

# Final Abstract

Final Report Approved on November 12, 2024

## M.L. 2020 Project Abstract

For the Period Ending June 30, 2024

**Project Title:** Developing Strategies To Manage PFAS In Land-Applied Biosolids

**Project Manager:** Summer Streets

**Affiliation:** Minnesota Pollution Control Agency

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**Funding Source:**

**Fiscal Year:**

**Legal Citation:** M.L. 2021, First Special Session, Chp. 6, Art. 5, Sec. 2, Subd. 04d

**Appropriation Amount:** \$1,404,000

**Amount Spent:** \$1,306,321

**Amount Remaining:** \$97,679

### Sound bite of Project Outcomes and Results

Environmental, human health, and economic impacts of PFAS in land-applied biosolids were investigated in this multi-part study. Soils that received biosolids had higher levels of PFAS than background. Laboratory studies demonstrated that PFAS do migrate through soils, presenting a potential risk to groundwater. Treatment and destruction costs are not affordable.

### Overall Project Outcome and Results

Biosolids and the soils they were applied to at three different farms were tested for PFAS using multiple methods. Each of the three farms identified three fields; one that had never received biosolids; one that received biosolids previously but not in the study year; and one that received biosolids during the study year. Soils were tested at 30 cm increments from 0 - 90 cm. Soils that received biosolids had a larger variety and higher concentrations of PFAS compounds than soils that never received biosolids. In addition, crops grown on these fields were collected and tested for PFAS. Corn stover, soybeans, and rye were tested. Uptake did occur in crops, especially in fields that received biosolids during the test year. Corn stover in particular seems to be susceptible to PFAS uptake. Corn stover is used as livestock feed. The same soils and biosolids were used in laboratory leaching tests to determine the rate at which different PFAS move through soil

and to estimate potential risks to groundwater. Shorter chain PFAS, in general, move more quickly through the soil than longer chain PFAS, posing a greater risks to groundwater in a shorter time period.

A sorbent material known as polyDADMAC effectively binds PFAS when added to biosolids before application to soils. However, risks associated with polyDADMAC are unknown and effectiveness in the field is untested. Finally, we evaluated the cost and effectiveness of over 50 PFAS removal and destruction technologies in municipal wastewater effluent, biosolids, landfill leachate and compost contact water using currently available technologies. We developed a statewide cost estimate for PFAS removal and destruction in municipal wastewater, biosolids, compost contact water, and landfill leachate. Statewide cost to treat and destroy PFAS in waste streams would range from \$14 to \$28 billion dollars.

### **Project Results Use and Dissemination**

The cost and effectiveness study was published in the peer-reviewed journal Water Environment Research. This publication is open access and readily available to the public. Three manuscripts detailing the results of the field and lab studies are in progress. Submission for peer review is expected in December of 2024. All publications will be open access. In additions, results have already been shared at scientific conferences, with more presentations planned going forward. Finally, the results of the field and laboratory study support MPCA's upcoming biosolids management strategy. Implementation of that strategy will begin in 2025.



## Environment and Natural Resources Trust Fund

M.L. 2020 Approved Final Report

### General Information

**Date:** December 11, 2024

**ID Number:** 2020-013

**Staff Lead:** Michael Varien

**Project Title:** Developing Strategies To Manage PFAS In Land-Applied Biosolids

**Project Budget:** \$1,000,000

### Project Manager Information

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### Project Reporting

**Final Report Approved:** November 12, 2024

**Reporting Status:** Project Completed

**Date of Last Action:** November 12, 2024

**Project Completion:** June 30, 2024

### Legal Information

**Legal Citation:** M.L. 2021, First Special Session, Chp. 6, Art. 5, Sec. 2, Subd. 04d

**Appropriation Language:** \$1,404,000 the second year is from the trust fund to the commissioner of the Pollution Control Agency to help municipal wastewater plants, landfills, and compost facilities protect human health and the environment by developing strategies to manage per- and polyfluoroalkyl substances (PFAS) in land-applied biosolids.

**Appropriation End Date:** June 30, 2024

## Narrative

**Project Summary:** This project helps municipal wastewater plants, landfills, and compost facilities protect human health and the environment by developing strategies to manage per- and polyfluoroalkyl substances (PFAS) in land-applied biosolids.

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

Environmental contamination of PFAS is a widespread issue of concern, and concentrations commonly found throughout Minnesota pose known risks to human and ecological health. Elevated levels of PFAS have been measured in Minnesota municipal biosolids, landfill leachate, and compost contact water. While land application of these biosolids has benefits for farming, land application is a known source of PFAS to groundwater, soil, surface water, and crops. Human health can be impacted when PFAS-contaminated water and food is consumed by people. There is still a lot we don't know about how PFAS moves out of biosolids and into the environment and food supplies. This study will allow us to proactively manage biosolids in a way that prevents environmental contamination by PFAS.

**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.**

Waste managers in Minnesota are already facing urgent concerns related to disposal of PFAS-contaminated wastes. They have an immediate need of tools to evaluate and manage PFAS in their land-applied waste streams. This project will focus on developing cost-effective, real world approaches for preventing, treating, disposal, and destruction of PFAS-contaminated land-applied wastes. This study will allow us to develop tools to proactively-manage biosolids in a way that prevents environmental contamination by PFAS.

The goals of this study are to:

- 1) Evaluate and characterize PFAS concentrations in land-applied biosolids.
- 2) Evaluate and characterize PFAS leaching from land-applied wastes into groundwater.
- 3) Evaluate and characterize PFAS uptake in feed crops.
- 4) Analyze alternative disposal and treatment options to develop tools for managing PFAS-contaminated waste streams.

**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?**

This project will give much-needed insight and understanding of: 1) the role land-applied wastes play in introducing PFAS to the environment; and 2) how those PFAS move once released. We will also develop cost-effective, practical tools to help municipalities manage their PFAS-containing wastes to prevent environmental contamination and protect human health.

## Project Location

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

Statewide

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

Statewide

**When will the work impact occur?**

During the Project and In the Future

## Activities and Milestones

### Activity 1: Controlled plot study to evaluate leaching of PFAS

**Activity Budget:** \$409,500

**Activity Description:**

A two year field study will be conducted at the Rosemount Research and Outreach Center (RROC) in Rosemount, MN and working farms in MN. This soil is typically used for row crop production in Minnesota. Soil types at working farms will be determined at the time of sampling in year two.

Controlled plots will be used to evaluate leaching and plant uptake under environmentally relevant conditions.

In year one, soybeans will be grown at RROC on land that has never received biosolids. This will provide a sort of baseline against which to compare year two data. Soil, groundwater, and soybeans will be tested for PFAS and soil health parameters.

In year two, we will partner with 3 wastewater facilities to identify farms that receive biosolids. For each of 3 facilities, 3 fields will be identified (total of 9 fields). Ideally, each set of 3 fields will include:

- One field that has never received biosolids
- One field that received biosolids in a previous year
- One field that will receive biosolids in the sampling year.

Multiple soil and crop samples will be analyzed for PFAS.

**Activity Milestones:**

Description	Approximate Completion Date
Secure partnerships with WWTP and Compost facilities	October 31, 2021
Sample plot soils prior to land application of amendments.	November 30, 2021
Purchase supplies for suction tubes, sample collection, and PPE	November 30, 2021
Develop plan for controlled plot study prior to first summer growing season	March 31, 2022
Install suction tubes in controlled plots for groundwater sampling	April 30, 2022
Plant first year soybeans at RROC	May 31, 2022
Collect soil, groundwater, and plant samples for PFAS analysis	October 31, 2022
Sample soil at field plots	April 30, 2023
Collect soil, groundwater, and plant samples for PFAS analysis	October 31, 2023
Two years of field study	June 30, 2024

### Activity 2: Laboratory investigation of PFAS fate and transport, and identification of 325 novel PFAS compounds in relevant media

**Activity Budget:** \$394,500

**Activity Description:**

An understanding of PFAS presence in, and movement through, biosolids will be achieved through a combination of targeted analysis (analogous to liquid chromatography-tandem mass spectrometry [LC-MS/MS]), high resolution mass spectrometry (HRMS) analysis, and laboratory column experiments. The latter will target a suite of biosolids that represent different waste inputs (e.g. yard waste vs. food waste, municipal vs. industrial) and biosolids treatment types. Results will be used to evaluate which PFAS are prevalent in biosolids and related media, evaluate trends in sorption of PFAS based on PFAS structure and geochemistry, and estimate the fraction of PFAS that may leach into the saturated

zone. The overarching benefit of this work will be the generation of information that can be used to develop best management practices related to PFAS in biosolids, thus reducing overall risks to human health and the environment.

**Activity Milestones:**

Description	Approximate Completion Date
Analyze preliminary (pre-application) samples from controlled plots for PFAS	December 31, 2021
Analyze soil, water, biosolids, and crops from 1st field study for PFAS	December 31, 2022
Setup and conduct soil leaching studies	December 31, 2022
Analyze soil, water, and crops from 2nd year field study	December 31, 2023

**Activity 3: SGS Axys Quantitative analysis of PFAS in land-applied wastes and relevant media**

**Activity Budget:** \$44,000

**Activity Description:**

Analysis of 40 PFAS compounds and their breakdown products in biosolids, compost, soil, water, and crops, to understand occurrence of PFAS in these wastes so that risk associated with land application can be characterized.

**Activity Milestones:**

Description	Approximate Completion Date
Analyze preliminary samples of biosolids, compost, and fertilizer for PFAS	November 30, 2021
Analyze pre-application soil and groundwater samples	November 30, 2021
Perform total oxidizable PFAS precursor analysis in soil after biosolids application	July 31, 2022
Analyze post-application soil and groundwater samples throughout 1st growing season	December 31, 2022
Analyze 1st year soybean harvest for PFAS	June 30, 2023
Analyze PFAS in equipment rinse blanks	October 31, 2023

**Activity 4: Developing PFAS management solutions for biosolids, landfills and compost**

**Activity Budget:** \$300,000

**Activity Description:**

The Request for Proposals (RFP) will encourage the state and national design community to apply for funds to complete an analysis of PFAS treatment and destruction options. The RFP contracting process will be managed by the MPCA contract staff, reviewed by MPCA engineers, and will comply with all state and federal regulations. The final candidate will be selected by a committee of MPCA engineering staff and municipal wastewater engineers under the guidance of the MPCA contract unit. Once the best candidate is selected, funds and necessary design information will be delivered to the contractor by the MPCA. The contractor will have 24 months to complete the deliverable.

**Activity Milestones:**

Description	Approximate Completion Date
MPCA completes administration of competitive RFP to identify project consultant	March 31, 2022
Kick-off meeting with consultant	April 30, 2022
Regular meetings with consultant to ensure progress on deliverable	May 31, 2024
Deliverable of best management practices report to MPCA	June 30, 2024

## Activity 5: Eurofins quantitative analysis of PFAS in land-applied wastes and relevant media

**Activity Budget:** \$256,000

### Activity Description:

Analysis of 40 PFAS compounds in biosolids, soil, water, and crops, to understand occurrence of PFAS in these wastes so that risk associated with land application can be characterized. Up to 415 samples will be analyzed by Eurofins.

### Activity Milestones:

Description	Approximate Completion Date
Analyze 90 soil samples and 6 aqueous blanks, before land application.	May 31, 2023
Analyze 90 soil samples and 6 aqueous blanks, post land application	June 30, 2023
Analyze 54 soil samples and 6 aqueous blanks, mid-season.	August 31, 2023
Analyze 90 soil samples and 6 aqueous blanks, post-harvest.	November 30, 2023
Analyze up to 60 crop samples and 4 aqueous blanks.	November 30, 2023

## Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Dr. Carl Rosen	University of Minnesota - Twin Cities	Dr. Rosen will conduct a two-year field study to evaluate leaching of PFAS from land-applied biosolids in typical Minnesota field conditions. Multiple soil, groundwater, and vegetation samples will be analyzed for PFAS and soil and crop health.	Yes
Dr. Jennifer Guelfo	Texas Tech University	Dr. Guelfo will conduct a laboratory investigation of PFAS fate and transport mechanisms to evaluate leaching of PFAS from biosolids and other wastes into the environment. A standardized soil leaching method will be established for comparison of PFAS leaching between sites and waste types. Non-targeted analytical techniques will be used.	Yes
SGS Axys Analytical Services, Ltd.	State contract lab providing PFAS analysis	Analysis of 40 PFAS compounds and their breakdown products in biosolids, ash, compost, soil, water, and crops, to understand occurrence of PFAS in these wastes so that risk associated with land application can be characterized.	Yes

## Dissemination

**Describe your plans for dissemination, presentation, documentation, or sharing of data, results, samples, physical collections, and other products and how they will follow ENRTF Acknowledgement Requirements and Guidelines.**

The results of this study will be compiled into a single final deliverable product report that will be freely available to the public on the MPCA webpage. The results of the study will also be submitted for publication into peer-reviewed journals and presented at conferences to make the results available to regulated authorities managing PFAS more broadly. We expect to generate at least two master degree level theses out of this project and these theses will be completed in publication ready journal format. We will disseminate the findings from the study to wastewater engineers, managers and operators through public presentations and publications in peer-reviewed journals. A key outcome from our work will be presentations at two local and statewide conferences.

Ultimately, this information will be used to guide Minnesota’s PFAS policy and help wastewater plants select PFAS management strategies. The federal EPA has expressed interest in the findings of this study and would use the results of this study to inform their Clean Water Act wastewater permitting responsibilities on a nationwide basis.

## 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?**

This project will support the long-term implementation goals of Minnesota to ensure appropriate disposal of wastes in Minnesota and to safeguard drinking water for current and future needs. This is a one-time funding request and no additional future support is envisioned. The MPCA will use this information, in close collaboration with regulated parties, to develop permitting and policy decisions that protect human health and the environment from PFAS.



## Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	\$ Amount	\$ Amount Spent	\$ Amount Remaining
<b>Personnel</b>										
							Sub Total	-	-	-
<b>Contracts and Services</b>										
University of Minnesota - Twin Cities	Subaward	A two-year controlled field plot study to evaluate leaching of PFAS from land-applied biosolids in typical Minnesota field conditions. In both years, multiple soil, groundwater, and vegetation samples will be analyzed for PFAS and soil and crop health.				0		\$409,500	\$409,500	-
Texas Tech University	Subaward	Laboratory investigation of PFAS fate and transport mechanisms to evaluate leaching of PFAS from land-applied biosolids and other wastes into the environment. A standardized soil leaching method will be established for comparison of PFAS leaching between sites and waste types. Up to 325 novel PFAS will be identified.				0		\$394,500	\$321,865	\$72,635
TBD	Professional or Technical Service Contract	The Request for Proposals (RFP) will encourage the state and national design community to apply for funds to complete an analysis of PFAS treatment and destruction options.				0		\$300,000	\$294,700	\$5,300
SGS Axys Analytical Services, Ltd.	Professional or Technical Service Contract	Analysis of 40 PFAS compounds and their breakdown products in biosolids, compost, soil, water, and crops, to understand occurrence of PFAS in these wastes so that risk associated with land application can be characterized.		X		0		\$44,000	\$42,851	\$1,149
Eurofins Environment Testing North Central	Professional or Technical Service Contract	Analysis of 40 PFAS compounds in soil, water, and crops to characterize PFAS occurrence, movement, and plant uptake in fields where biosolids are land applied.				-		\$256,000	\$237,405	\$18,595

							Sub Total	\$1,404,000	\$1,306,321	\$97,679
Equipment, Tools, and Supplies										
							Sub Total	-	-	-
Capital Expenditures										
							Sub Total	-	-	-
Acquisitions and Stewardship										
							Sub Total	-	-	-
Travel In Minnesota										
							Sub Total	-	-	-
Travel Outside Minnesota										
							Sub Total	-	-	-
Printing and Publication										
							Sub Total	-	-	-
Other Expenses										
							Sub Total	-	-	-
							Grand Total	\$1,404,000	\$1,306,321	\$97,679

## Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
<b>Contracts and Services</b> - SGS Axys Analytical Services, Ltd.	Professional or Technical Service Contract	Analysis of 40 PFAS compounds and their breakdown products in biosolids, compost, soil, water, and crops, to understand occurrence of PFAS in these wastes so that risk associated with land application can be characterized.	SGS Axys is one of the very few labs in the world doing low-level PFAS analysis on biosolids. We have over a decade of experience working with SGS and know from experience that their data quality are second to none. SGS also has a unique analytical list and the lowest reporting limits available at a commercial lab. SGS Axys is on a state master contract with MPCA.

Non ENRTF Funds

Category	Specific Source	Use	Status	\$ Amount	\$ Amount Spent	\$ Amount Remaining
<b>State</b>						
In-Kind	TBD	MPCA staff time equivalent to one FTE per study year.	Secured	\$360,000	\$150,000	\$210,000
In-Kind	TBD	University of Minnesota overhead	Secured	\$182,000	\$90,000	\$92,000
			<b>State Sub Total</b>	<b>\$542,000</b>	<b>\$240,000</b>	<b>\$302,000</b>
<b>Non-State</b>						
			<b>Non State Sub Total</b>	-	-	-
			<b>Funds Total</b>	<b>\$542,000</b>	<b>\$240,000</b>	<b>\$302,000</b>

## Attachments

### Required Attachments

#### *Visual Component*

File: [3cf35412-058.pdf](#)

#### *Alternate Text for Visual Component*

PFAS containing wastes are sent to wastewater treatment plants, landfills, and compost facilities. Each of these waste conveyances produces its own solid or liquid waste that is often land applied (e.g., biosolids, leachate, compost and compost contact water, respectively). Land-applied wastes are often applied to fields where crops are grown for livestock feed. PFAS can be taken up by crops grown on these fields, and PFAS can move into groundwater and surface water following land application...

### Supplemental Attachments

#### *Capital Project Questionnaire, Budget Supplements, Support Letter, Photos, Media, Other*

Title	File
Letter of Support from MCES	<a href="#">1da1f538-e29.pdf</a>
Background check	<a href="#">cc2558c3-7b6.pdf</a>
Is removal and destruction of perfluoroalkyl and polyfluoroalkyl substances from wastewater effluent affordable?	<a href="#">1539db2d-b09.pdf</a>
Evaluation of Current Alternatives and Estimated Cost Curves for PFAS Removal and Destruction from Municipal Wastewater, Biosolids, Landfill Leachate, and Compost Contact Water	<a href="#">b3369a55-dce.pdf</a>

#### *Media Links*

Title	Link
Is removal and destruction of perfluoroalkyl and polyfluoroalkyl substances from wastewater effluent affordable?	<a href="https://onlinelibrary.wiley.com/doi/full/10.1002/wer.10975">https://onlinelibrary.wiley.com/doi/full/10.1002/wer.10975</a>
Groundbreaking study shows unaffordable costs of PFAS cleanup from wastewater	<a href="https://www.pca.state.mn.us/news-and-stories/groundbreaking-study-shows-unaffordable-costs-of-pfas-cleanup-from-wastewater">https://www.pca.state.mn.us/news-and-stories/groundbreaking-study-shows-unaffordable-costs-of-pfas-cleanup-from-wastewater</a>

## Difference between Proposal and Work Plan

#### *Describe changes from Proposal to Work Plan Stage*

Budget changes to reflect amount of funds available. Removed landfill leachate from the work plan because it is being analyzed by MPCA in other programs.

## Additional Acknowledgements and Conditions:

The following are acknowledgements and conditions beyond those already included in the above workplan:

**Do you understand and acknowledge the ENRTF repayment requirements if the use of capital equipment changes?**

N/A

**Do you understand that travel expenses are only approved if they follow the "Commissioner's Plan" promulgated by the Commissioner of Management of Budget or, for University of Minnesota projects, the University of Minnesota plan?**

N/A

**Does your project have potential for royalties, copyrights, patents, sale of products and assets, or revenue generation?**

No

**Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?**

N/A

**Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?**

N/A

**Does your project include original, hypothesis-driven research?**

Yes

**Does the organization have a fiscal agent for this project?**

No

## Work Plan Amendments

Amendment ID	Request Type	Changes made on the following pages	Explanation & justification for Amendment Request (word limit 75)	Date Submitted	Approved	Date of LCCMR Action
1	Amendment Request	<ul style="list-style-type: none"> <li>• Project Collaborators - Project Partner Info</li> <li>• Activities and Milestones</li> </ul>	<p>Prior to year one biosolids land application, the University of Minnesota decided it was unwilling to allow biosolids land application on any UMN land. An alternative was identified in which we will work with 3 WWTPs to sample fields where they apply biosolids. Soil and corn, but not groundwater, will be tested for PFAS in the 2nd year. All samples will come from working farms.</p>	February 6, 2023	Yes	February 9, 2023
2	Amendment Request	<ul style="list-style-type: none"> <li>• Activities and Milestones</li> <li>• Budget - Professional / Technical Contracts</li> </ul>	<p>We need to change our analytical lab from SGS Axys to Eurofins due to extreme delays in data turnaround times at SGS Axys. SGS has been experiencing a severe labor shortage and currently has a data turnaround time of 20+ weeks, which is unmanageable for this project. Eurofins, a PFAS-accredited lab, was recently added to state contract. Eurofins runs the same method as SGS. Their turnaround time is 20 business days which is excellent.</p>	April 3, 2023	Yes	April 6, 2023

# Status Update Reporting

## Final Status Update August 14, 2024

**Date Submitted:** August 14, 2024

**Date Approved:** September 27, 2024

### Overall Update

This project had multiple goals: 1) Evaluate and characterize PFAS concentrations in land-applied biosolids; 2) evaluate and characterize PFAS leaching from land-applied biosolids and the potential for impacts to groundwater; 3) evaluate and characterize PFAS uptake in food crops grown on soils amended with biosolids, and 4) analyze alternative disposal and treatment options to develop tools for managing PFAS-contaminated waste streams. All goals were met.

All activities are complete, and dissemination is in progress. We are currently working on 3 manuscripts for submission to peer-reviewed journals. The first will describe the field work conducted under Activity 1, which includes analysis of biosolids, characterization of soils at MN farms that received those biosolids, and characterization of plant uptake in feed crops grown at those farms.

Two manuscripts will describe results of the laboratory study in Activity 2, including details of leaching, fate, and transport data obtained in the lab study, plus groundwater modeling predicting the movement of various PFAS through soil to the water table. The second manuscript will compare PFAS in Minnesota biosolids to biosolids analyzed in a national study.

A manuscript related to Activity 4 was published earlier this year.

### Activity 1

All sampling and analysis is complete.

Soil was tested for PFAS at farm fields that:

- 1) Have never received biosolids,
- 2) Have received biosolids in previous years, but not the test year;
- 3) Received biosolids in the test year.

All tested biosolids contained PFAS.

Fields that received biosolids had a larger variety and higher concentrations of PFAS compounds than soils that never received biosolids.

Fields that did not receive biosolids did have a few PFAS detections at concentrations equivalent to global background concentrations documented in peer-reviewed literature. The likely source in these fields is atmospheric deposition. Test fields were co-located, so differences cannot be attributed to variations in atmospheric deposition.

Corn stover, soybeans, and rye were tested were grown on these fields, sampled during harvest, and analyzed for PFAS. PFAS uptake did occur in crops from all fields, but uptake was more pronounced in fields that received biosolids during the test year compared to fields that did not receive biosolids.

Corn stover in particular seemed to be amendable to PFAS uptake. Corn stover (silage) is used as livestock feed.

*(This activity marked as complete as of this status update)*

### Activity 2

Biosolid-amended soil columns wherein soils were amended with one of two biosolids were analyzed to assess rate of



movement of individual PFAS compounds through the soil column. The data were used in a groundwater model to assess movement through soils to the water column. Some key findings include:

The majority of total PFAS was retained in the biosolids amended soil over the course of the column experiments. Only 11% ( Biosolid C) and 44% (Biosolid E) of the total PFAS mass eluted from the soils.

Amendment with polyDADMAC (a stabilizing agent) led to a 74% reduction of the total PFAS mass released in the eluate compared to columns with Biosolid E-amended soil and no polyDADMAC. Although this reduction works as a proof-of-concept for use of stabilization approaches, the suitability of polyDADMAC as a stabilization method in agricultural settings is unknown.

Column modeling showed increasing sorption with increasing chain-length, and the potential for a slowly desorbing (non-labile) fraction, particularly for stronger-sorbing PFAS such as PFOS. In some cases it appears that desorption is kinetically limited, so desorption kinetics may need to be included in larger-scale models of biosolids leaching from agricultural fields through the vadose zone.

*(This activity marked as complete as of this status update)*

### **Activity 3**

This activity was previously marked complete.

*(This activity marked as complete as of this status update)*

### **Activity 4**

This activity was previously marked complete.

*(This activity marked as complete as of this status update)*

### **Activity 5**

This activity was previously marked complete.

*(This activity marked as complete as of this status update)*

### **Dissemination**

Multiple manuscripts are currently in progress. One manuscript will describe the field study. Two manuscripts will describe the lab study, including one manuscript detailing results of leaching tests and groundwater modeling, and another comparing PFAS in MN biosolids with biosolids analyzed in a national study.

Manuscripts will be submitted to peer-reviewed journals likely in October 2024. The time to publication after submission is variable depending upon the journal, but usually takes at least a few months from submission to publication.

# Status Update Reporting

## Status Update April 1, 2024

**Date Submitted:** April 2, 2024

**Date Approved:** July 2, 2024

### Overall Update

This project is on track to be completed on time. Activities 3, 4, and 5 are now complete. Work completed under Activity 4 was published in a peer-reviewed journal. All sample analysis under Activities 3 and 5 is complete. All samples under Activity 1 have been collected and have been analyzed or are in the process of being analyzed. The project has now moved into data interpretation and preparation for publication.

### Activity 1

During this period, the final soil and plant tissue samples from participating grower fields involving three Wastewater Treatment Plant were collected. The samples were sent to Eurofins and TTU for PFAS analysis. Subsamples of soil and plant tissue were also sent to the U of MN Research Analytical Lab for trace and essential elemental analysis. Results for PFAS in soil and tissue have been received and data are currently being summarized. Elemental analysis of soils has been completed, and results are being summarized. Elemental analysis of plant tissue is in progress, with results expected in the next few weeks. Final report preparation is in progress.

### Activity 2

- Completed extraction of all post column experiment soil samples for targeted analysis and total oxidizable precursor assay.
- Conducted mass balances on PFAS in biosolids-amended soil, column eluates, and post-column experiment soils
- Conducted re-analysis of pre column soils to resolve mass balance issues in a single column experiment
- Began modeling of columns using HYDRUS-1D
- Began drafting a manuscript focused on column experiments
- Received, extracted, and analyzed soil samples from UMN

### Activity 3

This activity was previously marked complete.

*(This activity marked as complete as of this status update)*

### Activity 4

The evaluation of PFAS treatment and destruction cost and effectiveness is complete and published in a peer-reviewed journal.

*(This activity marked as complete as of this status update)*

### Activity 5

All samples submitted to Eurofins have been analyzed and data has been received.

*(This activity marked as complete as of this status update)*

### Dissemination

Activity 4 results were published in Water Environment Research.

<https://onlinelibrary.wiley.com/doi/full/10.1002/wer.10975>

Final publication is uploaded.

Data is currently being interpretation and written up for Activities 1 - 4 and will be submitted for publication no later

than June 30, 2024. A corresponding MPCA report summarizing the findings and recommendations will also be submitted to LCCMR and posted on MPCA's website no later than August 14, 2024.

# Status Update Reporting

## Status Update October 1, 2023

**Date Submitted:** October 3, 2023

**Date Approved:** January 17, 2024

### Overall Update

The various components of this project are on track for completion. Activity 1 (2-year field study) is nearing the end of the 2nd year. The last set of samples will be collected in October and sent to Eurofins for analysis. Activity 2 (lab investigation) has made great progress. Leaching columns have been performed and data are nearing finalization. Activity 3 was checked as complete as we are no longer using SGS Axys as our outside analytical lab. Rather we are using Eurofins (Activity 5). That has proven to be an excellent partnership and PFAS data for 236 soil samples have been returned by the lab in a timely fashion. Activity 4 is nearing completion and has been very successful. That work resulted in a first-of-its-kind report detailing the cost and effectiveness of available PFAS treatment and destruction technologies. A journal manuscript has been submitted for publication pending acceptance.

### Activity 1

Soil and crop samples were collected from 9 fields with a varied history of biosolids application.

Samples were collected from three depths: 0-1, 1-2 and 2-3 feet. Samples were collected in April, June, and August. A final round of soil samples will be collected in October.

Each sample consisted of six subsample cores at each depth and combined into one sample. Samples from these sampling dates have been sent to Eurofins and TTU for PFAS analysis and results have been received. Samples were also sent to the UMN Research Analytical Lab (RAL) for pH, and organic carbon, nutrients, and metals analysis. Results are pending.

Crop samples were collected in September from each field. Corn grain and stover were collected from fields where biosolids were applied. Soybeans were collected from fields that did not receive biosolids this year. Corn, soybean, and rye were collected on fields with no history of biosolids. These samples will be sent to Eurofins and TTU for PFAS analysis. A subsample will also be sent to the UMN RAL for elemental analysis.

### Activity 2

- Processed data from transport columns packed with biosolids-amended soil
- A second column experiment was conducted with the same biosolids-amended soil to test to evaluate experimental replicability
- A third column experiment was conducted with the same biosolids-amended soil but further amended with polydadmac as a screening for stabilization.
- Targeted analysis and TOP was completed on all eluates, and on 3 sections per column of the post-elution soils.
- Completed analysis of the soybean samples sent to TTU
- Received, extracted, and analyzed soil samples from UMN

### Activity 3

SGS Axys submitted PFAS data for the soybeans collected in 2021. No further samples will be sent to SGS. All remaining samples will go to Eurofins (Activity 5).

*(This activity marked as complete as of this status update)*

### Activity 4

The project final report has been completed and is available on the MPCA website. The final report evaluates PFAS treatment and destruction alternatives in the media's of municipal wastewater, municipal biosolids, compost contact water and landfill leachate. Cost estimates were developed for the most prudent and feasible PFAS treatment and

destruction alternatives and these cost curves were used to develop statewide cost estimates. A manuscript was developed and submitted to a peer reviewed journal, no response back from the journal has yet been received.

#### **Activity 5**

Since April 1, 2023 236 soil samples have been analyzed for PFAS by Eurofins. Data for all submitted samples have been received and are currently being evaluated.

#### **Dissemination**

The results of this project were disseminated across social media, radio, TV and a MPCA press release and over 7 million media contacts were made about the projects results! The results of this study were presented at the premier national wastewater conference, three regional conferences and was presented to the nationwide meeting of Clean Water Act administrators. The results were even referenced at the US house during committee debate over PFAS legislation.

# Status Update Reporting

## Status Update April 1, 2023

**Date Submitted:** April 3, 2023

**Date Approved:** April 6, 2023

### Overall Update

Significant progress has been made toward the completion of this project. The Year One field study is complete and data analyses for the samples collected by UMN in Year One are underway. Texas Tech is finalizing the results of its bench-scale PFAS leaching tests, and has completed analyses of several field samples collected by UMN. SGS is nearly finished analyzing all samples it has received to date. An amendment will be submitted to switch labs due to a serious delay in sample turnaround times at SGS. Barr Engineering submitted a final draft of its report on treatment and destruction methods and is on track to complete their portion of the project on time and under budget.

### Activity 1

An alternative study plan was developed to accomplish the objectives of the project because the project could not go forward as planned. This activity was amended and approved by LCCMR. Three wastewater treatment plants (WWTP) were identified for participation in the revised study. For each WWTP, three grower fields have been selected (total of 9 fields/treatments):

1. Biosolids applied either this fall or spring
2. Biosolids applied at least three years ago but not within the last two years
3. No history of biosolids

Preparations are being made to collect soil samples from the fields as soon as the ground is thawed. In the meantime, biosolids from each WWTP have been collected and are being analyzed for PFAS compounds by TTU, as well as for nitrogen, other nutrients and 503 metals by MVTL.

A revised plan of work has been completed.

Soybeans from year one are currently at SGS Axys being analyzed for PFAS. Data pending.

### Activity 2

Since October 1, 2022, the team at Texas Tech University (TTU) has completed high resolution mass spectrometry (HRMS) suspect screening analysis of PFAS coupled with semiquantitative estimates of their concentrations in 6 biosolids and 2 compost samples. We additionally finalized implementation of total oxidizable precursor (TOP) analysis on those samples. The team received and analyzed 26 soils samples from the University of Minnesota which represented depths of 0-3' from 10 sampling locations. These soils are representative of the soils that are incorporated along with biosolids in column studies using biosolids-amended soils, which were also initiated. Specifically, soils were mixed with biosolids at agronomic rates calculated by the team at University of Minnesota. The team at TTU built and programmed a fraction collector for automated collection of soil eluants and packed soils in columns that are 5cm in diameter and 15 cm in length. Saturated, upflow column studies have been run to date for a total of ~20 days per study. Samples were collected and analyzed for PFAS, and PFAS breakthrough in the first study was observed. Analysis of results from the second study is ongoing.

### Activity 3

Equipment rinse blanks were analyzed for PFAS by SGS Axys. Soybeans are currently being analyzed by SGS Axys and data is pending. SGS Axys is currently experiencing significant delays in reporting data due to severe staffing shortages that have resulted in a backlog of as many as 3,000 samples. Current sample turnaround time is 20+ weeks, which is not a workable situation for this project. An amendment will be submitted to use a different analytical lab running the same

method for the remainder of the project. Previous budget expenditure was listed as higher than the current budget expenditure because funds were placed in a purchase order with the expectation that SGS would complete the work. However, with the extended turnaround times, the decision was made to adjust the current purchase order downward to reflect only the samples that can be analyzed by SGS at this time.

#### **Activity 4**

The project is on track to be completed on time and under budget. Barr completed the final report on currently available PFAS treatment and destruction technologies and their costs. Within the next six months, Barr and Hazen will disseminate the results of the report at two regional and one national wastewater conference. The final report results are being formatted for publication in a peer reviewed journal by end of the second quarter of 2023.

#### **Dissemination**

Barr Engineering will begin presenting its findings related to treatment and destruction of PFAS in wastewater treatment facilities and landfills in April 2023. Barr is currently working on publishing its results. Dissemination of data from the field and lab studies being conducted by UMN and TTU will take place at the completion of the study in early 2024 through June 2024.

# Status Update Reporting

## Status Update October 1, 2022

**Date Submitted:** January 30, 2023

**Date Approved:** February 9, 2023

### Overall Update

Overall, Activities 2 and 4 are on track and on schedule as planned. We have faced significant challenges in moving forward with Activity 1, and Activity 3 is linked directly to samples collected in Activity 1. In short, UMN leadership, after initially agreeing to the project and approving the contract and work plan, decided the risk of liability related to apply PFAS-containing biosolids to land at the Rosemount Research and Outreach Center (RROC) was too great a risk to allow the project to proceed. The MPCA Commissioner's Office and legal team have been working with UMN to try to find a way to move forward. UMN researchers and MPCA staff are also looking for alternative options that would allow the project to move forward and while aligning with the original intent and as well as the appropriate language.

### Activity 1

Biosolids from 5 wastewater treatment facilities and compost from 2 municipal composting sites were characterized for moisture, nutrient, metal, and PFAS content. Samples were sent to TTU for further analysis. Lysimeters were installed to the 6 ft depth at the RROC. Soil samples at RROC on May 10 to the 3 ft depth at 1 ft increments and submitted for PFAS analysis. Water samples were collected for initial PFAS analysis on May 27 and a second set was collected on August 11. Irrigation water, lab water and rinsate controls were also submitted for PFAS analysis. All PFAS analysis was performed by SGS labs. Soybeans sent to TTU and SGS for analysis 1/24/23.

Year 2 plan as of 1/24/23: 3 WWTPs will provide access to 3 plots each (total 9 plots) where biosolids have been applied. Soil and corn will be sampled and analyzed for PFAS according to original year one plans. Goal is to find 1 field with no history of biosolids, 1 with past application, 1 with current application for each of 3 facilities. No groundwater samples as it will not be possible to install lysimeters.

### Activity 2

- Finalized targeted analysis on original biosolids samples and repeated targeted analysis on larger batches of biosolids as well as background soils received from UMN.
- Completed total oxidizable precursor assay on the original biosolids samples.
- Trained the PhD student on the project in processing of high resolution mass spectrometry suspect screening data.
- Completed suspect screening analysis of the original biosolids.
- Trained the PhD student on the project on the operation of saturated column experiments.

### Activity 3

Biosolids, soil, shallow groundwater from lysimeters, and equipment rinse blanks, soybeans all collected in Activity 1 have been analyzed for PFAS. Additional equipment rinse blanks and shallow groundwater from lysimeters are being analyzed now.

Update as of 1/24/23: Samples to be collected in new Activity 1 plans will be analyzed by SGS for PFAS.

### Activity 4

The PFAS treatment and destruction portion of this project is progressing well and is on track to meet project goals on time. Barr (and their sub-contractor Hazen) have screened and ranked all available PFAS treatment and destruction technologies applicable to municipal wastewater treatment, municipal biosolids, compost contact water and landfill leachate. The most promising three technologies for each media have been selected for more detailed cost estimating and very preliminary results are available (Summary: Treating and destroying PFAS is logistically complicated, expensive



and requires so much energy). Additionally, Barr/Hazen have begun evaluating the potential for regionalization of PFAS and treatment destruction technologies in order to more cost-effectively treat and destroy PFAS at a statewide level. Barr/Hazen have developed a preliminary manuscript publication plan, have submitted one abstract to present at a regional conference and are planning on submitting two more abstracts to present at national conferences.

### **Dissemination**

The project is in process and dissemination plans have not changed at this time. Dissemination plans for Activity 4 remain as planned. Activity 1 has faced significant challenges as described in the overall summary. Activities 2 and 3 are linked to Activity 1. Completion and dissemination will depend upon the final decisions by UMN to allow Activity 1 to move forward, and whether a satisfactory alternative can be identified if UMN decides against allowing Activity 1 to resume as planned.

# Status Update Reporting

## Status Update April 1, 2022

**Date Submitted:** April 1, 2022

**Date Approved:** April 4, 2022

### Overall Update

To date, all contracts are in place with partners at the University of Minnesota, Texas Tech University, SGS Axys Analytical Services, and Barr Engineering. Overall, the project is on track to with our original goals and schedules.

### Activity 1

The field plot study plan is in place, including a quality assurance project plan (QAPP). Partnerships have been secured with wastewater treatment facilities and compost facilities. Initial biosolids and compost samples have been analyzed for PFAS, nutrients, and metals. Suction tube supplies have been purchased and are on track for installation in April 2022. Soil sampling will also take place in April. The original goal was November 2021, however, contracts were not yet in place and the soil was frozen. The delay in soil sampling does not affect or delay the field plot study.

*(This activity marked as complete as of this status update)*

### Activity 2

Initial biosolids and compost screening samples have been received by TTU and are in process. Planning for soil leaching column tests is in place. This activity is on track with all goals and milestones.

*(This activity marked as complete as of this status update)*

### Activity 3

Initial biosolids and compost samples have been analyzed by for PFAS. Data have been received and reviewed. This activity is on track with all goals and milestones.

*(This activity marked as complete as of this status update)*

### Activity 4

MPCA developed a competitive request for proposal to solicit contractors to investigate PFAS treatment and destruction technologies. Barr engineering was selected as the contractor. The contract was signed on March 4, 2022 and work has officially begun on the project. No money has been spent on this part of the project so far

*(This activity marked as complete as of this status update)*

### Dissemination

Dissemination is scheduled to occur at project completion and no later than June 30, 2024. This project is on track with this goal.