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

Project Title: **ENRTF ID: 172-E**

Developing Innovative Mercury Capture Technology for Crematoria Emissions

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

Total Project Budget: $ 435,984

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

Summary:

The proposal project develops affordable and easy to use technology to capture mercury in crematoria emissions. This prevents contamination of our water resources, impacting the food chain and human health.

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Sponsoring Organization: U of MN

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Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

Objective: Build and optimize a mercury capture device for crematoria emissions. Goal: To reduce mercury contamination of Minnesota waterways.

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency
_____ Capacity Readiness	_____ Leverage	_____ TOTAL	_____%

I. PROJECT STATEMENT

The objective of this proposal is to develop an easy to use and affordable capture device to prevent mercury in crematoria emissions from being released into the environment. Crematoria remain a controversial topic in many Minnesota communities due to their toxic emissions. Mercury in the emissions, due to dental amalgam fillings, contributes to increased levels of mercury in Minnesota soils and waterways, affecting the food chain and human health. Implementation of reduction technologies and phase-out of mercury-containing products will lead to zero mercury emissions by 2025 for many industries. In contrast, emissions of mercury from cremation and other small emitters are steadily rising, and are projected to continue increasing to 2025 and beyond.

Stronger environmental regulations and improved technology limit mercury exposure from large emitters, such as coal-fired power plants. However, these controls are not in use by small-scale emitters such as crematoria, since they are unaffordable. We propose development of a simple drop-in filter for crematoria exhaust ductwork that contains a particulate form of selenium (Se), which has a known strong affinity for mercury in its vapor state. The mercury filter will be structured so that it can be removed and changed, allowing the filter to be safely disposed of or recycled to recover the mercury.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Design, build, and test a flow system for mercury vapor capture. Budget: $173,782

In this activity we will develop and test a system to capture mercury vapor at the high temperatures of cremation. Our basic system will consist of a tube furnace capable of heating to at least 1000°C, with fittings to allow controlled flows of an inert carrier gas or air. Sample holders for testing candidate mercury sorbents and dental amalgam/mercury will be fitted within the furnace. A vapor phase mercury analyzer, i.e., an atomic absorption spectrometer similar to those used in stack emissions testing, will be calibrated and utilized to precisely measure mercury in the emissions.

Outcomes	Completion date
1. Functioning laboratory flow system built and operational	09/01/18
2.Vapor phase mercury analyzer set-up and calibrated	10/31/18
3.Begin consultations with crematoria owners on device, placement, testing	01/01/19

Activity 2: Develop and optimize sorbents to capture mercury. Budget: $161,473

In this activity a prototype panel of sorbents will be designed and fabricated for mercury vapor capture. We will use inexpensive and commonly available selenium (Se) particles, which are known to have a high affinity for mercury. Se particles with wide range of concentrations and sizes will be synthesized and measured using dynamic light scattering. Then a variety of refractory substrates, such as commercial zeolites, silica sand, ceramic woven textile, and clay materials will be utilized to anchor the panel of Se particles and form “sorbents” for testing. In a series of experiments, the sorbents will be exposed to mercury vapor emitted from heated dental amalgam/mercury over different temperature ranges. Exposure tests will take place under inert gas (nitrogen) flow, airflow, and passive convection. Mercury collection by the sorbents will be quantified using energy-dispersive X-ray spectroscopy. Output gas flow for mercury content will be determined using the atomic absorption-based mercury vapor analyzer.

Outcomes	Completion date
1. A comparative analysis of mercury collected by a panel of sorbents	07/30/19
2. Identification of optimal mercury capture sorbents, temperature ranges	10/01/19
3. An analysis of mercury capture and/or escape in flow exhaust from system	10/01/19
4. Crematoria owners to participate in testing recruited	10/01/19

Activity 3: Design prototype filter and field test in crematoria. Budget: $100,729

In this activity prototype sorbents in sufficient quantity for testing in working crematoria will be fabricated, and a carrier filter device designed. We will work with our contacts among crematoria owners/

operators to get feedback on our filter design and ease of use, and arrange for field-testing. There are approximately 60 operating crematoria in Minnesota, with equipment that varies extensively in age and size. We will measure a variety of cremation chambers and ductwork in order to maximize filter effectiveness for mercury capture.

Outcomes	Completion date
1. Prototype filter with optimal mercury capture sorbent developed	07/01/20
2. Filter placement in crematoria ductwork determined	10/31/20
3. Field testing of our new mercury capture device completed	05/01/21
4. Field test data on mercury capture in crematoria analysis completed	06/30/21

III. PROJECT STRATEGY

A. Project Team/Partners

Project Partners Receiving ENRTF Funds: ***Dr. Sandra Myers***, U of MN, will serve as PI and project manager for the team. She will be responsible for all reports and deliverables, and will manage all activities related to dental materials and crematoria sciences. ***Dr. James Marti***, U of MN Minnesota Nano Center, will be a Co-PI, directing all nanotechnology and laboratory related activities. ***Two part-time technicians*** (Roger McMeekin & TBD) in the Nano Center will be under Dr. Marti's direct supervision and will perform all laboratory procedures for this project. ***Dr. Walter Bowles***, retired U of MN faculty, will work with our contacts in the cremation industry on product development, and to coordinate actual crematoria testing. **Two expert consultants** (TBD), chemistry and ceramics, will provide input on development of mercury sorbents and capture technology.

B. Project Impact and Long-Term Strategy

Minnesota is a state that contains the headwaters of two major rivers, more than 10,000 lakes, and over 100,000 miles of rivers and streams. The Mississippi River, one of the longest rivers in the world at 2530 miles, is the second most polluted waterway in the US. The contamination extends to many lakes and streams in Minnesota, which are too polluted for safe boating, fishing, swimming, and/or drinking water. One of the ultimate challenges, in addressing the problems of pollution, is creating and enabling solutions that can make a lasting impact. The Pollution Prevention Act of 1990 calls for pollution to be prevented or reduced at the source whenever feasible, and release into the environment to be a last resort. Our Team strongly agrees and believes the best long-term strategy and cure for pollution is always prevention, particularly when it comes to mercury in the environment. With this in mind, our team proposes to develop cost effective technology to prevent release of mercury from crematoria, one facility at a time.

A very important lasting impact of this project will be to decrease mercury landing in bodies of water, where it is eventually transformed into neurotoxic methyl mercury, and accumulates in carnivorous fish such as walleye and northern pike. Consumption of fish is the primary route of mercury exposure in Minnesota and across the United States. Populations impacted include wildlife and all humans, especially the unborn and young children. Methyl mercury, even in small amounts, can result in serious life-long health and neurological problems in children. Our project is transformational in its approach to both: 1) capture and recycle toxic mercury in crematoria emissions, and 2) benefit society by maintaining cremation as a viable cost-effective option for final disposition. Our long-term strategy is to see this technology widely adopted for use in Minnesota and beyond.

C. Timeline Requirements

The project is proposed for 3 years beginning July 1, 2018 and ending June 30, 2021. This time frame will allow for adequate development, design and laboratory testing of the proposed device to capture mercury. It will also allow our team time to interface closely with crematoria owners for their input, and to complete onsite field-testing of our device in crematoria across the state. The progress and results of this project will be disseminated through presentations and peer-reviewed publications by our Team, and in briefings to the LCCMR as requested. Progress on this project will be regularly presented for review to our colleagues in mortuary and cremation sciences.

2018 Detailed Project Budget

Project Title: *Development of Technology to Capture Mercury From Cremation*

IV. TOTAL ENRTF REQUEST BUDGET 3 years (7/1/2018-6/30/2021)

BUDGET ITEM	AMOUNT
Personnel	$340,094
Project Manager - Dr. Sandra Myers (Assoc Prof), 1-person year-round 25% salary, Fringe 33.5% ($35,192/yr x 3yrs)	$105,577
Co-Investigator - James Marti (Ass't. Lab. Dir.), 1-person year round 15% salary, Fringe 33.5% ($24,287/yr x 3 yrs)	$72,859
Lab Tech #1 - Roger McMeekin, 1-person year round 50% Salary, Fringe 33.5% ($27,800/yr x 2.5 yrs).	$67,056
Lab Tech #2 - To Be Named, 1-person year round 50% Salary, Fringe 33.5% ($27,800/yr x 2 yrs).	$55,602
Walter R. Bowles, Ph.D., Research Consultant (UofM Retired Faculty) $100/hr. for Fifteen 6 hr. days Yrs 1-3 (45 days @ $600/day)	$27,000
Ceramics Consultant (UofM Faculty Expert) $100/hr. for Ten 6 hr. days in Yr. 1 (10 days @ $600/day)	$6,000
Chemistry Consultant on Mercury (UofM Faculty Expert) $100/hr. for Ten 6 hr. days in Yr. 1 (10 days @ $600/day)	$6,000
Equipment / Lab Supplies & Lab Services:	$ 83,390
Equipment - Atomic absorption mercury analyzer	$ 17,429
Lab supplies: lab disposables (safety), labeling, storage containers, hard drive storage	$ 1,200
Chemicals (including selenium precursors)	$ 4,200
Dental Amalgam and Substrates	$ 1,200
Mercury indicators	$ 2,400
Valves, plumbing	$ 500
Publication Costs - Open Access Journals @ $1,800	$ 1,800
Lab services fees - Nano Center nano-materials processing/testing fees - 24 mos of 4 hr. sessions @ $63.30/hr., $1,772/mo and $21,264 per yr - http://www.mnc.umn.edu/	$ 42,528
Lab services fees - Nano Center analyze mercury emissions - ~ $1/minute @ 60 min/session for 105 sessions (3.5 sess/mo.) over 30 mos.	$ 6,324
Lab services Fees - Characterization Facility Scanning Electron Microscope (SEM) fees - $48/hr. 4-hr.sess. 30 sessions over 30 mos. - http://www.charfac.umn.edu/instruments/	$ 5,809
Travel: *Investigators (P.I. and Dr. Bowles) out-of-metro travel to 15 (of ~ 20 recruited) crematoria to recruit, enroll, install emissions capturing apparatus, and collect data. Most travel mileage $100 and per diem $75. 15 trips/yr/investigator, over 2.5 years, and ~ 37 trips/investigator over 30 mos., 1/3 trips/yr add $100/night hotel (remote areas of MN).*	$ 12,500
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$435,984

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: *Indicate any additional non-state cash dollars secured or applied for to be spent on the project during the funding period. For each individual sum, list out the source of the funds, the amount, and indicate whether the funds are secured or pending approval.*	$ -	*Indicate: N/A*
Other State $ To Be Applied To Project During Project Period: *Indicate any additional state cash dollars (e.g., bonding, other grants) secured or applied for to be spent on the project during the funding period. For each individual sum, list out the source of the funds, the amount, and indicate whether the funds are secured or pending approval.*	$ -	*Indicate: N/A*
In-kind Services To Be Applied To Project During Project Period: *The foregone federally negotiated ICR funding @ 54% MTDC, constitutes the University of Minnesota's cost share to the project.*	$ 226,020	*Indicate: Pending*
Past and Current ENRTF Appropriation: *Specify dollar amount and year of appropriation from any current ENRTF appropriation for any directly related project of the project manager or organization that remains unspent or not yet legally obligated at the time of proposal submission. Be as specific as possible. Indicate the status of the funds.*	$ -	Indicate: N/A
Other Funding History To Date Total:	$ 43,376	
Other Funding History: *Development of a Nanoparticle-Based Mercury Scrubber. University of Minnesota Institute on the Environment, Mini-Grant MF-0023-15 (December 2015 – December 2016, $2,500) (Significant outcome was the Dental Mercury Summit held November 17, 2016 @ the University of Minnesota Alumni Center)*	$ 2,500	*Obligated & Spent*
Other Funding History: *Dental Mercury and Cremation: Development of a Nanoparticle-Based Mercury Scrubber Matching Funds ($10,000): University of Minnesota Institute on the Environment (December 2016 - $5,000) & University of Minnesota School of Dentistry (December 2016 - $5,000)*	$ 10,000	*Obligated & Spent*
Other Funding History: *Quantifying Mercury Emissions Resulting from the Cremation of Dental Amalgam in Minnesota. State of Minnesota Pollution Control Agency & United States Environmental Protection Agency, (August 2013 – 2015, $33,376)*	$ 33,376	*Obligated & Spent*

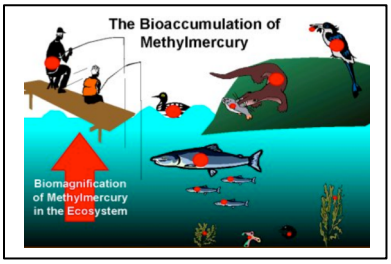
VISUAL ILLUSTRATION OF PROPOSAL INFORMATION

Objective: Build and optimize a mercury capture device for crematoria emissions
Goal: To reduce mercury contamination of Minnesota waterways

Smoke from Crematorium

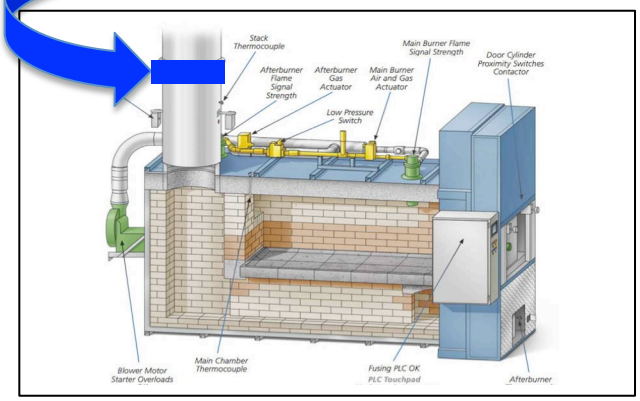
Mercury in dental amalgam fillings vaporizes during cremation and is emitted into the environment.

Mercury eventually deposits on soils and bodies of water where it accumulates in fish and ultimately animals.

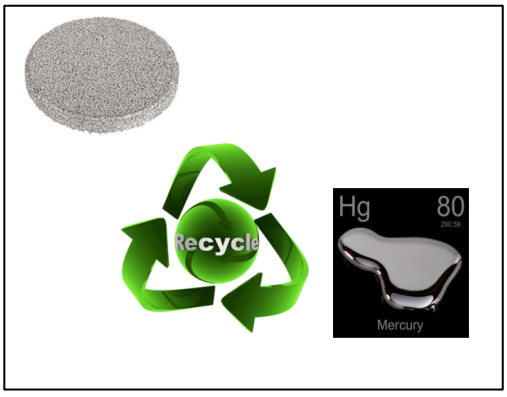


Nano-selenium sorbents are >100 times more effective than non nano-sorbents in sequestering mercury. Use to build affordable mercury capture device (filter) for crematoria exhaust:

Insert capture device in crematoria exhaust ductwork to capture mercury



Remove used mercury capture device for safe disposal or to reclaim and/or recycle mercury



Project Manager Qualifications

Dr. Sandra Myers is currently an Associate Professor in the University of Minnesota School of Dentistry, joining the faculty in 1994. She has spent the past 27 years of her career in academics serving patients, teaching students, and working on research. Her experience and knowledge of the dental profession and clinical dentistry is comprehensive. She has completed formal education programs in dental assisting, dental hygiene, dentistry, and oral pathology, and has extensive work experience in each of these respective dental fields.

Since December 2007, her research has centered on the issue of mercury released into the environment from dental amalgam fillings during cremation. This builds on her early career experiences in forensic dentistry and interest on the effects of fire on teeth.* From 2013 to 2015, Dr. Myers was the Principal Investigator on a grant, awarded by the Minnesota Pollution Control Agency (MPCA) in conjunction with the EPA. The objective of this grant was to begin to determine the extent of dental amalgam (mercury) currently in the mouths of Minnesotans. A copy of the final report is posted on the MPCA website: https://www.pca.state.mn.us/sites/default/files/aq-ei2-07a.pdf.

Dr. Myers and her Team have recently presented at meetings of the Minnesota Funeral Directors Association, Cremation Association of North America, and Air and Waste Management Association of North America. In November 2016, Dr. Myers hosted and presented an update on the dental mercury problem at the *Dental Mercury Summit*, held at the U of MN Alumni Center. Dr. Myers has participated in all areas concerning mercury emissions from cremation, including: meetings to draft legislation in Minnesota for dental amalgam abatement prior to cremation, speaking at funeral director town hall meetings, working with the medical device center to explore removing existing amalgams prior to cremation, assessing anatomy bequest donors for types of dental restorations, and working with the Minnesota Nano Center to develop methods to capture mercury released during cremation.

Dr. Myers has worked with funeral directors and crematoria owners to validate their needs, and pains/gains for an acceptable solution to the mercury emissions problem. Customer discovery and validation efforts have determined crematoria owners as early first adopters for any new technology under development. Crematoria owners care about harmful emissions, but do not have an acceptable cost-effective solution available to them. Currently, Dr. Myers is working with Dr. James Marti, a Senior Scientist in the Minnesota Nano Center, to develop an affordable mercury capture filter for use in crematoria. The project builds logically on Dr. Myers passion to improve air and water quality in Minnesota and beyond, while at the same time helping Minnesota citizens and crematoria owners keep cremation a cost-effective viable option for final disposition. This LCCMR proposal compliments Dr. Myers' unique background, and importantly incorporates an interested collaborative team of partners and stakeholders, both within and outside the University.

Organization Description

This project utilizes the Minnesota Nano Center (MNC), located in the Physics and Nanotechnology Building on the Twin Cities Campus of the University of Minnesota. The MNC has over $20 million of equipment in place, and offers expanded facilities for research in basic nanoscience and in applied nanotechnology. The facilities support researchers working in the three main areas of nanotechnology today: small-scale devices, nanomaterials, and biomedical applications of nanotechnology. The central core laboratory is an open facility that supports research involving small-scale materials, including nanoparticles and micron-scale powders. Dr. Myers' Team will utilize the nanomaterials lab to 1) make, modify, test, and customize materials to capture mercury vapor in a high temperature environment, and 2) design a usable carrier device with these materials to capture mercury in crematoria exhaust emissions.

*Myers SL, Williams JM, Hodges JS. Effects of extreme heat on teeth with implications for histologic processing. J Forensic Sci. 1999 Jul;44(4):805-9.