Environment and Natural Resources Trust Fund
2019 Request for Proposals (RFP)

Project Title: **ENRTF ID: 175-E**

Cheap Efficient Reactor to Remove Toxic Organic Compounds

Category: E. Air Quality, Climate Change, and Renewable Energy

Sub-Category:

Total Project Budget: $ 728,365

Proposed Project Time Period for the Funding Requested: June 30, 2022 (3 yrs)

Summary:

This project is to develop a new reactor to remove toxic organic compounds from vehicles and chimneys. The technology is very cheap and highly efficient to improve Minnesota air quality.

Name: Tianhong Cui

Sponsoring Organization: U of MN

Title: Professor

Department:

Address: 111 Church Street Southeast

Minneapolis MN 55455

Telephone Number: (612) 626-1636

Email tcui@me.umn.edu

Web Address

Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

One page vidual components

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency
_____ Capacity Readiness	_____ Leverage	_____ TOTAL	_____%
____ If under $200,000, waive presentation?			

PROJECT TITLE: Cheap Efficient Reactor to Remove Toxic Organic Compounds

I. PROJECT STATEMENT

The objective of this project is to develop a cheap and efficient reactor to remove airborne polycyclic aromatic hydrocarbons (PAHs). PAHs are a large group of organic compounds. They are highly lipid-soluble and can be absorbed at the lungs, guts and skins of human beings. Once absorbed, their mutagenic and carcinogenic activity through biotransformation can be fatal to one's health. Every year there are more and more PAHs released as pollutants from vehicles and chimneys of wood burning combustors. However, there is no commercial filter that can efficiently remove PAHs because they are very small organic compounds. This proposed work is to develop a new waste treatment technique that can decompose PAHs very efficiently from the sources. The proposed PAH reactor is formed by carbon nanotubes and titanium dioxide composite using advanced manufacturing. It is to combine ultraviolet radiation to decompose PAHs, making the dust and gases clean and innocuous. Titanium dioxide is a semiconductor with a desirable photocatalytic property under ultraviolet light irradiation. Carbon nanotubes, with very large surface area, support the active catalyst, titanium dioxide, to react with the PAHs. Currently, research on PAHs remediation techniques is minimal, due to the numerous difficulties associated with decomposition. The proposed PAH reactor will fill the research gap, and pave a new way for the development of PAHs remediation. Advanced manufacturing techniques at the University of Minnesota allow development of a suitable instrument for reliable and efficient PAH remediation at a very low cost. In addition, the PAH reactor can be assembled with vehicle exhaust systems and chimneys to eliminate PAHs contamination at their sources in Minnesota.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: *Development of highly efficient reactor to remove organic compounds* **Budget: $473,865**

The objective of this activity is to develop highly efficient reactors using carbon nanotubes and titanium dioxide. They are very cheap, efficient, and reliable for PAHs decomposition. The PAH reactors will be designed and fabricated to remove PAHs in airborne dust and gases. The shell of the reactors is transparent to allow ultraviolet light radiation to shine in. The reactor will reduce the concentration of PAHs down to 10% of the original value, while the cost is one fifth of automobile exhaust catalytic convertors or chimney filters.

Outcomes	Completion Date
1. Layer-by-layer self-assembled carbon nanotubes/ titanium dioxide nanocomposite; reactor modeling/ simulation and hardware development for continuous decomposition of PAHs in dust and gases; Initial testing results for small-size reactors validation in lab	*6/30/2020*
2. Decomposition efficiency will be tested in comparison with conventional results in the lab; Improved reactors with revised design, fabrication, and testing will be provided; Reactor tests of PAHs decomposition of dust and gas samples will be conducted	*6/30/2021*
3. Comprehensive assessment of the techniques will be completed	*6/30/2021*

Activity 2: *Standard-size reactors and field testing on chimneys and vehicles* **Budget: $254,500**

Standard-size reactors are assembled with chimneys and vehicle tailpipes. A test site will be set up to demonstrate the feasibility of the reactors. Field tests will include simulating a chimney or a vehicle tailpipe and testing the efficiency of the reactor in the field. Upon completion of the project, we will demonstrate the reactors to the stakeholders and LCCMR committee members and officials.

Outcomes	Completion Date
1. Standard size air reactors will be designed and developed	*12/31/2021*
2. Test sites with chimneys and automobile tailpipes will be set up	*6/30/2021*
3. Field tests will be performed with a chimney and decomposition efficiency will be tested	*6/30/2021*

III. PROJECT PARTNERS:

A. Partners receiving ENRTF funding

Name	Title	Affiliation	Role
Tianhong Cui	Professor	University of Minnesota	PI
Terrence Simon	Professor	University of Minnesota	Co-PI

Tianhong Cui, the Distinguished McKnight University Professor in Mechanical Engineering at the University of Minnesota, will serve as PI and project manager. He will be responsible for overseeing the project, all reports, and deliverables. Professor Terrence Simon, the Ernst Eckert Professor of Mechanical Engineering, will serve as co-PI. He will supervise the modeling/ simulation and efficiency testing of the PAH reactors. The research assistants will work on the design, fabrication, and testing of the PAH reactors. Professors Cui and Simon and their assistants will conduct in-lab tests, PAHs concentration analysis and field tests of the proposed reactors with chimneys and vehicle tailpipes.

IV. LONG-TERM IMPLEMENTATION AND FUNDING:

Every year there are 3,200 tons of PAHs generated in the USA, among which Minnesota takes a big share. PAHs are well known as carcinogens, mutagens, and teratogens. Minnesota Pollution Control Agency (MPCA) works together with other agencies and advocacy groups in developing strategies to prevent, reduce, or mitigate airborne PAHs contaminants, and to alleviate their damage to human health and the environment. The most efficient and economic strategy is to remove PAH contamination from the sources. From 2013 to 2015, over 15 PAH monitoring sites were placed in Mille Lacs and South Minneapolis by the MPCA. MPCA is now conducting a two-year program to measure PAH concentration at the facilities. However, few PAH remediation instruments are commercially available as PAHs have numerous structures and they are very small and difficult to collect. Minnesota State currently provides strong support for air quality improvement because of the increasing threat of air borne contaminations. As there is no specific PAH decomposition instrument, the reactors for PAH removal become especially important. This proposal will provide cheap, but high-performance, techniques, i.e. a unique photocatalytic reactor, for treatment of Minnesota's exhaust air pollutants from chimneys and vehicles. Upon completion, this project will realize economical and high-performance airborne pollutant treatment techniques for continuous purification of exhaust gas. The knowledge learned throughout the project will provide a solid foundation for further research and development efforts that would lead to eventual implementation of this novel technique, to a broader treatment of Minnesota's air. This research will provide a solution to current ineffective PAHs mitigation plight, and help implement the MPCA's clear air strategy, and thus ensure human health in Minnesota. In addition, we plan to file patents on the proposed PAH reactors for commercialization in the future. We can extensively use the reactors for PAHs decomposition of pollutants from chimneys, vehicle tailpipes, etc. As a result, the innovative technology can benefit local residents by purifying the air in Minnesota.

V. TIME LINE REQUIREMENTS:

This project is planned for 3 years, from July 1, 2019 to June 30, 2022. The first two years will focus on the reactor development, and Year 3 will focus on development of standard size reactors and field tests. The results of this study will be disseminated through oral and poster presentations by faculty and research assistants involved in the project, briefings to the LCCMR, as requested, and peer-reviewed publications. We also intend to present progress on this project periodically to relevant personnel who are interested in the results, specifically, those at the Minnesota Pollution Control Agency and environmental protection advocacy groups.

2019 Proposal Budget Spreadsheet

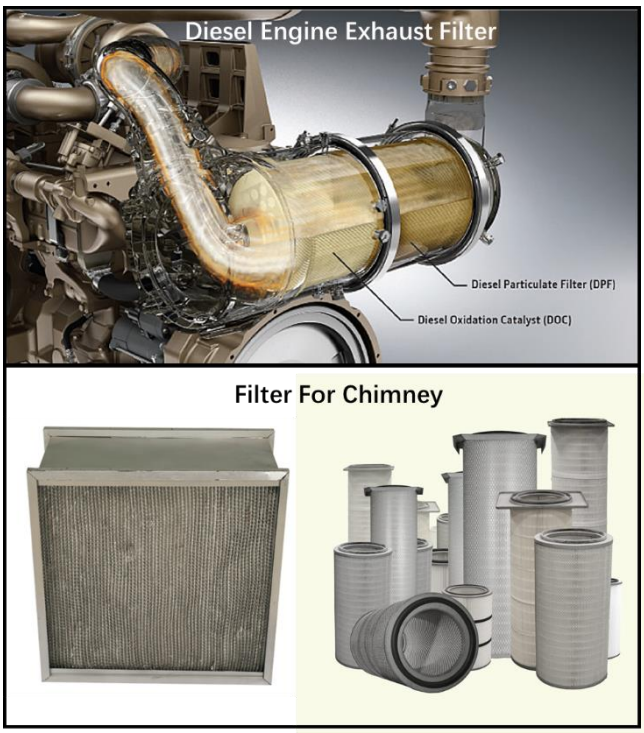
Project Title: Cheap Efficient Reactor to Remove Toxic Organic Compounds

IV. TOTAL ENRTF REQUEST BUDGET *[3]* **years**

BUDGET ITEM (See "Guidance on Allowable Expenses")	**AMOUNT**
Personnel:	$ 592,865
Tianhong Cui PI/PD, 1 month/year, 3 years, including 33.5% benefits ($70,903)	
Terry Simon, Co-PI, 1 month/year, 3 years, including 33.5% benefits ($77,651)	
3 ME Graduate Research Assistants, 50%, 3yrs, including 15% benefits plus tuitions, for analysis of the performance of the reactor module, for help in designing the validation test facility and for helping with the effluent tests. ($444,311)	
Professional/Technical/Service Contracts:	
Equipment/Tools/Supplies:	$ 47,000
Materials & Supplies (gas, drugs, metals), Combustors, Misc small items (fan, ducts, fasteners) ($11,000), Pollution measurement lab use fee ($5,000) , Machine shop ($10,000), Materials and supplies for reactor fabriction and testing ($21,000)	
Acquisition (Fee Title or Permanent Easements):	
Travel:	$ 7,500
Domestic travel: Mileage, lodging, and meals for travel to and between the solar testing sites and the university based on the university compensation policy	
Additional Budget Items: Scientific Services (ie. Characterization Facility) - Nano Center ($42,000) Scientific Services (ie. Characterization Facility) - charact fac ($24,000) Fabrication CSE shop (15,000)	$ 81,000
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 728,365

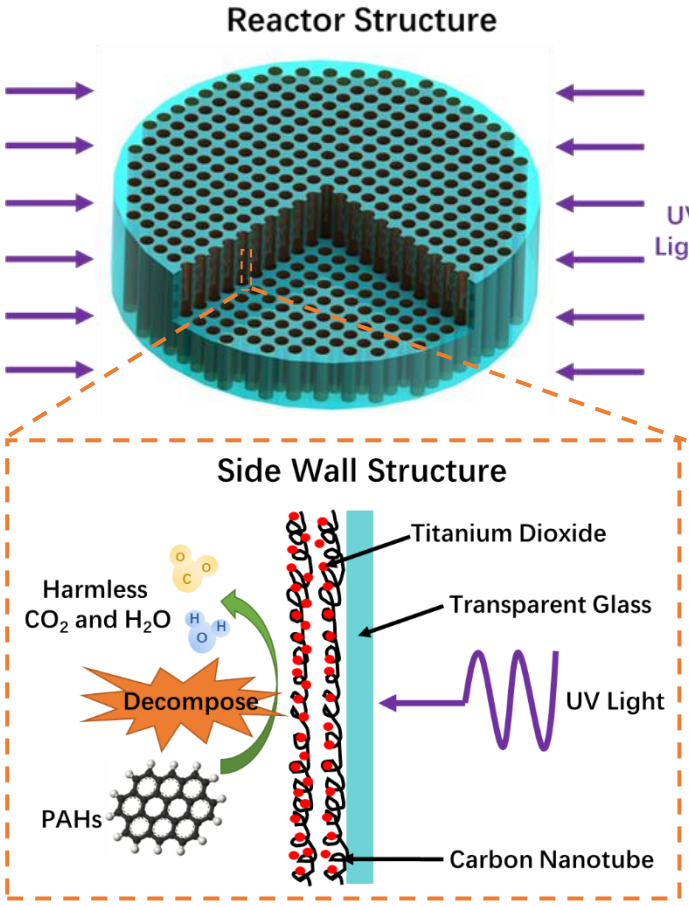
V. OTHER FUNDS *(This entire section must be filled out. Do not delete rows. Indicate "N/A" if row is not applicable.)*

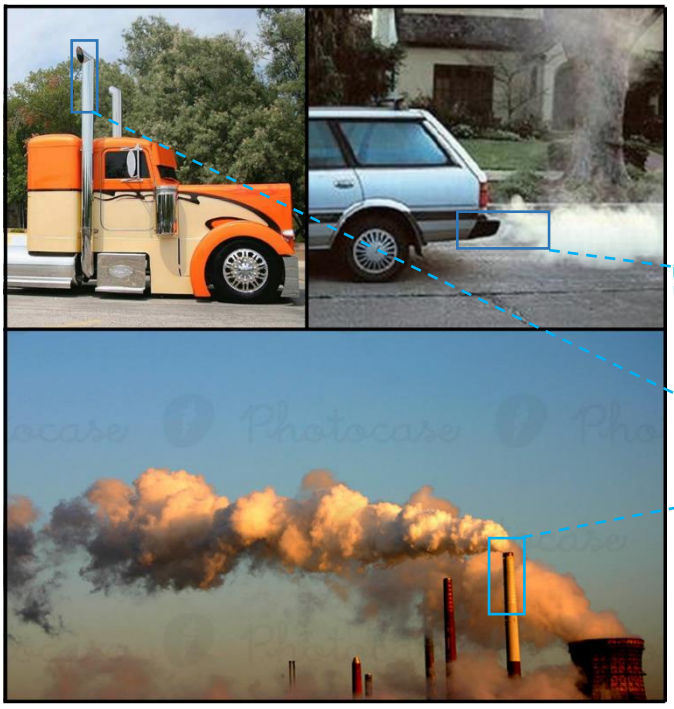
SOURCE OF FUNDS	**AMOUNT**	**Status**
Other Non-State $ To Be Applied To Project During Project Period:	$ -	
Other State $ To Be Applied To Project During Project Period: University of Minnesota Overhead	$ 303,224	*Secured*
In-kind Services To Be Applied To Project During Project Period:	$ -	
Past and Current ENRTF Appropriation:	$ -	
Other Funding History:	$ -	

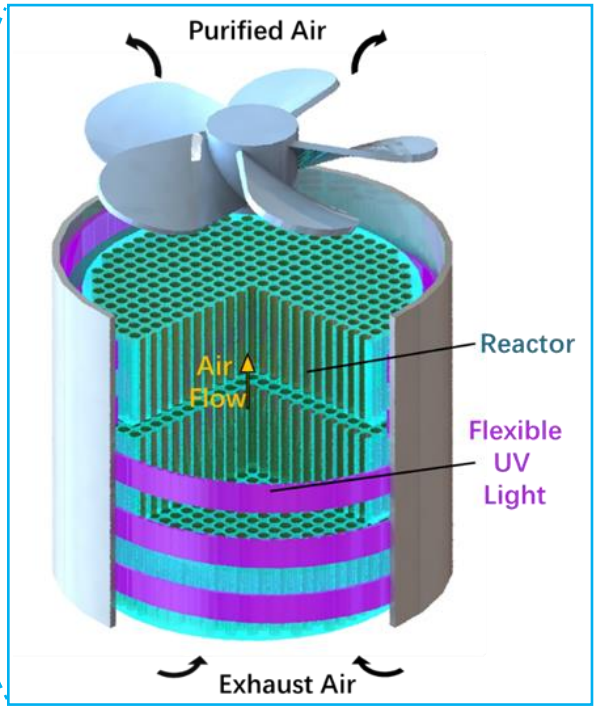


Current Technology

New Technology Proposed







Reactor Applications to Decompose Toxic Organic Compounds from Diesel Trucks, Old Cars, and Chimneys of Wood Burning

Project Manager Qualifications

Professor Tianhong Cui is currently a Distinguished McKnight University Professor of Mechanical Engineering at the University of Minnesota. From 1995 to 2003, he held research or faculty positions at Tsinghua University, University of Minnesota, National Laboratory of Metrology in Japan, and Louisiana Tech University, respectively. He is a leading expert in advanced micro- and nano-manufacturing.

Professor Terrence Simon, the Ernst Eckert Professor of Mechanical Engineering, has been a member of the Heat Transfer Laboratory since 1980 and was the Director of the Thermodynamics and Heat Transfer Division from 1997 to 2005. His research deals with transport in steady and unsteady, turbulent and transitional flows, including flows through porous media, and boiling heat transfer.

Organization Description

Professor Tianhong Cui in Mechanical Engineering will serve as PI and project manager. He will be responsible for overseeing the project, all reports, and deliverables. He will supervise two full-time Ph.D. students to work on design, fabrication, and characterization of air reactors for polycyclic aromatic hydrocarbons decomposition. Professor Cui will hold weekly meetings with his advisee to ensure good progress of this proposed work, in addition to some daily technical discussion with his graduate research assistant. Professor Terrence Simon will supervise one full-time Ph.D. student to work on molding and simulation of PAH reactors, and will carry out lab and field tests of PAHs removal using the reactors developed.

Photocatalytic air reactor including manufacturing and characterization will be performed at the University of Minnesota in the Technology Integration & Advanced Nano/Microsystems Laboratory (TIAN Lab), located in room ME4128 of the Mechanical Engineering Building, on the Minneapolis campus of the University of Minnesota. Professor Cui is the director of TIAN Lab equipped with the state-of-the-art instrument and facilities to conduct the proposed research, with a variety of fabrication and characterization equipment and tools, sufficient for Professor Cui, his Ph.D. students to design, fabricate, characterize and analyze the proposed reactors. Modeling and experimental work on reactors will be implemented at Thermal and Heat Transfer Laboratory directed by Professor Terrence Simon at the University of Minnesota.

The proposed other part of fabrication work will be partially done in Minnesota Nano Center (www.nfc.umn.edu) at the University of Minnesota in a 7000 square foot facility, including 3000 square feet of class 10 clean room. The Lab contains all of the major pieces of processing equipment. Minnesota Nano Center well maintains these systems, keeps safe operating procedures, and trains students. State support, support from NSF through NNIN, and industry usage allows Minnesota Nano Center to offer academic rates that are normally less than half of the actual cost of operation. In 2014, NFC took possession of a second clean room as part of a new Physics and Nanotechnology Building. The new building is across the street from the ECE Building which houses the existing clean room. At 5000 square feet under filter and almost 10,000 square feet gross, it is more than double the existing space. In addition to expanding the suite of clean room tools available, the lab will also operate two new non-clean core labs that support research in nanomaterials and nanotechnology.