Environment and Natural Resources Trust Fund
2018 Request for Proposals (RFP)

Project Title: **ENRTF ID: 089-B**

Polycyclic Aromatic Hydrocarbons Abatement using Non-Thermal Plasma Technology

Category: B. Water Resources

Total Project Budget: $ 820,000

Proposed Project Time Period for the Funding Requested: 3 years, July 2018 to June 2021

Summary:

The proposed project is aimed to develop an innovative non-thermal plasma based technology for the cost effective and sustainable removal of polycyclic aromatic hydrocarbons from Minnesota air and waters.

Name: Roger Ruan

Sponsoring Organization: U of MN

Address: 1390 Eckles Avenue

St. Paul Minn 55108

Telephone Number: (612) 625-1710

Email ruanx001@umn.edu

Web Address biorefining.cfans.umn.edu

Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

Point sources of polycyclic aromatic hydrocarbons; where the non-thermal plasma (NTP) system could be installed; and past experience with development of NTP systems for air and liquid treatment.

_____ Funding Priorities _____ Multiple Benefits _____ Outcomes _____ Knowledge Base

_____ Extent of Impact _____ Innovation _____ Scientific/Tech Basis _____ Urgency

_____ Capacity Readiness _____ Leverage _______ TOTAL ______%

PROJECT TITLE: Polycyclic aromatic hydrocarbons abatement using non-thermal plasma technology

I. PROJECT STATEMENT

The proposed project is aimed to develop a non-thermal plasma (NTP) based technology for the cost effective and sustainable removal of polycyclic aromatic hydrocarbons (PAHs) from Minnesota air and waters. PAHs are released from both natural and anthropogenic sources and have detrimental biological effects, toxicity, mutagenecity and carcinogenicity. In fact they were one of the first atmospheric pollutants to be identified as being carcinogenic, and therefore cause significant concerns. This year's ***LCCMR RFP has specifically identified PAHs as contaminants of interest*** in both air and water and seeks innovative approaches to the mitigation of PAHs in order to reduce their impacts on human health, the environment, or natural resources. In recent years, some methods involving bioremediation, chemical oxidation, and physical decomposition were investigated. Some of these methods are proven viable but suffer limitations such as slow process, limited to solid wastes, high temperature, and low energy efficiency.

Incineration plants, coal gasification and liquefying plants, and petroleum refineries are major contributors to airborne PAHs. Since these are point sources, the flue gases are easier to be treated than the non-point source pollutants such as automobile exhaust. A study by Minnesota Pollution Control Agency (MPCA, 2012) found that about 70% of the PAHs in the runoff water was from coal tar-based sealant. Combined sewer overflows (CSOs) may contain high concentration of PAHS. Unlike water that enters the sewer system, the CSOs may be discharged without treatment. CSOs is considered point source pollution, and therefore it is possible to treat the CSO water before it is discharged to the water bodies nearby.

The ***goal*** of the proposed project is to explore and demonstrate the feasibility of using non-thermal plasma to decompose PAHs in air and water at the point of source. NTP reactors can be implemented where flue gas is exhausted or CSOs are collected (See visual document for illustration). Non-thermal plasma, energized by electrical discharge, consists of extremely reactive particles that can attack and decompose chemicals in contact. Because the energy coupled into the electrical discharge volume is highly selective, i.e., most of the energy is used to generate chemically active species, other than to heat the gases, NTP induced processes are of high energy efficiency compared with thermal plasma and many other chemical and physical processes.

Two activities will be planned for this project in order to achieve the goal. First, we will examine the effect of NPT process on PAHs in general and the effectiveness of different reactors under various conditions. We have in the past worked with NPT reactors. We will examine the performance of various reactor types in terms of decomposition and energy efficiency and feasibility for scaling up. Second, once the feasibility is confirmed, we will design and construct small scale NTP systems for further testing and development of an NTP based technology for removal of PAHs from air and waters. These systems will also be used for demonstration of feasibility and applicability to the stakeholders.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Investigate non-thermal plasma process for decomposition of PAHs in air and water **Budget: $ $375,000**

The objective of the activity is to prove the concept using non-thermal plasma (NTP) to decompose PAHs present in air and water and to understand how process variables affect the effectiveness of the process. Two simple NPT devices will be developed, one for air and one for water treatment. These devices will be operated under different electrical power conditions and fed with air or water containing different types and levels of PAHs. Four kinds of PAHs will be tested in the study. Effect of solid catalysts on PAH decomposition will also be investigated. The experimental data will be analyzed to provide confirmation of the concept and good understanding of the process.

Outcome	Completion Date
1. Two non-thermal plasma *reactor devices will be developed*	*12/31/2018*

2. The non-thermal plasma *reactors will be tested with PAHs containing air and water under different conditions and performance data will be collected*	*12/31/2019*
3. The effect of catalysts on PAHs decomposition will be understood	*12/31/2019*
4. A comprehensive analysis of the concept will be conducted and an evaluation report will be produced.	*12/31/2019*

Activity 2: Construct and test non-thermal plasma demo systems **Budget: $ $445,000**

Based on the knowledge gained from Activity 1, we will develop bench scale mobile NPT reactors for further testing and improvement of the process. These mobile reactor units can be moved to sites of source of PAH contaminants for testing. A detail analysis of mass and energy balance will be carried out with these units. Demonstration of proof of concept will be conducted towards the end of the project.

Outcome	**Completion Date**
1. Small scale mobile non-thermal plasma reactors (300-500CFM air and 1-3 gallon/min water) will be designed and constructed	*12/31/2020*
2. Systematic testing of the reactors in labs and on sites of PAH source will be conducted	*6/30/2021*
3. Detail analysis of mass and energy balance will be conducted	*6/30/2021*
4. Demonstration of proof of concept will be conducted.	*6/30/2021*

III. PROJECT STRATEGY

A. Project Team/Partners

Roger Ruan, professor in Bioproducts and Biosystems, will serve as PI and project manager. He will be responsible for overseeing the project, all reports, and deliverables. He will also develop initial testing devices for feasibility study and NTP systems for further testing and technology development. Paul Chen, associate professor in Bioproducts and Biosystems, will be a co-PI responsible for carrying out experiments to investigate the feasibility of the proposed process, study the effects of key process variables on decomposition of PAHs, and conducting evaluation and analysis of the NPT systems and experiments.

B. Project Impact and Long-Term Strategy

Upon completion of the project, an NTP process for cost effective removal of PAHs will be developed and evaluated. The knowledge learned throughout the project will provide foundation for further research and development efforts that would lead to eventual implementation of the novel technology for practical mitigation of PAH related air and water pollution problems and improve Minnesota air and water quality.

C. Timeline Requirements

This project is planned for 3 years beginning July 1, 2018 and ending June 30, 2021. The first 18 months will be focused on the feasibility and understanding of the proposed process, and the second 18 months will be focused on development and evaluation of two NPT based systems, one for air and one for water treatment to remove PAHs.

2018 Detailed Project Budget

Project Title: Abatement of polycyclic aromatic hydrocarbons (PAHs) contaminants in Minnesota air and water using non-thermal plasma technology

IV. TOTAL ENRTF REQUEST BUDGET *3* years

BUDGET ITEM	AMOUNT
Personnel:	
Roger Ruan, PI/PD, 10%, 3 years, including 31.8% benefits, leading and managing project, overlooking R&D, leading demonstration, supervising postdocs and RA	$ 53,000
Paul Chen, co-PI, 20%, 3yrs, including 31.8% benefits, project coordination, conducting R&D, project evaluation, progress report	$ 72,000
1 research associate 100%, 3yrs, including 22.40% benefits, conducting R&D, operations, demonstration, data analysis	$ 190,000
2 Graduate Research Assistants, 50%, 3yrs, including 17.6% benefits plus tuitions, conducting R&D, operationg, demonstration	$ 277,000
Equipment/Tools/Supplies:	
High voltage power supply	$15,000
Plasma monitor and analyzer	$15,000
Laboratory supplies including chemicals, gas supply, PAHS, analytical supplies, catalysts, glassware, tubings, plumbing supplies, containers, printing	$16,000
Components for fabrication of lab scale experimental reactors	$35,000
Components for fabrication of small scale NTP testing and demo reactor systems	$40,000
Components for fabrication of small scale CHIEF testing and demon system	$90,000
Travel:	
For researchers to travel to collect samples in fields and between campus and demonstration site over the 3 yr project period	$2,000
Additional Budget Items:	
Analytical services including instrument repaire and service, outside chemical analysis service	$15,000
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	**$820,000**

V. OTHER FUNDS

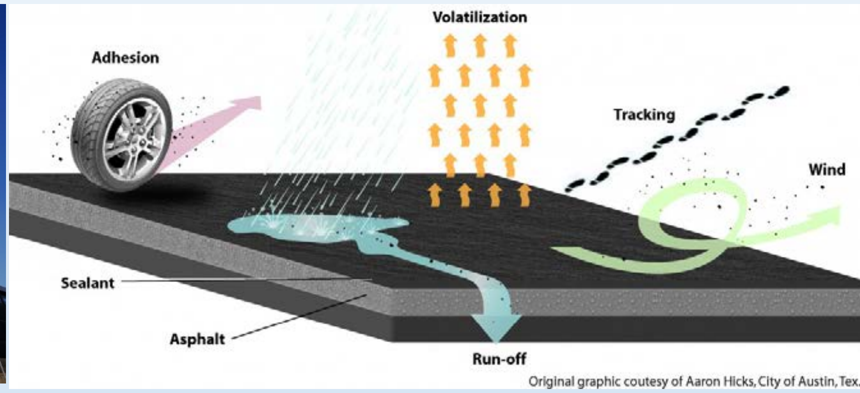
SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ Being Applied to Project During Project Period:		
University of Minnesota unrecovered indirect cost match	$ 307,000	*secured*
Other State $ Being Applied to Project During Project Period:	$ -	
In-kind Services During Project Period:		
Past and Current ENRTF Appropriation:	$ -	
Development of Innovative Sensor Technologies for Water Monitoring (ML 2016)	$ 234,044	unspent
Utilization of Dairy Farm Wastewater for Sustainable Production (ML 2016)	$ 176,630	unspent
Renewable and Sustainable Fertilizers Produced Locally (ML 2015)	$ 120,102	unspent
Demonstrating innovative technologies to fully utilize wastewater resources (ML 2014)	$ 1,000,000	spent
Pyrolysis pilot project (ML 2007)	$ 900,000	spent
Algae for Fuels Pilot Project (ML 2010)	$ 867,195	spent

Polycyclic aromatic hydrocarbons (PAHs) abatement using non-thermal plasma technology

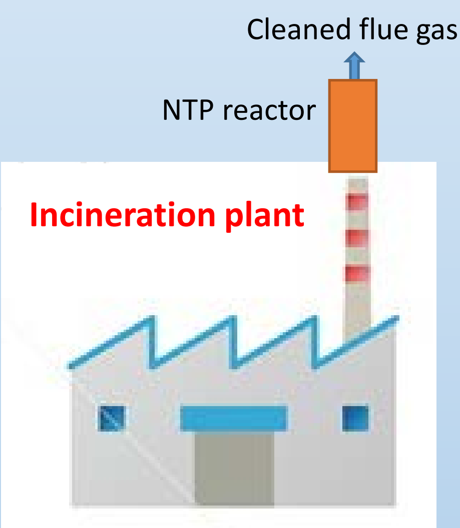
Roger Ruan and Paul Chen, UMN

Point sources of polycyclic aromatic hydrocarbons

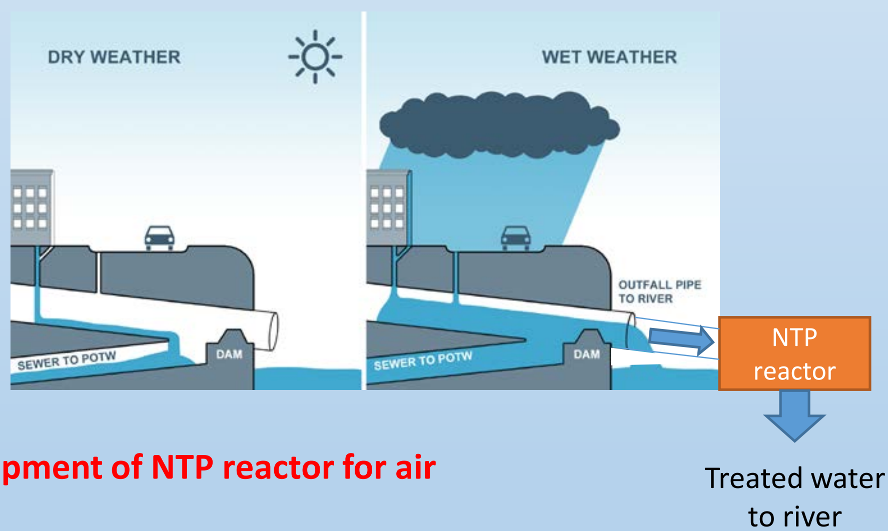
PAHs from incomplete combustion of solid and liquid fuels



PAHs from coal and petrol based sealants and other products in runoff water



Runoff and combined sewer overflows water



Past experience with development of NTP reactor for air and liquid treatment

Non-thermal plasma reactors for animal housing air treatment

Concentrated high intensity electric field (CHIEF) system for liquid treatment

Project Manager Qualifications and Organization Description

Dr. Roger Ruan, Professor and Director, Center for Biorefining and Department of Bioproducts and Biosystems Engineering, University of Minnesota, is the project manager of the proposed project. Dr. Ruan's research focuses on renewable energy and the environment as well as food safety and quality. Dr. Ruan has published over 350 papers in refereed journals, books, and book chapters, and over 300 additional meeting papers and other reports, and holds 15 US patents. He has supervised more than 40 graduate students, 60 post-doctors, research fellows, and other engineers and scientists, and 7 of his students hold university faculty positions. He has received over 150 projects totaling over $35 millions in various funding for research. He served an editor-in-chief of the *International Journal of Agricultural and Biological Engineering* and editorial board member of *Journal of Food Process Engineering*, and Associate Editor of *Transactions of ASABE*, *Engineering Applications in Agriculture, and Transactions of CSAE*. Dr. Ruan has given over 200 invited symposium presentations, company seminars, and short courses, and has been a consultant for many local, national, and international companies and agencies in renewable energy and environment as well as food and value-added processing areas. Dr. Ruan has also given frequent interviews on related topics to various news media.

Dr. Ruan and his colleague and co-PI of the project Dr. Chen have extensive experience with non-thermal plasma technology. They developed many non-thermal plasma devices and investigated deodoring of animal house air using non-thermal plasma and ozone technologies. In addition, they conducted research on using non-thermal plasma technology for disinfection of pathogens in animal blood, liquid foods, and solid foods, and on food process equipment/plant environment. Three to five logs reduction in total bacteria counts have been demonstrated in their studies. They are the inventors of a number US patents involving the non-thermal plasma technology. They have developed numerous non-thermal plasma reactors including those for animal housing environment as shown in Maps and Visual document. This experience will provide a good basis for them to develop and test non-thermal plasma reactors for cost effective removal of polycyclic aromatic hydrocarbons.

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.