



# Environment and Natural Resources Trust Fund (ENRTF)

## M.L. 2019 ENRTF Work Plan (Main Document)

---

**Today's Date:** August 27, 2018

**Date of Next Status Update Report:** March 1, 2020

**Date of Work Plan Approval:**

**Project Completion Date:** June 30, 2022

**Does this submission include an amendment request?**

---

**PROJECT TITLE:** Benign Design: Environmental studies leading to sustainable pharmaceuticals

**Project Manager:** William Arnold

**Organization:** University of Minnesota

**College/Department/Division:** Civil, Environmental, and Geo- Engineering

**Mailing Address:** 500 Pillsbury Dr. SE

**City/State/Zip Code:** Minneapolis, MN 55455

**Telephone Number:** 612-625-8582

**Email Address:** arnol032@umn.edu

**Web Address:** www.williamarnold.org

---

**Location:** Statewide

---

**Total Project Budget:** \$415,000

**Amount Spent:** \$0

**Balance:** \$415,000

---

**Legal Citation:** M.L. 2019, Chp. xx, Sec. xx, Subd. xx

**Appropriation Language:**

## I. PROJECT STATEMENT:

Many pharmaceuticals contain fluorine in their chemical structures. *There is limited information about how fluorine-containing pharmaceuticals are degraded during wastewater treatment or in the environment, and even less about the products that form.* This is important because one potential breakdown product is the **highly toxic fluoroacetate** while another is the non-toxic fluoride (which is in toothpaste). We need to understand which wastewater treatment and natural processes lead to toxic versus non-toxic breakdown products. Data will be needed for systems such as oxidation ponds in outstate Minnesota as well as in the wastewater treatment plants used in cities. *The objective of this proposal, therefore, is to gain the knowledge necessary to understand both how to best remove fluorinated pharmaceuticals from water and to allow the development of “benign by design” fluorinated chemicals.* Specific goals are to:

- Measure reaction rates and products of fluorinated pharmaceuticals when they are exposed to sunlight,
- Measure reaction rates and products of fluorinated pharmaceuticals in advanced treatment systems,
- Develop environmentally benign fluorinated magnetic resonance imaging (MRI) agents,
- Establish computational tools to predict the reactivity of fluorinated pharmaceuticals, and
- Disseminate the findings to water utilities and the MN Department of Health

There are fewer than 10 natural chemicals that contain fluorine. Because natural fluorinated organic compounds are few, the environmental pathways for processing synthetic fluorinated chemicals may not be as robust as those for other potential water pollutants. The presence of fluorinated chemicals in Minnesota’s waters has received substantial attention. These compounds, however, are only a small subset of fluorochemicals used. In particular, a broad range of pharmaceuticals, including antibiotics, steroids, antidepressants, imaging agents, and statins contain fluorine. This could lead to accumulation of specific pharmaceuticals and their fluorinated degradation products in Minnesota’s environment. Overall, we lack specific knowledge of

- 1) the **reaction intermediates and end products of synthetic fluorinated pharmaceuticals** in natural and engineered aquatic environments,
- 2) the level and type of fluorine incorporation that **maximizes utility and minimizes environmental impact of pharmaceuticals**, and
- 3) means to **predict the reactivity** and reaction pathways of fluorine-containing species under a variety of conditions.

Modern society requires effective pharmaceuticals, pesticides, and commercial/industrial compounds. The release of such chemicals into the environment is either necessary or inevitable, and having a sustainable society dictates that these chemicals be readily degradable after their desired function is achieved and that any degradation products are benign. This research project will provide critical knowledge that will lead to better wastewater treatment, prevent the accumulation of unanticipated and potentially toxic byproducts in the environment, guide the design of future pharmaceutical compounds, and protect of Minnesota’s water resources as well as human and environmental health.

## II. OVERALL PROJECT STATUS UPDATES:

**First Update March 1, 2020**

**Second Update September 1, 2021**

**Third Update March 1, 2021**

**Fourth Update September 1, 2022**

**Fifth Update March 1, 2022**

**Final Report between project end (June 30) and August 15, 2022**

**III. PROJECT ACTIVITIES AND OUTCOMES:**

**ACTIVITY 1 Title: *Identify toxic and non-toxic fluorinated products formed during wastewater treatment and environmental processing of pharmaceuticals***

**Description:** The rate at which fluorinated pharmaceuticals are degraded in wastewater oxidation ponds and rivers/lakes via photolysis and in advanced treatment systems for wastewater treatment will be measured. Fluorinated reaction products will be measured. The hypothesis to be tested is that fluorinated pharmaceuticals and imaging agents break down into fluorinated intermediate and product structures with the potential for environmental persistence and toxicity.

**ACTIVITY 1 ENRTF BUDGET: \$ 144,000**

<b>Outcome</b>	<b>Completion Date</b>
<i>1. Reaction rates of fluorinated pharmaceuticals wastewater and river water in sunlight</i>	January 30, 2021
<i>2. Reaction rates of fluorinated pharmaceuticals under advanced treatment conditions</i>	October 31, 2021
<i>3. Reaction product identification</i>	January 30, 2022

**First Update March 1, 2020**

**Second Update September 1, 2021**

**Third Update March 1, 2021**

**Fourth Update September 1, 2022**

**Fifth Update March 1, 2022**

**Final Report between project end (June 30) and August 15, 2022**

**ACTIVITY 2 Title: *Synthesis of new polyfluorinated MRI agents that breakdown during wastewater treatment or in the environment***

**Description:** Potential new MRI reagents with superior sensitivity and minimal environmental persistence will be synthesized. All synthesized compounds will be tested under the reaction conditions of Activity 1. Current clinical trials are using perfluorochemicals which will be environmentally persistent, and our work will provide critical knowledge about how to make fluorinated structures that are medical useful yet environmentally benign.

**ACTIVITY 2 ENRTF BUDGET: \$ 128,000**

<b>Outcome</b>	<b>Completion Date</b>
<i>1. Development of environmentally friendly MRI reagents</i>	December 31, 2021
<i>2. Evaluation of sunlight and advanced treatment of MRI reagents</i>	June 30, 2022

**First Update March 1, 2020**

**Second Update September 1, 2021**

**Third Update March 1, 2021**

**Fourth Update September 1, 2022**

**Fifth Update March 1, 2022**

**Final Report between project end (June 30) and August 15, 2022**

**ACTIVITY 3 Title: *Assess the parameters that dictate reaction rates and products of pharmaceuticals containing fluorine***

**Description:** While it is known that many fluorinated compounds are unreactive, a better understanding of how reactions of fluorinated pharmaceuticals occur under a variety of conditions is needed. We will develop computational methods to predict how fluorinated compounds breakdown under water treatment conditions and in sunlight. The theoretical results will be tested during the experiments performed in Activities 1 and 2. This will facilitate prediction of which compounds may accumulate in the environment and which are likely to be degraded.

**ACTIVITY 3 ENRTF BUDGET: \$ 143,000**

<b>Outcome</b>	<b>Completion Date</b>
<i>1. Modeling of reactive states/energies of reactions</i>	October 31, 2021
<i>2. Development of tools to predict reactivity of fluorinated pharmaceuticals</i>	June 30, 2022

**First Update March 1, 2020**

**Second Update September 1, 2021**

**Third Update March 1, 2021**

**Fourth Update September 1, 2022**

**Fifth Update March 1, 2022**

**Final Report between project end (June 30) and August 15, 2022**

#### **IV. DISSEMINATION:**

**Description:** Results will be disseminated by publication in peer-reviewed journals, presentations and conferences, and via a final report. Funds are requested to make journal articles open access. Data sets will be archived in the Data Repository for the University of Minnesota (<https://conservancy.umn.edu/handle/11299/166578>), a publically available collection of research data. ENTRF support will be acknowledged on all disseminated materials.

The Minnesota Environment and Natural Resources Trust Fund (ENRTF) will be acknowledged through use of the trust fund logo or attribution language on project print and electronic media, publications, signage, and other communications per the [ENRTF Acknowledgement Guidelines](#).

**First Update March 1, 2020**

Second Update September 1, 2021

Third Update March 1, 2021

Fourth Update September 1, 2022

Fifth Update March 1, 2022

Final Report between project end (June 30) and August 15, 2022

**V. ADDITIONAL BUDGET INFORMATION:**

**A. Personnel and Capital Expenditures**

Explanation of Capital Expenditures Greater Than \$5,000: N/A

Explanation of Use of Classified Staff: N/A

**Total Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation:**

Enter Total Estimated Personnel Hours for entire duration of project: 6108	Divide total personnel hours by 2,080 hours in 1 yr = TOTAL FTE: 2.93
--	---

**Total Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation:**

Enter Total Estimated Contract Personnel Hours for entire duration of project: N/A	Divide total contract hours by 2,080 hours in 1 yr = TOTAL FTE: N/A
--	---

**VI. PROJECT PARTNERS:**

The project team will be led by William Arnold University of Minnesota; Dept. of Civil, Environmental, and Geo-Engineering) collaborating with William Pomerantz and Christopher Cramer (Dept. of Chemistry, UMN) . Dr. Arnold has expertise in the environmental analysis, fate, and transport of organic contaminants and has been studying the fate of pharmaceuticals in the environment for 20 years. Dr. Pomerantz is an expert in the development of new fluorinated molecules, and Dr. Cramer’s expertise is in theoretical chemistry and predicting the environmental fate of pollutants. Two graduate students and an undergraduate students will conduct the research activities. Their duties will include collecting water samples, performing experiments, data analysis, and presenting the results at in-state scientific conferences.

**A. Partners outside of project manager’s organization receiving ENRTF funding: N/A**

**B. Partners outside of project manager’s organization NOT receiving ENRTF funding: N/A**

**VII. LONG-TERM- IMPLEMENTATION AND FUNDING:** The long-term goal of the project is to prevent wastewater treatment plants, whether they be oxidation ponds in out-state Minnesota or advances treatment plants in cities, from becoming hotspots of fluorochemical contamination. This project will provide information about specific chemicals that could be problematic, wastewater treatment techniques that result in non-toxic (fluorinated) reaction products, and means to new fluorochemicals that are of medical use but environmentally benign. The proposed study will help to safeguard Minnesota’s lakes and rivers and human and animal health.

**VIII. REPORTING REQUIREMENTS:**

- Project status update reports will be submitted March 1 and September 1 each year of the project
- A final report and associated products will be submitted between June 30 and August 15, 2022

**IX. SEE ADDITIONAL WORK PLAN COMPONENTS:**

**A. Budget Spreadsheet**

**B. Visual Component or Map**

**C. Parcel List Spreadsheet: N/A**

**D. Acquisition, Easements, and Restoration Requirements: N/A**

**E. Research Addendum**

**Attachment A:**  
**Environment and Natural Resources Trust Fund**  
**M.L. 2019 Budget Spreadsheet**



**Legal Citation:**  
**Project Manager:** William Arnold  
**Project Title:** Benign Design: Environmental Studies Leading to Sustainable Pharmaceuticals  
**Organization:** University of Minnesota  
**Project Budget:** \$415,000  
**Project Length and Completion Date:** 3 years, June 30, 2022  
**Today's Date:** August 27, 2018

<b>ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET</b>	<b>Budget</b>	<b>Amount Spent</b>	<b>Balance</b>
<b>BUDGET ITEM</b>			
<b>Personnel (Wages and Benefits)</b>	\$ 350,000	\$ -	\$ 350,000
William Arnold, Project Manager (75% salary, 25% fringe benefits). 4% FTE for years 1 - 3. Overall project coordination, lead Task 1 studies, co-lead Task 3. \$34,500			
William Pomerantz, co-Project Manager (75% salary, 25% fringe benefits). 4% FTE for years 1 - 3. Lead Task 2, co-lead Tasks 1 and 3. \$20,000			
Christopher Cramer, co-Project Manager (75% salary, 25% fringe benefits). 2% FTE for years 1 -3. Lead Task 3. \$22,400			
Graduate student Research assistant 1, Perform environment fate studies for Task 1, perform computations in Task 3 (55% salary, 45% fringe benefits) 50% FTE for years 1 &2, 25% for Year 3. \$124,100			
Graduate student Research assistant 2, Synthesize new MRI reagents in for Task 2, perform computations in Task 3 (55% salary, 45% fringe benefits) 25% FTE for year 1, 50% for Years 2&3. \$124,500			
Undergraduate researcher. Assist with laboratory experiments. 10 hrs per week during academic year, 40 hours per week in summer. (100% salary). \$24,900			
<b>Equipment/Tools/Supplies</b>			
Laboratory Supplies (chemical and isotopically labelled standards, chemical reagents, necessary glassware, solvents, consumable supplies, laboratory notebooks, software licenses, instrument operation)	\$ 27,000	\$ -	\$ 27,000
Analytical time for identification of breakdown products using NMR	\$ 7,000	\$ -	\$ 7,000
Analytical time for identification of breakdown products using mass spectrometry	\$ 21,000	\$ -	\$ 21,000
<b>Travel expenses in Minnesota</b>			
University vehicle rental and hotel stays to collect water samples. Presentation of results at local conferences. Reimbursement will be according to University of Minnesota guidelines.	\$ 4,000	\$ -	\$ 4,000
<b>Other</b>			
Publication charges to make to make published journal articles (2-3) immediately available via open access to maximize data availability and dissemination	\$ 6,000	\$ -	\$ 6,000
<b>COLUMN TOTAL</b>	<b>\$ 415,000</b>	<b>\$ -</b>	<b>\$ 415,000</b>

<b>OTHER FUNDS CONTRIBUTED TO THE PROJECT</b>	<b>Status (secured or pending)</b>	<b>Budget</b>	<b>Spent</b>	<b>Balance</b>
<b>Non-State:</b>		\$ -	\$ -	\$ -
<b>State:</b>		\$ -	\$ -	\$ -
<b>In kind:</b> Because the project is overhead free, laboratory space, electricity, and other facilities/adminstrative costs (54% of direct costs excluding permanent equipment and graduate student tuition benefits) are provided in-kind.	secured	\$ 178,500	\$ -	\$ 178,500

<b>PAST AND CURRENT ENRTF APPROPRIATIONS</b>	<b>Amount legally obligated but not yet spent</b>	<b>Budget</b>	<b>Spent</b>	<b>Balance</b>
<b>Current appropriation:</b>		\$ -	\$ -	\$ -
<b>Past appropriations: N/A</b>		\$ -	\$ -	\$ -

# Fluorinated pharmaceuticals and toxic byproducts in Minnesota lakes and rivers

*Oxidation ponds*

*Antibiotics, statins, etc  
often contain fluorine*



*Advanced treatment*



## **Outcomes:**

1. Assess toxic byproduct formation
2. Identify wastewater treatment processes that lead to non-toxic products
3. Improve outstate and urban wastewater treatment
4. Develop rules for environmentally benign design of new compounds