>

## Administrative Use

**Does your project include restoration or acquisition of land rights?**

No

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

Yes

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

Yes

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

No

**Does your project include original, hypothesis-driven research?**

Yes

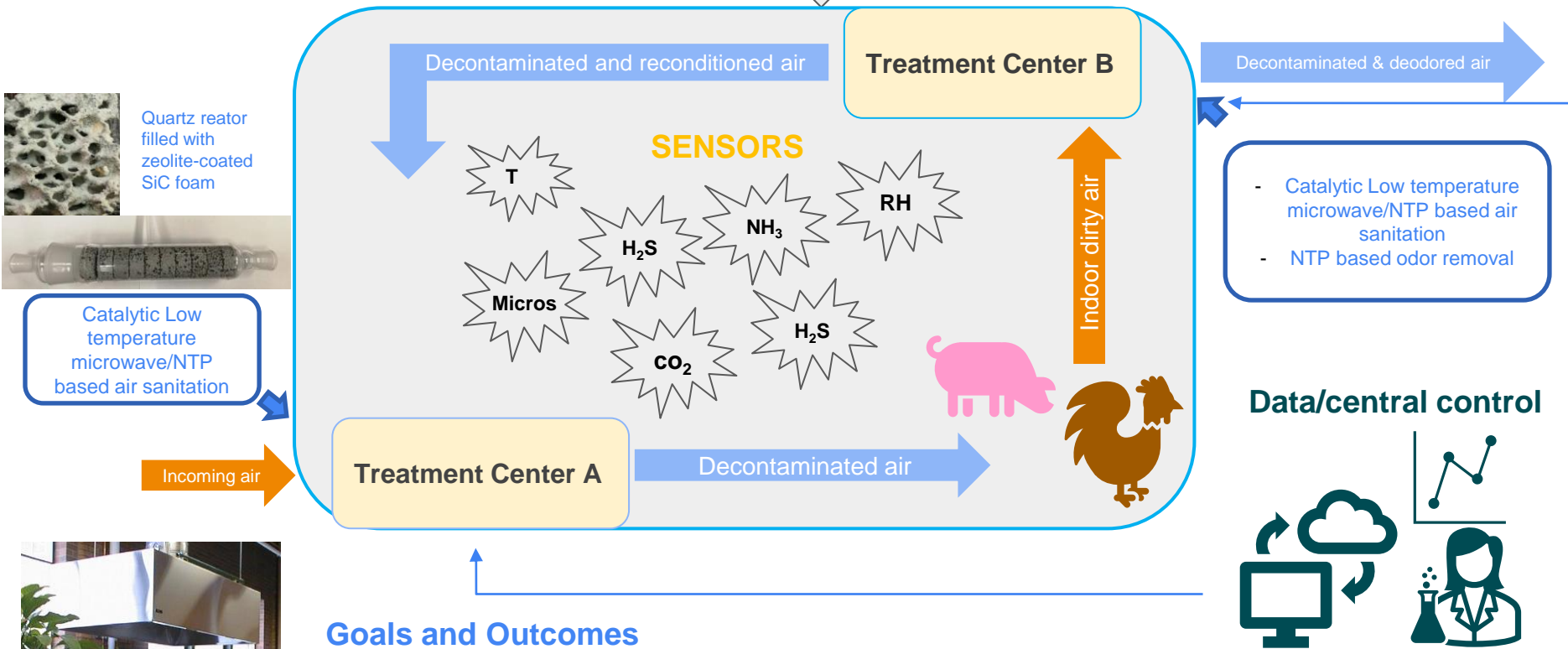
**Does the organization have a fiscal agent for this project?**

No



- Hazardously virus concentration due to the density of livestock
- Required high ventilation rates (12-500 cu ft/min)
- Constant toxic air irritates eye and respiratory system of staff
- Poor air quality circulation endangers livestock and human health

## Smart ventilation system



## Goals and Outcomes

- 1) Development of airborne microbe inactivation process and device
- 2) Inactivation of airborne pathogen surrogates in lab conditions
- 3) Surrogate inactivation and methane, hydrogen sulfide and odor removal in an enclosed swine production or nursery space
- 4) Research findings dissemination and communication with stakeholders, external fundings and industrial partnerships will be sought for further R&D efforts.

