Environment and Natural Resources Trust Fund

2023 Request for Proposal

General Information

Proposal ID: 2023-042

Proposal Title: Dry State Biofiltration to Cleanup Animal Farming Emissions

Project Manager Information

Name: Ping Wang

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

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Project Basic Information

Project Summary: This work develops novel bioactive filters which can be managed as regular air filters, but can absorb and digest airborne VOCs to fight in-situ air pollution generated in animal farming.

Funds Requested: $200,000

Proposed Project Completion: June 30, 2025

LCCMR Funding Category: Small Projects (H)

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

Project Location

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

Region(s): Metro, Central,

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

Statewide

When will the work impact occur?

In the Future

Narrative

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

Minnesota smells. The unpleasant foul smell from animal farming is not only familiar to local MN residents, but has also been complained 500-mile away in Kansas City, Missouri (1). Animal farming and the rapidly growing organic composting in Minnesota are generating enormous emission of ammonia and hydrogen sulfide that smell, along with many other volatile organic compounds (VOCs, such as methane, ethanol and acids, aldehydes and ketones) that do not smell much, but can deteriorate air quality and boost greenhouse effect in a significant way. According to studies published in recent years (2~4), animal houses, silage and waste composting sites that are associated with livestock production generate over 100 different types of VOCs, with 50 most significant VOCs had been well determined and measured. So far, there is essentially no mature technology developed to treat animal farming emissions. Most of the traditional industrial technologies such as adsorption and incineration, as well as liquid phase biodegradation, suffer from various drawbacks when considered for treatment of such air pollution, such as secondary emission and waste generation, low efficiency with diluted and seasonal air pollution, and requirements professional expertise and personnel for operation.

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.

We have previously succeeded in developing activated carbon fibers using bio-resources for physical absorption of airborne VOCs (5). More recently, we further demonstrated that bacteria biofilms could be grown on such fibrous activated carbons. More interestingly, such supported biofilms could operate under dry conditions and achieve direct biodegradation of airborne VOCs. In this project, we seek the development of such gas-phase biofilm reactors for comprehensive on-site treatment of multiple volatile organic matters emitted from animal farming operations (including husbandry, silage and waste composting sites). Bio-based carbonaceous fibrous materials will be inoculated with bacteria consortia (all natural strains) to form syntrophic biofilms that can uptake and degrade a wide spectrum of VOCs from a passing-through gas phase under ambient conditions. Such bioactive filters promise several unique characteristics that can embrace well the challenges faced in air cleanup for animal farming:

1. Can be installed and operate like regular air filters, without requiring professional personnel services;
2. No water and nutrition amendment requirements, no secondary emissions nor wastewater generation;
3. All the organic maters will be transformed into biomass or CO2, and the filters can be retrieved, re-carbonized and reused easily; and
4. Can degrade all major animal farming VOCs simultaneously.

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?

Animal farming accounts ~50% of agriculture economy in MN, is ranked as #7 in the nation. Pollution emissions from animal farming is, however, far beyond its economic share. It contributes ~90% of ammonia emission and ~52% of anthropogenic methane emission. There is an urgent need to cleanup such emissions. Hitherto here is essentially no mature technology that can effectively treat such air pollution which is seasonal and scattered state-wide. Success in this project can be translated into air cleanup technologies that serve different unit operations including silage, husbandry houses and waste composting involved in poultry, hog, dairy and cattle production.

Activities and Milestones

Activity 1: Construction and Characterization of VOC-Degrading Consortium Biofilms -Yr 1

Activity Budget: $99,183

Activity Description:
Naturally evolved microbial species can take a wide variety of energy and nutrient sources. While neighboring microbes may fundamentally compete for nutrients, the excreted products from one strain may be taken as energy or nutrient sources by other strains - a phenomenon known as syntrophic (or cross-feeding) coordination. This research activity is to develop an optimal microbial consortium for efficient degradation of animal farming VOCs, assuming that competition for favorite feed along with syntrophic coordination among microbial species will both promote VOC degradation. Bacterial species of different biodegradation traits will be selected, including Pseudomonas, Methanotrophs and algal species. Their growth characteristics will be examined under feeding with typical VOCs including methane, ammonia, alcohols and organic acids. Species showing diversified VOC preferences will then be applied for construction of supported consortium biofilm on carbonized cellulosic fibers. We will test two different strategies for biofilm construction: one is co-culturing mode (CCM), in which all strains will be inoculated onto the same support; the other is separated inhabitation mode (SIM), where each strain uses a different support but will be assembled into one reactor. Their favorite feeding conditions and efficiency will be studied, thus allowing optimal reactor design.

Activity Milestones:

Description		Completion Date
1.	Identification of ideal microbial species for different Animal Farming VOC components;	September 30, 2023
2.	CCM biofilm construction and activity characterization;	December 31, 2023
3.	SIM biofilm construction and activity characterization; and	May 31, 2024
4.	Efficiency analysis and identification best biofilm pattern for subsequent reactor construction.	June 30, 2024

Activity 2: Degradation Efficiency Evaluation and Optimization of Consortium Biofiltration Reactor – Yr 2

Activity Budget: $100,817

Activity Description:
Activity 2 will test the performance of consortium biofilm biofiltration reactors at lab-scale assemblies. Carbon fiber supported biofilm filter panels will be assembled into tubular reactors (plug flow reactors, or PFR, where gaseous feed passes through biofilm panels perpendicularly, see attachment of visual component). Future in-field installations may apply multiple stages of PFR reactors, but biofiltration efficiency will be evaluated in form of single-staged lab-scale reactor of two sizes (2 and 10 L) in this project. The reactors will be continuously fed with VOC mixtures mimicking what typically reported for corn silage and cattle house. The smaller reactor will be constructed and tested to evaluate and optimize structural (biomass loading density, spatial separation between panels, porosity of fibers) and operational parameters (concentration, humidity and temperature). Gas samples from inlet and outlet of the reactor will be monitored with respects to concentration and CO2 generation. Optimized structural and operational factors will be applied for subsequent construction of a larger scale reactor, which will be equipped with multiple sampling sites along the axial direction of PFR reactor. That will allow detection of the formation of intermediate metabolites to assess the syntrophic coordination inside the reactor, in addition to rates of VOC degradation.

Activity Milestones:

Description		Completion Date
1.	Biofilm PFR reactor structural and operational optimization;	December 31, 2024

2.	Long term operational and metabolic coordination efficiency evaluation; and	May 31, 2025
3.	Degradation kinetic assessment and optimized PFR biofiltration scale-up design basis.	June 30, 2025

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?

The proposed research will demonstrate the feasibility of biofiltration for air cleanup in animal farming, and set forth the engineering basis for scale-up bioreactor designs. Upon success with the project, the PI will seek commercial (including local animal farms) and environment protection organization sources, as well as industrial partners in air filtration and bio-products, to promote the technology for a pilot-scale in-field developmental study toward ultimately commercial applications.

Project Manager and Organization Qualifications

Project Manager Name: Ping Wang

Job Title: Professor

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

The PI was educated as a biochemical engineer, has over 25 years of research experience in areas of biotechnology and bio-materials. He has so far published over 100 research papers, 9 patents and is an awardee of NSF Young Faculty Career Award, AIChE Biotech Division Plenary Award, and university outstanding research award. The PI has successfully managed previously research projects supported by NSF, EPA, DOE, USDA, in addition to several MN state, industrial and internal grants. The PI's research emphasizes both basic and applied science, had previously succeeded in transferring patented technologies to industries, and had established long-term collaboration with numerous industrial members of Iprime (www.iprime.umn.edu, which is a university-industry research consortium and collaboration platform of UMN).

The proposed project applies bio-based materials and biocatalysis for environmental protection, more specifically for air cleanup associated with animal farming sectors, an area around which the PI's current research is centered. That has been proposed based on a previous seed grant research in the PI's lab, supported by MnDrive Environment Fund of UMN, exploring novel technologies for treatment of air pollution. In fact, a core long-term research interest of the PI is on green chemical technologies, especially the use of environmentally friendly biocatalysis and bioprocessing to serve the growing needs in renewable products and environmental protection. Toward that, the PI and his co-workers have explored previously biocatalysis in nonaqueous and non-traditional media to facilitated organic synthesis and enhanced enzymatic conversion of CO2; designed and fabricated varies nanostructures to improve protein and enzyme stability under extreme conditions for bio-active functional materials such as self-cleaning automobile coatings. The proposed gas phase biofiltration is indeed a natural extension of the PI's previous work on non-traditional bioprocessing technologies. More details of the PI's qualification is included in the attached CV.

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

Organization Description:

The University of Minnesota-TC (UMN) is the land- grant university of Minnesota, dedicated to innovation in knowledge discovery and education. The PI's lab is hosted at the Biotechnology Institute (BTI), which has established a Biotechnology Resource Center (BRC) that includes biological engineering, production and analytical capabilities, with a fermenter operating at a capacity of 500 L. Both the PI's lab and BRC are managed following all related Federal and State Lab Safety, Bio Security, Personnel and Financial Managing regulations. The PI's research has 400-square feet in lab space, equipped with fume hoods, water, adequate lab bench space and standard laboratory equipment are available. This lab has all of the necessary equipment for molecular biology, microbiology, enzyme assays, carbon material preparation, and biological processing experiments. Major equipment available for the proposed project (both the PI's

lab and BRC) include Atomic Force Microscope (AFM), Scanning Electronic Microscope (SEM), Thermogravity Analysis (TGA), Differential Scanning Calorimetry Analysis (DSC), LC-Mass Spectrometry and GC-Mass Spectrometry.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Graduate Student		Researcher			47%	2		$106,420
Undergraduate student		Assist in lab and experiment set up, conduct some experiments			0%	0.4		$12,120
							Sub Total	**$118,540**
Contracts and Services								
							Sub Total	**-**
Equipment, Tools, and Supplies								
	Tools and Supplies	Mostly used for materials and chemical purchases, and construction of lab-scale biofiltration reactors equipped with online sampling and GC analysis capabilities	lab supplies to conduct experiments					$76,460
							Sub Total	**$76,460**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Conference Registration Miles/ Meals/ Lodging	2 trips, 2 people	Attend state and national conferences for technical and scientific communications, publishing research results and develop potential collaborations					$5,000

							Sub Total	**$5,000**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$200,000**

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: 3c501ec9-5b8.pdf

Alternate Text for Visual Component

A schematic description of the proposed bio-filtration technology along with preliminary test results...

Optional Attachments

Support Letter or Other

Title	File
Cited References	95389224-673.pdf
CV of PI	3a971767-63a.pdf
Institutional Approval to Apply	4f391c3b-1bb.pdf

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? If so, describe here:

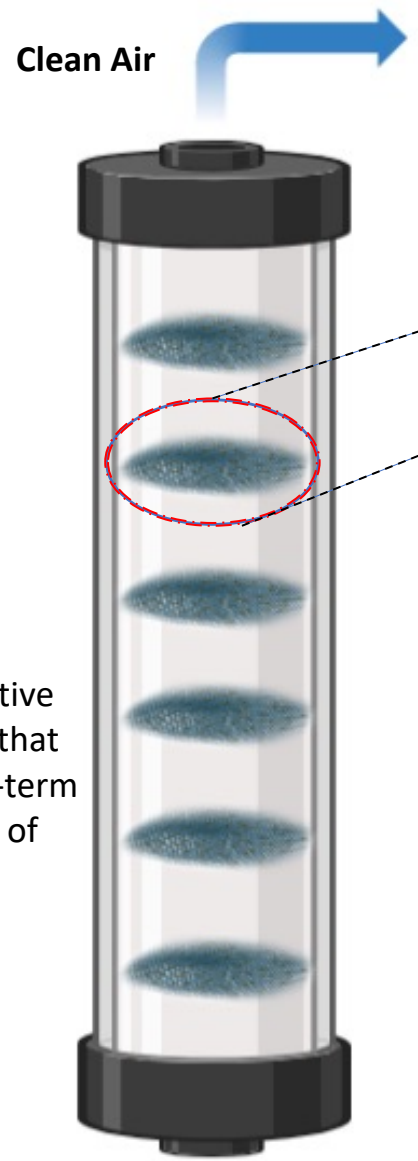
Yes, In the early developmental stage, wish the 80% of the revenues can be applied for project improvement and development; once reached large-scale application stage, revenues-return can be split between the project and ENRTF 50-50.

Does your project include original, hypothesis-driven research?

Yes

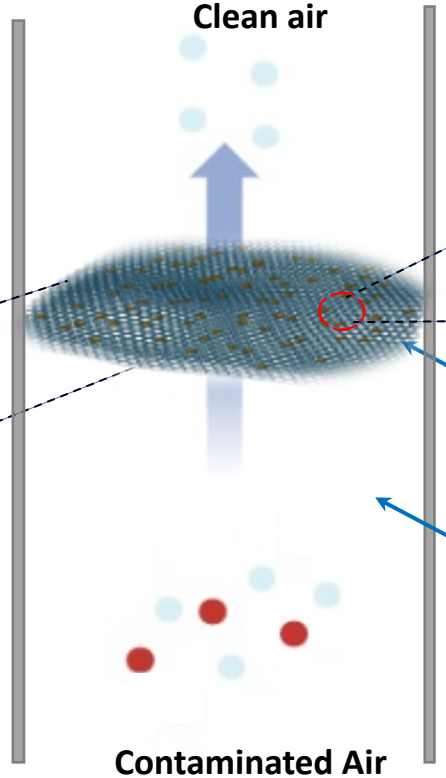
Does the organization have a fiscal agent for this project?

No



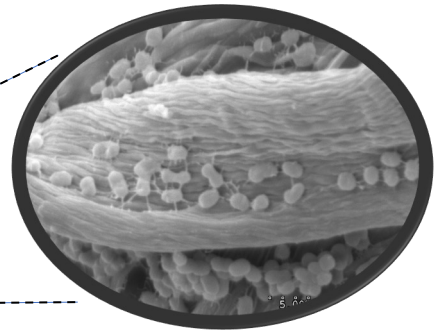
1

A typical bio-active filter assembly that can afford long-term biodegradation of airborne VOCs.



2

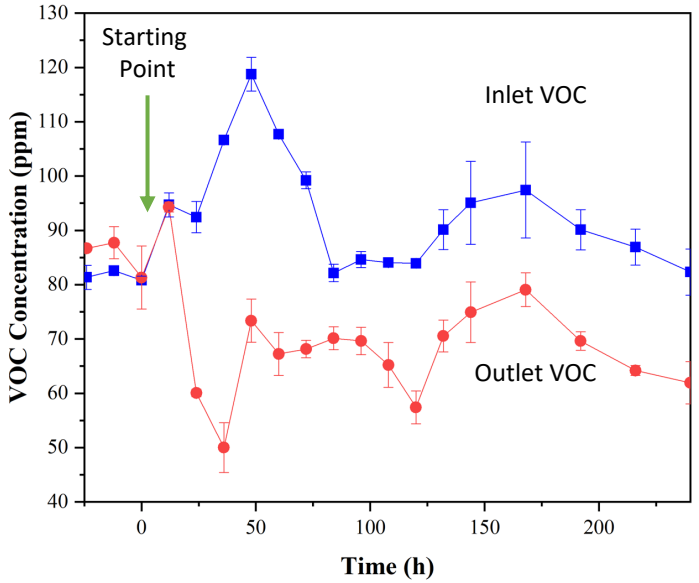
Biofilters can be installed like regular air filter panels, and can be replaced, regenerated and reused.



Supported-Biofilm Filter Panel

3

SEM image from a preliminary test with carbon fiber-supported *P putida* biofilm for model VOC degradation.



4

Single-Staged Lab-Scale Biofiltration Tests: as little as 3 grams of bioactive carbon fiber filter could remove ~30% of model VOC over an extended time period.

Schematic description of the proposed Biofiltration for air cleanup against animal farming air pollution, targeting over 50 smelling and ozone formation VOCs. (1) A typical biofilter assembly; (2) Biofilter panels function as air passing through; (3) A sample image of carbon fiber-supported natural *P putida* biofilm; (4) Data of preliminary proof-of-concept tests.