2019 Project Abstract
For the Period Ending June 30, 2023

PROJECT TITLE: Reducing Municipal Wastewater Mercury Pollution to Lake Superior

PROJECT MANAGER: Scott Kyser
AFFILIATION: Minnesota Pollution Control Agency
MAILING ADDRESS: 520 Lafayette Road
CITY/STATE/ZIP: St. Paul 55155
PHONE: 651-757-2665
E-MAIL: Scott.Kyser@state.mn.us
WEBSITE: Http://www.pca.state.mn.us
FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: M.L. 2019, First Special Session, Chp. 4, Art. 2, Sec. 2, Subd. 04h

APPROPRIATION AMOUNT: $250,000
AMOUNT SPENT: $ 250,000
AMOUNT REMAINING: $ 0

Sound bite of Project Outcomes and Results
This study identifies wastewater treatment technologies and mechanisms that municipalities can use to treat mercury to low-levels. Cost-effective wastewater technologies that treat solids can be leveraged to also treat mercury to low-levels and this information can be used to reduce discharged mercury which protects the environment and human health.

Overall Project Outcome and Results
Minnesota cities need guidance on the wastewater treatment technologies currently available to effectively reduce mercury pollution. To evaluate effective mercury treatment technologies, sixteen municipal wastewater plants water chemistry was analyzed in detail, and 154 municipal wastewater treatment plants were evaluated for generalized mercury removal performance. By analyzing a broad spectrum of wastewater technologies and chemistries, the mechanisms and treatment process that remove mercury are now better understood.

Mercury entering treatment plants binds to biological particles as they form during biological treatment and the intensity of biological treatment is positively related to the amount of mercury binding. Once mercury is bound to biological particles, effective removal of particulates (defined as <2-5 mg/L solids) is the most effective way to remove mercury to low levels (< 2 ng/L Hg). To achieve low-level mercury removal, conventional technologies such as trickling filters, conventional activated sludge and stabilization ponds are insufficient and advanced tertiary filtration technologies such as media filtration, cloth membranes and membrane bioreactors are necessary. The most reliable technologies to remove mercury and solids to low-levels were membrane bioreactors and cloth membranes. These findings are relevant to all municipal wastewater treatment plants, but unique considerations should be given to treatment system with high mercury loading from industrial users or when dissolved mercury is high.

This project is significant because it provides a first of its kind framework that engineers and cities can use to select and evaluate wastewater technologies to reduce their discharge of mercury to the environment in a cost-effective manner and protect water quality. This information will also allow policymakers and engineers to develop effective guidance documents to reduce mercury loadings from wastewater treatment plants in Minnesota and nationwide.

Project Results Use and Dissemination

The results of this study have been disseminated in three Minnesota wastewater conferences, one national conference and in a presentation by the MPCA to the federal Environmental Protection Agency. This information has been used by MPCA wastewater engineers to develop internal guidance documents about how to approve the plans and specifications of new wastewater treatment plants and there are plans to make this guidance document external. Wastewater managers in other states and sovereign tribal nations have expressed interest in the results of this study and plan to use it to develop mercury policy.

Environment and Natural Resources Trust Fund (ENRTF)
M.L. 2019 ENRTF Work Plan Final Report(Main Document)

Date of Submission: September 26, 2023

Final Report

Date of Work Plan Approval: June 5, 2019

Project Completion Date: June 30, 2023

PROJECT TITLE: Reducing Municipal Wastewater Mercury Pollution to Lake Superior

Project Manager: Scott Kyser

Organization: Minnesota Pollution Control Agency

College/Department/Division: Wastewater Effluent Limits

Mailing Address: 520 Lafayette Road

City/State/Zip Code: St. Paul 55155

Telephone Number: 651-757-2665

Email Address: Scott.kyser@state.mn.us

Web Address: Http://www.pca.state.mn.us

Location: Statewide, Northeast

Total Project Budget: $250,000

Amount Spent: $250,000

Balance: $ 0

Legal Citation: M.L. 2019, First Special Session, Chp. 4, Art. 2, Sec. 2, Subd. 04h as extended by M.L. 2022, Chp. 94, Sec. 2, Subd. 19 (c.1) [to June 30, 2023]

Appropriation Language: $250,000 the first year is from the trust fund to the commissioner of the Minnesota Pollution Control Agency to evaluate and summarize current technologies to help municipal wastewater plants in the Lake Superior basin save money and reduce mercury pollution to Lake Superior and other Minnesota waters.

M.L. 2022 - Sec. 2. ENVIRONMENT AND NATURAL RESOURCES TRUST FUND; EXTENSIONS. [to June 30, 2023]

I. PROJECT STATEMENT:

This technology transfer project helps the municipal wastewater plants in the Lake Superior basin reduce mercury pollution and save money.

Many Minnesota cities need guidance on the wastewater treatment technologies available to cost-effectively reduce mercury pollution. This project will produce a document that summarizes and evaluates mercury treatment technologies, allowing municipalities to select a mercury treatment strategy that appropriately meets their community's needs while also minimizing mercury pollution.

Every surface water of the state requires protection from mercury pollution, primarily because of human fish consumption but also because of risks to aquatic life. In the Lake Superior basin the protective water quality standard is 1.3 ng/L. In order to protect human health and aquatic life, all 16 municipal WWTPs in the Lake Superior basin will eventually (dependent on affordability) need to comply with mercury effluent limits protective of the 1.3 ng/L.

Some treatment systems in the Lake Superior basin successfully operate technologies that cost-effectively comply with mercury limits. (See partial list of technologies at right). Currently, each facility that is not meeting effluent limits needs to individually implement a costly compliance study when a permit is renewed. This project will compile technology transfer information into a single publically-accessible document, allowing wastewater facilities in the Lake Superior Basin to learn which technologies effectively reduce mercury pollution and save over $70,000 in engineering fees for individual compliance studies. Since treatment effectiveness depends on water characteristics, this study will visit and sample individual treatment plants to identify important differences in wastewater characteristics that impact mercury treatment. The results of this study will provide the MPCA with consistent information it could not otherwise obtain to help develop a more robust and systematic mercury permitting strategy for municipal WWTPs. Eventually, the results of this project will lead to *lower mercury inputs to Lake Superior and other Minnesota waters* by systematically identifying *cost-effective means to remove mercury from wastewater*.

Technologies
✓ **Dual Media Filters *(Aurora, Duluth)***
✓ **Solid Contact Clarifiers *(Silver Bay)***
✓ **Cloth Media Filters *(Central Iron Range)***
✓ **Cerium Precipitation *(Virginia)***
✓ **Ferric Precipitation *(Hibbing)***
✓ **Alum Precipitation (Hoyt Lakes, Babbitt)**
✓ **Membrane Bio-Reactors *(Gilbert)***
✓ **Stabilization Ponds (Biwabik)**

II. OVERALL PROJECT STATUS UPDATES:

First Update March 1, 2020

Research Update

The first phase of the project involved reviewing and analyzing the MPCA records of the Lake Superior Basin wastewater plants to understand each plant's performance, particularly in solids removal and mercury levels, prior to visiting the facility. We were particularly interested in correlating changes or break points observed in the data with the timeline of any facility and/or influent changes. The current focus of the literature review has been on water chemistry properties and mechanisms involving mercury complexation. Additionally, we are reviewing ligand extraction methods of previous studies to determine the best method for this project.

Over the fall of 2019, we conducted 10 wastewater treatment plant visits (10 in Lake Superior Basin + Detroit Lakes) and observed a variety of secondary and tertiary treatment systems. An additional site visits are being scheduled. Each site visit included a plant tour with the wastewater operator and/or manager, discussion of the plant schematics, overall plant performance and chemical use, and cost of tertiary/future tertiary treatment, where applicable. Grab samples were collected at each facility at the influent, effluent, and if applicable, post-secondary treatment locations for physical/chemical analysis. Samples collected for mercury

analysis followed clean hand/dirty hand procedure and were preserved in new bottles to minimize contamination.

Sample analysis currently consists of major ion characterization, solids concentration (TSS/VSS), total and soluble mercury concentration, dissolved organic carbon (DOC) concentration, and specific ultraviolet absorption (SUVA). We plan on returning to a select set of facilities to collect larger quantities of each sample for elemental analysis of dissolved organics and ligand extractions to further understand how mercury partitions within the dissolved fraction.

Project Management Update

In the first 9 months of the project, we hired a graduate student and undergraduate student at UMD to help work on the project. Our graduate student was serving as a teaching assistant in Fall 2019 and began working 20 hrs / wk on the project in January 2020. A subaward with Gustavus Adolphus College for analysis of mercury is approved and we expect results from the first round of mercury sampling to become available this spring. Contracts are also in place with labs at UMN to quantify major cations and anions as well as DOC.

As of 12/31/2019, $11,300 has been expended on Salaries and Fringe ($9,300) and Supplies ($2,000). We expect more progress on the project and an increased rate of expenses in the spring semester as our graduate student begins focusing more intentionally on the literature review, analysis of perliminary data, and planning for preliminary lab experiments.

Second Update September 1, 2020

During the Spring and summer of 2020, we made progress on summarizing demographics and industrial sources for communities involved in our study to understand their comparability and whether they are characteristic of most municipalities facing low Hg limits in the Lake Superior Basin. One problematic issue identified by municipalities in terms of meeting Hg effluent limits was bypass due to high flows under inflow and infiltration (I & I) and available information about I&I from initial interviews was compiled. A synthesis of Title 22 technologies certified for particle removal was compared with technologies present at the plants visited in our synoptic sampling. Next steps are to bring historical and new data on Hg and particles into this synthesis. We made some contacts for sampling and assessing the distribution of media at a few plants with the goal of understanding whether in-place media is consistent with that specified in the design.

In order to characterize the materials involved in binding Hg in wastewater, we began isolating particulate- and dissolved- organic matter (POM and DOM) from a few priority plants to quantify elemental composition (C, N, S). A framework for considering the plants and plant locations involved in the study has been developed which highlights a span of important characteristics across the range of conditions present in wastewater plants in the Lake Superior basin. We received additional wastewater from 4 plants judged to have characteristically different conditions (source water and unit operations) and began isolating DOM from the wastewater in the lab. Finally, preliminary laboratory results for mercury, particulates, and DOM were evaluated by binning data according to plant location or other important characteristics such as surface water source and tertiary treatment technology and making plots of parameters including total-, dissolved-, and particulate- mercury, solid-liquid partitioning strength, DOM vs. POM, and net removal efficacy for particulate and dissolved Hg.

Project Management update

We began executing contracts with partner labs for chemical analysis. Results from labs were checked against expectations and collated into spreadsheets for data synthesis and analysis. We reported preliminary lab results to the plants interested in the data from our visit last fall and arranged for sample

collection for follow-up testing at several plants. We hired a second graduate student to work on the project, she will start in September, 2020. As of 6/30/2020, $36,128 has been expended on the project for Salaries and Fringe ($27,827) and Supplies ($7,702) and Travel ($598). We continued and accelerated progress on the project and an increased rate of expenses in the Fall/Winter 2020 as two graduate students begins focusing more intentionally on the literature review, analysis of preliminary data, and lab experiments.

Third Update March 1, 2021

During the fall semester of 2020 and winter of 2021, we visited a several more wastewater plants to continue collecting samples for detailed mercury and carbon and sulfur chemistry in dissolved and solid phases of wastewater. We filtered and preserved water, and sent it to labs for analysis. The data that has come back from labs has been entered into spreadsheets and we have summarized the statistics of various water chemistry parameters.

MS student Geordee Spilkia had her Thesis proposal that summarized our interpretation of the data we have collected from Minnesota wastewater plants in the Lake Superior basin. The results suggest that Hg is mostly attached to particles in wastewater, but that a significant amount of Hg remains in the dissolved phase, assumedly attached to dissolved organic matter. Even at TSS concentrations less than 10 mg/L, Hg removal appears to continue with additional TSS removal down to below 2 mg/L TSS. The ratio of particulate Hg (per volume) to dissolved Hg (per volume) decreases significantly from influent to effluent, but the concentration of Hg on TSS (per mg TSS) was generally higher (relative to water) in the effluent compared to the influent. Similar trends were observed when particulate and dissolved concentrations were normalized for carbon and sulfur content (Hg per mg S), though a limited dataset currently constrains this interpretation based on elemental quantities.

Additional research on how the technologies involved in Hg removal in Minnesota relate to the framework implemented for water reuse in California's Title 22 water reuse guidance has been completed. The technologies recommended by the Title 22 have been assessed by their capabilities to remove turbidity of wastewater to a low enough level that fecal coliform is no longer prominent in the wastewater and the water can be safely reused. We are compiling information to evaluate a similar framework for the removal of TSS to a certain level as a means to "pre-screen" certain technologies for mercury removal efficacy. In the arrowhead region in Minnesota, we collected media from several plants with dual media filters. A size comparison of Title 22 recommended filter media to the media sampled is currently in progress.

We continued executing contracts with partner labs for chemical analysis. A second MS student, Kelsey Hogan, started to work on the project this fall semester. Her contributions will be on evaluating technologies for tertiary municiapal water treatment and their relation to TSS and Hg removal. As of 3/31/2021, $44,673 has been expended on the project for Salaries and 41,517 had been expended for Fringe. Supplies have totaled ($13,247) and Travel ($851). Mercury analysis has totaled $8,790. We have experienced some delays due to COVID travel restrictions, lack of student access to the lab, and delays in receiving results from partner labs, but anticipate progress on the project to continue during the Spring and Summer of 2021. We will transition to additional staff (undergrads, possibly postdoc

Fourth Update September 1, 2021

During the spring and summer of 2021, significant progress was made in interpreting the results of the wastewater samples collected for mercury analysis. MS student Geordee Spilkia successfully defended her thesis. A presentation on the impact of total suspended solids and dissolved organic matter was made by MS student Spilkia at the CSWEA 94th Annual Meeting (virtual) on May 18. A recording of the video presentation can be made available upon request. The key findings of the presentation were that targeting a 100% removal of solids is the most cost-effective strategy to treat mercury to low-levels and that managing dissolved organic carbon treatment is equally important.

Our second MS student, Kelsey Hogan, made several visits to collect water samples at wastewater plants in the Lake Superior basin. Hogan and Co-PI Adrian Hanson have also begun investigating the impact of filter media design and installation on mercury removal at several plants with dual-media filters. Equipment to collect filter media was used to gather samples and standard lab methods were used to measure the filter media characteristics. MS student Hogan has begun working with a very large historic dataset from MPCA using the statistical software R. Hogan has extracted the data relevant to understanding mercury removal in wastewater plants of the Lake Superior basin (including influent & effluent samples) and has made preliminary publication ready plots of several parameters analogous to the procedures that MS student Spilkia presented in her thesis.

We are currently drafting the first of two manuscripts for submission to a journal. The manuscript will detail the chemical mechanisms (binding coeffecients, organic matter, etc…) that govern low-level mercury treatment in the context of the 12 municipal wastewater treatment plants evaluated. The next steps for these dissemination activities will be discussed at scheduled bi-weekly meetings over the next few months.

Fifth Update March 1, 2022

During the fall and winter of 2021-2022, we made significant progress in summarizing and interpreting data from the MPCA's historic database. A major effort was spent merging the information from the MPCA's "Unit Operations Catalog" with historic data for mercury. Careful attention was paid to dividing wastewater plant's mercury data into categories with similar treatment technologies in order to lay the groundwork for an analysis of which technologies can reliably remove mercury to very low levels. MS student Kelsey Hogan made a presentation on the differences in mercury removal observed at treatment plants with different technologies at the CSWEA's 36th Annual Conference on the Environment (virtual) on November 9. She received several good questions from WWTP administrators and engineering consultants following the presentation.

Measurements of mercury and elemental composition of particles and dissolved organic matter were completed for samples collected from several WWTP. These samples will help to verify some trends we observed in earlier stages of the project and provide a more robust dataset for drawing conclusions. PI Johnson and Project manager Kyser met regularly over the past several months to consolidate the interpretation of MS Student Spilkia's thesis into a concise story in preparation for submission to a peer-reviewed journal. Additional venues to disseminate the information from the project to audiences at regional and national venues are being discussed.

A total of $216,441.19 has been spent on the project and $33,558.81 remains in the budget.

Update as of June 30, 2022:

Project extended to June 30, 2023 by LCCMR 6/30/22 as a result of M.L. 2022, Chp.94, Sec. 2, Subd. 19, legislative extension criteria being met.

Sixth Update as of September 1, 2022:

The last physical water samples were analyzed, processed and evaluated in the context of previously collected data. This analysis provides a more robust analysis and understanding of mercury wastewater treatment. The 2nd and final grad student (Kelsey Hogan) successfully defended her masters degree thesis on mercury wastewater treatment. Her thesis was written in the form a final report and analyzed the mercury treatment performance of of over 300 municipal wastewater treatment plants in Minnesota. Significant progress was made in turning the results of this study into the first peer-reviewed article of this study; the manuscript draft is about 90% complete. We expect to submit this manuscript for publication in November of 2023 and the second manuscript will likely be submitted in May 2023.

Dr. Nathan Johnson presented the results of this study at the American Chemical Society Fall 2022 meeting in Chicago Illinois. Dr. Nathan Johnson will present at the Minnesota Water Resource Conference in October 2023.

Seventh Update as of March 1, 2023:

Work has continued on developing a first manuscript for publication and the draft is approximately 90% complete. We are on target to finalize the final report and have two publications by the time this project is over. We will likely use the additional budget to pay for open access for the two journals.

Final Report as of June 30, 2023 (to be submitted before August 15, 2023):

Minnesota cities need guidance on the wastewater treatment technologies currently available to effectively reduce mercury pollution. To evaluate effective mercury treatment technologies, sixteen municipal wastewater plants relevant water chemistry were analyzed in detail, and 154 municipal wastewater treatment plants were evaluated for generalized mercury removal performance. By analyzing a broad spectrum of wastewater technologies and chemistries, the mechanisms and treatment process that remove mercury are now better understood.

Mercury entering treatment plants binds to biological particles as they form during biological treatment and the intensity of biological treatment is positively related to the amount of mercury binding. Once mercury is bound to biological particles, effective removal of particulates (defined as <2-5 mg/L solids) is the most effective way to remove mercury to low levels (< 2 ng/L Hg). To achieve low-level mercury removal, technologies such as trickling filters, conventional activated sludge and stabilization ponds are insufficient and advanced tertiary filtration technologies such as media filtration, cloth membranes and membrane bioreactors are necessary. The most reliable technologies to remove mercury and solids to low-levels were membrane bioreactors and cloth membranes. These findings are relevant to all municipal wastewater treatment plants, but unique considerations should be given to treatment system with high mercury loading from industrial users or when dissolved mercury is high.

This project is significant because it provides a first of its kind framework that engineers and cities can use to select and evaluate wastewater technologies to reduce their discharge of mercury to the environment in a cost-effective manner and protect water quality. This information will also allow

policymakers and engineers to develop effective guidance documents to reduce mercury loadings from wastewater treatment plants in Minnesota and nationwide.

III. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1 Title: *Evaluate 13 of the 16 wastewater plants and seven different treatment technologies in the Lake Superior Basin*

Description: We will inventory previously collected mercury measurements from Minnesota WWTPs and existing treatment technologies. MPCA and UMD engineers will visit WWTPs for basic site assessments of treatment processes targeting mercury removal and contact site and/or design engineers. Drawing on literature descriptions of solids-removal technologies and mercury adsorption, we will articulate a framework for evaluating the mechanisms of mercury removal and the associated technology costs. We will compile and evaluate this existing information to understand, at a basic level, which technologies are effectively removing mercury from MN wastewater. A site-specific evaluation of each WWTP in the table below will place their effectiveness in the context of known Hg removal mechanisms. The 13 selected wastewater plants encompass the common types of wastewater treatment and will allow for a translation of the results of this study to a broad array of municipal wastewater plants in Minnesota and nationally. A statistical evaluation of data across all the evaluated WWTPs will provide a basis for evaluating Hg removal more broadly. *Key outcomes of this activity will be* 1) systematic documentation of effective mercury removal processes in MN; and 2) cost estimates associated with treatment technologies for mercury removal. These cost estimates will be useful for both facility capital expense planning as well as MPCA permit evaluations.

Wastewater Class	**Facility**
Dual Media Filters	Aurora, Duluth, Two Harbors
Alum Precipitation	Babbit, Hoyt Lakes, Mountain Iron
Cerium Precipitation	Virginia
Ferric Precipitation	Hibbing
Cloth Disk Filter	Central Iron Range
Sand Filter	Eveleth
Solid Contact Clarifiers	Silver Bay
Membrane Bio Reactors	Gilbert
Stabilization Ponds	Biwabik

ACTIVITY 1 ENRTF BUDGET: $122,000

Outcome	**Completion Date**
1. Review of existing mercury wastewater treatment performance: statistical analysis of existing Hg removal data from MN WWTP in relation to compliance with wastewater effluent limits.	August 2020
2. Evaluate and document costs for mercury treatment technologies: white-paper-style description of Hg removal mechanisms including cost and effectiveness	December 2020
3. Recommendations providing a basis for guidance document: site-specific evaluation of Hg removal at 13 WWTP	June 2021

Activity 1: Second Update September 1, 2020

Hired second grade student who will focus on evaluating data. Evaluated compliance data for all WWTPs in the study. Reviewed literature on mercury treatment.

Activity 1: Third Update March 1, 2021

Evaluated costs of wastewater treatment in the context of title 22. Statistical mechanisms of mercury removal evaluated. Site-specific evaluations of wastewater treatment evaluated.

Activity 1: Fourth Update September 1, 2021

An in-depth and in-person analysis of the 12 municipal wastewater treatment plants has been completed. All 12 plants have been visited at least twice and sampled at least twice. In-depth discussions with the wastewater operators have occurred to better understand the operation of their plant. An understanding of cost of design has been initiated.

Activity 1: Fifth Update March 1, 2022

Measurements of mercury and elemental composition of particles and dissolved organic matter were completed for samples collected from several WWTP. These samples will help to verify some trends we observed in earlier stages of the project and provide a more robust dataset for drawing conclusions. PI Johnson and Project manager Kyser met regularly over the past several months to consolidate the interpretation of MS Student Spilkia's thesis into a concise story in preparation for submission to a peer-reviewed journal. Additional venues to disseminate the information from the project to audiences at regional and national venues are being discussed.

Update as of June 30, 2022:

Project extended to June 30, 2023 by LCCMR 6/30/22 as a result of M.L. 2022, Chp.94, Sec. 2, Subd. 19, legislative extension criteria being met.

Activity 1: Sixth Update as of September 1, 2022:

The final measurements of mercury and elemental composition were sampled and analyzed over the summer. These samples made the previously visualized trends even more robust and allowed for deeper conclusions about the role the suspended solids treatment plays in low-level mercury treatment. PI Johnson and Project manager Kyser met regularly over the past several months to consolidate the interpretation of MS Student Spilkia's thesis into a concise story in preparation for submission to a peer-reviewed journal. An individualized analysis of each wastewater treatment plants performance in the Lake Superior watershed was performed.

Activity 1: Seventh Update as of March 1, 2023:

Nathan Johnson hired an undergraduate part time to visualize some of the final results of the project. This resulted in some nice figures and a better story for future publications. All data has been collected and being assembled into the final report and future publications.

Activity 1: Final Report as of June 30, 2023 (to be submitted before August 15, 2023):

A statistical analysis of existing mercury wastewater treatment performance was performed for every wastewater treatment plant (n=154) that had available data and analysis of discharge limit compliance occurred. A white paper style analysis of Hg removal mechanism including cost-effectiveness happened, cloth disk membranes were the most cost-effective way to remove mercury to low-levels. The performance of every

wastewater treatment plant in the Lake Superior Basin (two declined to participate) was analyzed and their mercury removal performance was analyzed.

ACTIVITY 2 Title: *Targeted sampling of mercury treatment technologies to develop a treatment design theory*
Activity 2 will measure mercury and water characteristics in 13 of the 16 wastewater from WWTPs in the Lake Superior basin, encompassing a variety of representative treatment technologies. This in-depth sampling will complement existing compliance monitoring data in order to identify how mercury responds to different treatment technologies. Water samples from key locations in WWTPs treatment chain will be separated in the lab into 4 different "phases" to understand how water characteristics change the treatability of mercury. Additional laboratory investigations will elucidate which "phases" of mercury are conducive to enhanced removal with candidate treatment technologies. *A key outcome from this activity will be* the documentation of critical water chemistry parameters that impact mercury removal for each evaluated technology. These tests will ensure that treatment technologies are transferrable across different water types.

ACTIVITY 2 ENRTF BUDGET: $118,000

Outcome	Completion Date
1. Mercury chemistry samples from all MN treatment technology types: synoptic sampling of plants with different water chemistry	February 2021
2. Evaluate key water characteristics impacting mercury removal performance: identify how Hg "phases" depend upon water chemistry	February 2021
3. Document providing basis for evaluating transferability: synthesis of key Hg removal mechanisms and water chemistry parameters for effective removal technology	June 2022

Activity 2: Second Update September 1, 2020

During the Spring and summer of 2020, we made progress on summarizing demographics and industrial sources for communities involved in our study to understand their comparability and whether they are characteristic of most municipalities facing low Hg limits in the Lake Superior Basin. One problematic issue identified by municipalities in terms of meeting Hg effluent limits was bypass due to high flows under inflow and infiltration (I & I) and available information about I&I from initial interviews was compiled. A synthesis of Title 22 technologies certified for particle removal was compared with technologies present at the plants visited in our synoptic sampling. Next steps are to bring historical and new data on Hg and particles into this synthesis. We made some contacts for sampling and assessing the distribution of media at a few plants with the goal of understanding whether in-place media is consistent with that specified in the design.

Activity 2: Third Update March 1, 2021

Additional research on how the technologies involved in Hg removal in Minnesota relate to the framework implemented for water reuse in California's Title 22 water reuse guidance has been completed. The technologies recommended by the Title 22 have been assessed by their capabilities to remove turbidity of wastewater to a low enough level that fecal coliform is no longer prominent in the wastewater and the water can be safely reused. We are compiling information to evaluate a similar framework for the removal of TSS to a certain level as a means to "pre-screen" certain technologies for mercury removal efficacy. In the arrowhead region in Minnesota, we collected media from several plants with dual media filters. A size comparison of Title 22 recommended filter media to the media sampled is currently in progress.

Activity 2: Fourth Update September 1, 2021

The synoptic sampling of WWTPs has been completed and final analytical results are trickling in. The key phases of mercury have been confirmed to be the total and dissolved phases. The strength of binding of mercury to particulate matter is particularly important and the aging and ionic composition of the organic matter is central. These results are very promising and provide strong clues as to the best technologies capable of treating mercury cost-effectively.

Activity 2: Fifth Update March 1, 2022

During the fall and winter of 2021-2022, we made significant progress in summarizing and interpreting data from the MPCA's historic database. A major effort was spent merging the information from the MPCA's "Unit Operations Catalog" with historic data for mercury. Careful attention was paid to dividing wastewater plant's mercury data into categories with similar treatment technologies in order to lay the groundwork for an analysis of which technologies can reliably remove mercury to very low levels. MS student Kelsey Hogan made a presentation on the differences in mercury removal observed at treatment plants with different technologies at the CSWEA's 36th Annual Conference on the Environment (virtual) on November 9. She received several good questions from WWTP administrators and engineering consultants following the presentation.

Update as of June 30, 2022:

Project extended to June 30, 2023 by LCCMR 6/30/22 as a result of M.L. 2022, Chp.94, Sec. 2, Subd. 19, legislative extension criteria being met.

Activity 2: Sixth Update as of September 1, 2022:

Final chemical analysis of the data was completed and this allowed for the report to start to finalized the conclusions of the report. It has become clear that the report will have conclusive positive results about the ways municipal wastewater treatment plants can achieve low-level mercury limits. MS student Kelsey Hogan defended her thesis. Dr. Nathan Johnson presented the results of this study at the American Chemical Society Fall 2022 meeting in Chicago Illinois. Dr. Nathan Johnson will present at the Minnesota Water Resource Conference in October 2023.

Activity 2: Seventh Update as of March 1, 2023:

No significant changes from last time. Continued progress on final report writing and manuscript submission with a target completion date of June 30, 2022.

Activity 2: Final Report as of June 30, 2023 (to be submitted before August 15, 2023):

The key mechanisms and wastewater parameters that control of mercury removal at wastewater treatment plants were identified. Mercury entering treatment plants binds to biological particles as they form during biological treatment and the intensity of biological treatment is positively related to the amount of mercury binding. Once mercury is bound to biological particles, effective removal of particulates (defined as <2-5 mg/L solids) is the most effective way to remove mercury to low levels (< 2 ng/L Hg). To achieve low-level mercury removal, technologies such as trickling filters, conventional activated sludge and stabilization ponds are insufficient and advanced tertiary filtration technologies such as media filtration, cloth membranes and membrane bioreactors are necessary. The most reliable technologies to remove mercury and solids to low-levels were membrane bioreactors and cloth membranes. These findings are relevant to all municipal wastewater

treatment plants, but unique considerations should be given to treatment system with high mercury loading from industrial users or when dissolved mercury is high.

The report results were compiled and key treatment mechanisms were identified. Wastewater plants around Minnesota and nationwide should be able to use this information to reduce their mercury loading.

ACTIVITY 3 Title: *Technology transfer communication and outreach*

We will disseminate the findings from the proposed study to Minnesota wastewater engineers, managers and operators through public presentations and publications in peer-reviewed journals. *The key outcome from this activity will be* presentations at local and statewide wastewater conferences.

ACTIVITY 3 ENRTF BUDGET: $10,000

Outcome	Completion Date
1. Present results to MN conference for wastewater operators & engineers	June 2022
2. Preparation of manuscripts for peer-reviewed publication	June 2022

Activity 3: First Update March 1, 2020

Over the fall of 2019, we conducted 10 wastewater treatment plant visits (10 in Lake Superior Basin + Detroit Lakes) and observed a variety of secondary and tertiary treatment systems. An additional site visits are being scheduled. Each site visit included a plant tour with the wastewater operator and/or manager, discussion of the plant schematics, overall plant performance and chemical use, and cost of tertiary/future tertiary treatment, where applicable. Grab samples were collected at each facility at the influent, effluent, and if applicable, post-secondary treatment locations for physical/chemical analysis. Samples collected for mercury analysis followed clean hand/dirty hand procedure and were preserved in new bottles to minimize contamination.

Sample analysis currently consists of major ion characterization, solids concentration (TSS/VSS), total and soluble mercury concentration, dissolved organic carbon (DOC) concentration, and specific ultraviolet absorption (SUVA). We plan on returning to a select set of facilities to collect larger quantities of each sample for elemental analysis of dissolved organics and ligand extractions to further understand how mercury partitions within the dissolved fraction.

Activity 3: Second Update September 1, 2020

Due to Covid-19, we didn't make any serious plans for presenting the work at conferences. We're going to wait another year to present at conference when it is safer. The goal is still to produce a product in the form of a manuscript, that is an ongoing process. Students are formatting their work to do that.

Activity 3: Third Update March 1, 2021

MS student Geordee Spilkia had her Thesis proposal that summarized our interpretation of the data we have collected from Minnesota wastewater plants in the Lake Superior basin. Abstract submitted to the 2021 MN Water resources conference for presentation – no results as of yet.

Activity 3: Fourth Update September 1, 2021

A presentation on the impact of total suspended solids and dissolved organic matter was made by MS student Spilkia at the CSWEA 94th Annual Meeting (virtual) on May 18. A recording of the video presentation can be made available upon request.

Activity 3: Fifth Update March 1, 2022

MS student Kelsey Hogan made a presentation on the differences in mercury removal observed at treatment plants with different technologies at the CSWEA's 36th Annual Conference on the Environment (virtual) on November 9. She received several good questions from WWTP administrators and engineering consultants following the presentation.

Update as of June 30, 2022:

Project extended to June 30, 2023 by LCCMR 6/30/22 as a result of M.L. 2022, Chp.94, Sec. 2, Subd. 19, legislative extension criteria being met.

Activity 3: Sixth Update as of September 1, 2022:

Dr. Nathan Johnson presented the results of this study at the American Chemical Society Fall 2022 meeting in Chicago Illinois. Dr. Nathan Johnson will present at the Minnesota Water Resource Conference in October 2023.

Activity 3: Seventh Update as of March 1, 2023:

We have targeted the journal Science: Water Research and Technology for publication and open access journal fees are about $3000. We will use the remaining funds from this portion of the project to make sure the results are available in a open access journal.

Activity 3: Final Report as of June 30, 2023 (to be submitted before August 15, 2023):

The results of this study have been disseminated in three Minnesota wastewater conferences, one national conference and in a presentation by the MPCA to the federal Environmental Protection Agency. This information has been used by MPCA wastewater engineers to develop internal guidance documents about how to approve the plans and specifications of new wastewater treatment plants and there are plans to make this guidance document external. Wastewater managers in other states and sovereign tribal nations have expressed interest in the results of this study and plan to use it to develop mercury policy.

A manuscript has been prepared for submission to the journal Science: Water Research and Technology and will be submitted in August of 2023. This manuscript details the chemical mechanisms that remove mercury at municipal wastewater treatment plants. There are plans to prepare another article for submission on the statistical analysis of 154 municipal wastewater treatment plants.

IV. DISSEMINATION:

Description:
We will disseminate the findings from the study to wastewater engineers, managers and operators through public presentations and publications in peer-reviewed journals. The key outcome from this activity will be presentations at two local and statewide wastewater conferences.

The final report will be available on the MPCA webpage and will be used to inform MPCA mercury wastewater treatment permitting policy.

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

No updates to report yet on dissemination because the project just started and no significant results to report yet.

Second Update September 1, 2020

We have applied to present at two conferences but have yet to hear back. Presenting at conference is a little weird this year because of COVID-19 and most conferences have moved towards all digital. It's possible that the project spending in this section will be a little light going forward because travel and lodging costs associated with conferences are going to be non-existent. TBD ¯_(ツ)_/¯

Third Update March 1, 2021

No official word on conferences yet. Covid has made attending conferences strange and difficult. Hopefully conferences in 2021 will be better!

Fourth Update September 1, 2021

Plans are being made to present at a conference this year and the first draft manuscript is being submitted for publication.

Fifth Update March 1, 2022

The first manuscript of this project will be submitted within the next three months.

Update as of June 30, 2022:

Project extended to June 30, 2023 by LCCMR 6/30/22 as a result of M.L. 2022, Chp.94, Sec. 2, Subd. 19, legislative extension criteria being met.

Sixth Update as of September 1, 2022:

Final report nearing completion

Seventh Update as of March 1, 2023:

Final report complete

Final Report as of June 30, 2023 (to be submitted before August 15, 2023):

The results of this study have been disseminated in three Minnesota wastewater conferences, one national conference and in a presentation by the MPCA to the federal Environmental Protection Agency. This information has been used by MPCA wastewater engineers to develop internal guidance documents about how to approve

the plans and specifications of new wastewater treatment plants and there are plans to make this guidance document external. Wastewater managers in other states and sovereign tribal nations have expressed interest in the results of this study and plan to use it to develop mercury policy.

A manuscript has been prepared for submission to the journal Science: Water Research and Technology and will be submitted in August of 2023. This manuscript details the chemical mechanisms that remove mercury at municipal wastewater treatment plants. There are plans to prepare another article for submission on the statistical analysis of 154 municipal wastewater treatment plants.

V. ADDITIONAL BUDGET INFORMATION:

A. Personnel and Capital Expenditures

Explanation of Capital Expenditures Greater Than $5,000: None expected

Explanation of Use of Classified Staff: None expected

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

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

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: ---	Divide total contract hours by 2,080 hours in 1 yr = TOTAL FTE: 2.6

VI. PROJECT PARTNERS:

A. Partners outside of project manager's organization receiving ENRTF funding
University of Minnesota Duluth

B. Partners outside of project manager's organization NOT receiving ENRTF funding

None

VII. LONG-TERM- IMPLEMENTATION AND FUNDING:

Reducing mercury discharges to Minnesota waterbodies is part of the MPCA's long term strategy to reduce pollution. The MPCA undertakes routine measurements for mercury in wastewater discharges, surface waters, and fish and these ongoing measurements will be ultimately be used to evaluate the effectiveness of the proposed work in reducing mercury pollution from wastewater plants. The results of this study will be incorporated into regular discussions with wastewater treatment facilities in the Lake Superior Basin and throughout the state. This study will not need long term funding past this funding cycle.

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, 2023

IX. SEE ADDITIONAL WORK PLAN COMPONENTS:

A. Budget Spreadsheet
B. Visual Component or Map
C. Parcel List Spreadsheet
D. Acquisition, Easements, and Restoration Requirements
E. Research Addendum

Attachment A:
Environment and Natural Resources Trust Fund
M.L. 2019 Budget Spreadsheet
Legal Citation: M.L. 2019, First Special Session, Chp. 4, Art. 2, Sec. 2, Subd. 04h
Project Manager: Scott Kyser
Project Title: 58B Reducing Municipal Wastewater Mercury Pollution to Lake Superior
Organization: MPCA
Project Budget: $250,000
Project Length and Completion Date: 4 years, June 30, 2023
Today's Date: September 25th, 2023

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits)	$ 179,127	$ 179,127	$ -
Principal Investigator: UMD Proffessor: $17,258 (74.5 % salary, + 25.4 % benefits) 3.5 % FTE each year for 3 years			
Co- Principal Investigator: UMD Proffessor $14,159 (74.5 % salary, 25.4 % benefits) 2 % FTE each year for 3 years			
UMD Graduate Students: Research Assistant $128,176 (54 % salary, 9.6 % benefits, 36.4 % tuition remission) 50 % FTE each year for 3 years			
Undergraduate Laboratory Assistant: Research Assistantship $19,534 (96 % salary, 4 % benefits) 25 % FTE each year for 3 years			
Professional/Technical/Service Contracts	$ 26,915	$ 26,915	$ -
Contract with laboratory to perform mercury analysis. Laboratory with capability of specialized Hg			
Contract with lab to perform routine water chemistry (DOC & cations/anions). Lab TBD. $7,665			
Equipment/Tools/Supplies (Supplies for UMD laboratory analysis)	$ 38,219	$ 38,219	$ -
Sampling bottles and sampling supplies ($7,750)			
Water filtration tubing and pump ($2,469)			
Consumable lab supplies for Hg and carbon analysis: ($28,000)			
Capital Expenditures Over $5,000			
	$ -	$ -	$ -
Fee Title Acquisition			
	$ -	$ -	$ -
Easement Acquisition			
	$ -	$ -	$ -
Professional Services for Acquisition			
	$ -	$ -	$ -
Printing			
Travel expenses in Minnesota	$ 5,739	$ 5,739	$ -
- 10 regional WWTP * 75 miles/trip * 2 trips/year * 0.545/mile = $2,515			
- Trips to two conferences to present - $1,715			
- Trips to St Paul: 3/yr * 300/trip * 0.545/mile = $1,509			
travel expenses and conference cost	$ -	$ -	$ -
Other			
	$ -	$ -	$ -
COLUMN TOTAL	$ 250,000	$ 250,000.00	$ -

OTHER FUNDS CONTRIBUTED TO THE PROJECT	Status (secured or pending)	Budget	Spent	Balance
Non-State:		$ -	$ -	$ -
State:		$ -	$ -	$ -
In kind:		$ -	$ -	$ -

PAST AND CURRENT ENRTF APPROPRIATIONS	Amount legally obligated but not yet spent	Budget	Spent	Balance
Current appropriation:		$ -	$ -	$ -
Past appropriations:		$ -	$ -	$ -