Taconite Industry Mercury Reduction Overview

Annual Statewide Mercury TMDL Implementation Plan Oversight Committee Meeting

October 1, 2019

wq-iw4-02h5

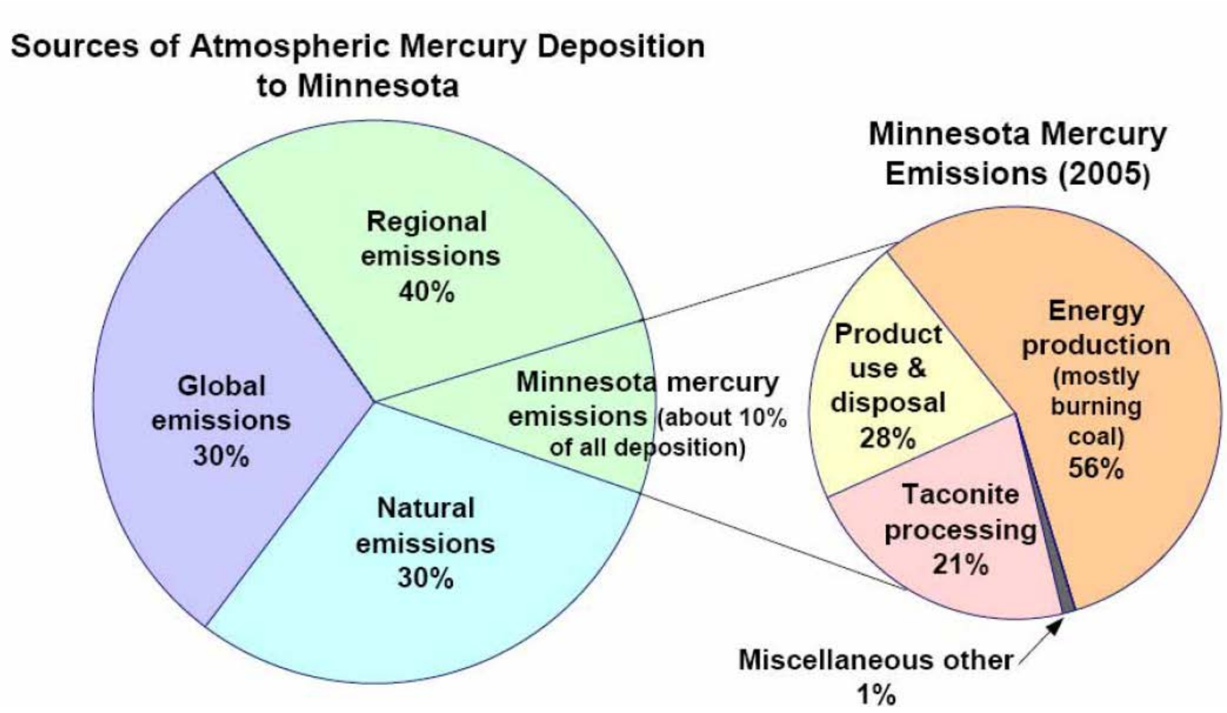
Meeting Agenda

- Background on Minnesota Mercury TMDL and Rule
- History of Taconite Mercury Reduction Research
- Technology Evaluation Process
- Summary

Background on Minnesota Statewide Mercury TMDL and Rulemaking

Background on Hg TMDL and Rulemaking– Mercury Source Contributions

- "Mercury can be carried great distances on wind currents before it is brought down to earth in rain and snow. As a result, **about 90%** of the mercury deposited on Minnesota comes from other states and countries."



Source: MPCA Mercury Source Summary Publication, p-p2s4-06, February 2013

Background on TMDL Implementation Plan – U.S. Mercury Source Reductions Needed

4.6 Out-of-state Sources

As noted in the Statewide Mercury TMDL and shown in Figure 1, about 90% of the mercury that is deposited on Minnesota originates as air emissions from sources outside of the state. While some of this mercury comes from naturally occurring sources, the MPCA estimates that the remaining sources of human-caused deposition are about evenly split between sources from within North America (mostly the United States) and the rest of the world. To fully implement the TMDL, these sources too must reduce their contribution to Minnesota deposition by about 93% from 1990 levels.

While the responsibility for reducing these out-of-state emissions lies with others and is not the focus of this implementation plan, stakeholder-recommended strategies call for the MPCA to work with other states' environmental agencies, the EPA, other federal agencies, the Minnesota congressional delegation, and others as appropriate to establish policies to achieve emission reductions from sources in the United States and other countries. The objectives of this work shall be to establish policies and programs that result in significant emission reductions and consistency of policies among states and countries. This goal includes consistent policies among all U.S. states as well as international requirements, and the international transfer of successful technologies and programs.

Reference – Interaction Needed with EPA and States to meet TMDL Target - From Section 4.6 of the 2009 TMDL Implementation Plan

Table 12 Summary of Reduction Targets

Sector	1990 Emissions	2000 Emissions	Target #1	Target #2	Target #3
Energy	1,667	1,834	675	470	313
Material Processing	723	758	550	280	138
Products	8,881	1,045	475	350	338
All sources	11,272	3,638	1,700	1,100	789

For Target #1, when the national emission reductions are expected to reach 65% from 1990, the state target of 1700 pounds [Target #1] must be reached. If the state target is not met, regulatory tools will be developed as necessary to reach target goals, unless achieved national reductions exceed their target and obviate the need for some of the state reductions.

For Target #2, when the national emission reductions are expected to reach 80% from 1990, the state target of 1100 pounds [Target #2] must be reached. If the state target is not met, regulatory tools will be developed as necessary to reach target goals, unless achieved national reductions exceed their target and obviate the need for some of the state reductions.

For Target #3, when the national emission reductions are expected to reach 93% from 1990, the state target of 789 pounds [Target #3] must be reached. If the state target is not met, regulatory tools will be developed as necessary to reach target goals, unless achieved national reductions exceed their target and obviate the need for some of the state reductions.

Reference – Minnesota TMDL Reduction Targets Based on Achieved National Emission Reductions – From Section 11.4.2 of the 2007 TMDL

Background on Hg TMDL and Rulemaking – Mercury Emissions Reduction Target

- **Pre-TMDL Voluntary Reductions:**
  - 2,901 lb of mercury in devices removed from taconite plants between 1990 and 2005
  - 2009 TMDL Implementation Plan goal for the statewide category of "Sale, Use & Disposal of Mercury-containing Products" was to reduce emissions by 88 lbs.

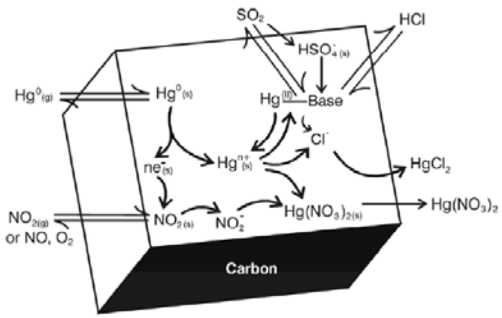
- **MPCA TMDL (2007) and TMDL Implementation Plan (2009):**
  - Voluntary collaboration with stake holders
  - Research and testing of potential technologies
  - The 2007 TMDL goal of "achieving the 75% mercury reduction target will incorporate the concept of Adaptive Management." The technology must:
    - "be technically and economically feasible;"
    - "not impair pellet quality;" and
    - "not cause excessive corrosion to pellet furnaces and associated ducting and emission-control equipment"

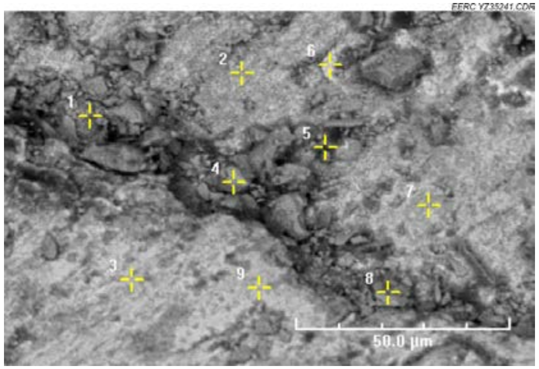
- **Minnesota Mercury Air Emission Reduction and Reporting Rules (2014)**
  - By 12/31/2018, taconite facilities are required to evaluate Hg reduction technologies capable of achieving a 72% reduction by 1/1/25. If no technology exists, the facilities may submit an alternative reduction plan.
  - Evaluations incorporated the concept of Adaptive Management:

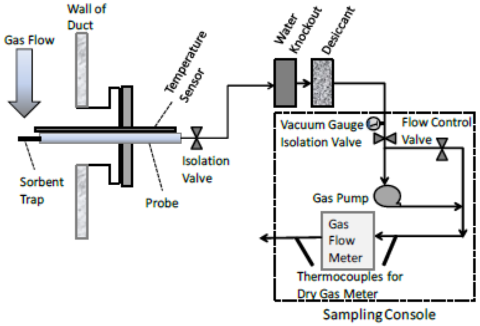
    "The MPCA and its stakeholders have always viewed the strategy as objectives or criteria for the companies when making decisions in the development of control technologies; that as research continues and as technology improves, <u>each decision will evaluate whether the technology meets the companies objectives related to cost, pellet quality, and the potential for furnace corrosion</u>."

    Source: MPCA Response to Comments on Mercury Rule (7/14/14)

History of Mercury Reduction Research and Testing







History of Taconite Mercury Research and Testing (1997- 2018)

1. Pre-TMDL Implementation Plan DNR Research (Pre-TMDL research), 1997 - 2009
2. Phase I – Minnesota Taconite Mercury Control Advisory Committee (Phase I), 2009 - 2012
3. Phase II – Extended Testing of ACI (Phase II), 2013
4. Gore Technology Demonstrations (GORE™), 2014 - 2015
5. Site-specific Pilot Testing and Evaluations, 2016 – 2018

History of Research–
1. Pre-TMDL Implementation Research

Date Tested	Method
1997	Mercury Emissions from Taconite Pellet Production
2001	Mercury Removal from Induration Off Gas by Wet Scrubbers
2003	Distribution of Mercury in Taconite Plant Scrubber Systems
2004	Mercury Capture at Taconite Processing Facilities
2003	Mercury Release from Taconite Processing
2005	Mercury Transport in Induration Furnaces
2005	Mercury Vaporization Characteristics of Taconite Pellets
2005	Mercury Chemistry of Iron Oxides during Taconite Processing
2005	Fate of Mercury Captured by Wet Scrubber
2006	Mercury Oxidation by NaCl Addition to Greenball
2007	Mercury Oxidation by Focused Halide Injection
2007	In-Scrubber Mercury Oxidation
2007	Mercury Separation from Scrubber Solids
2008	High Energy Dissociation Technology (HEDT) for Mercury Oxidation and Capture
2009	Demonstration of Mercury Capture in Fixed Bed
2009	Assessment of Potential Corrosion Induced by Bromine Species
2007-2009	Mercury Control from Bromine Injection into Taconite Induration Furnaces

History of Research –
2. Phase I – Technology Screening

- Minnesota Taconite Mercury Control Advisory Committee (MTMCAC) formed in 2009
  - industry, state, and academic technical experts
- Funded by six taconite facilities, MN DNR Environmental Cooperative Research Program (ECR), and the US Environmental Protection Agency - Great Lakes Restoration Initiative (EPA-GLRI)
- MTMCAC selected six projects for evaluation
  - Focused on testing of activated and brominated carbon sorbents
- Research conducted between 2010 and 2012

History of Research –
2. Phase I – Technology Screening

Project Number	Technology Tested or Project Description	Testing Contractor
1*	Activated carbon injection and scrubber additives	University of North Dakota
2	Activated carbon injection	Albemarle
3	Fixed activated carbon beds	ADA - Environmental Solutions
4*	Activated carbon injection with a baghouse	Energy & Environmental Research Center
5	Activated carbon addition to greenballs	University of North Dakota
6	Corrosion potential of bromide injection	Energy & Environmental Research Center

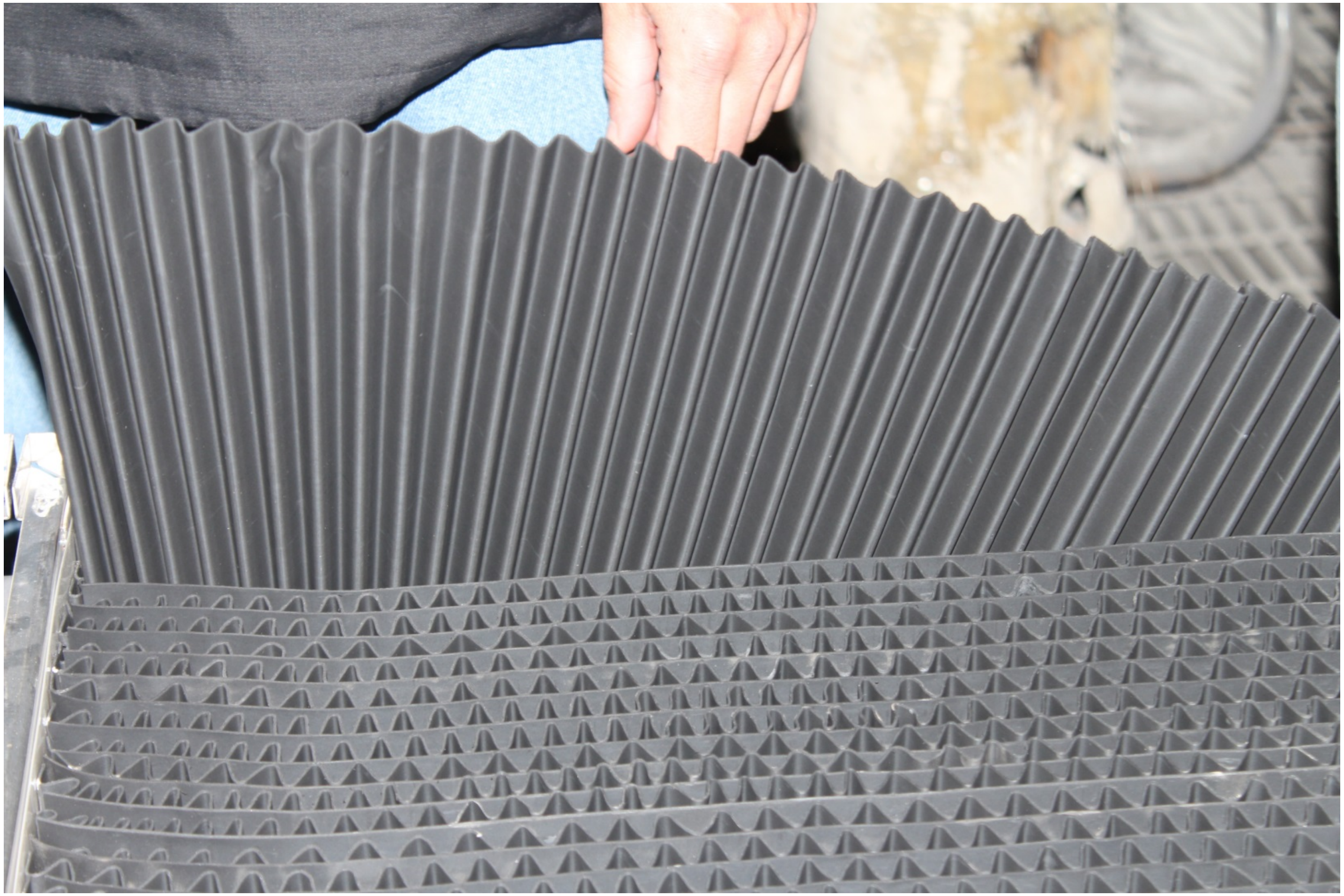
* Results from these tests were the most promising and were further evaluated

History of Research –
3. Phase II – Extended Testing of ACI

- Phase II on-site testing began in October 2012 and was funded by the 6 taconite facilities.
- Some mercury reduction observed with ACI, but did not consistently meet the 72% reduction objective.
- Increased particulate-bound mercury emissions were observed, i.e. potential for increased local deposition.
  - *"Ultimately, the M30B method results show that ACI reduces gaseous mercury but that a substantial amount of particle bound mercury is formed during ACI injection and some of this particulate fraction escapes the wet scrubber and is emitted at the stack."*
  - *"Despite the four criticisms mentioned above, the reports do provide relatively strong evidence that the re-emission of particulate bound mercury is a pervasive issue that must be solved before brominated activated carbon injection methods can be considered suitable for the taconite industry."*

  Reference: 10/31/14 Letter from Michael Berndt, MNDNR, to Hongming Jian, MPCA, re: Review of Phase II Hg Control Reports.
- Although no facility exceeded particulate matter (PM) limits, significantly higher PM emissions were observed.

History of Research –
4. GORE™



History of Research –
4. GORE™

- Extended in-plant testing occurred for 1-3 months at
  - ArcelorMittal Minorca
  - United Taconite
  - U. S. Steel Minntac
- Some mercury reductions occurred, but varied significantly
- Mercury reduction efficiency decreases with decreasing SO_2 concentrations, i.e. when utilizing natural gas instead of coal.
- The facilities observed increased differential pressure and plugging in the air handling ducts and scrubbers (similar to testing at Xcel Sherco). May require additional membrane washing.
- The membrane washwater contained high levels of sulfate and mercury and would require additional wastewater treatment systems

History of Research –
5. Site Specific Testing and Gap Filling

- The taconite facilities conducted additional site-specific testing of ACI, halide injection, and scrubber solids removal.
- Testing was conducted to gather additional data for facilities to finalize their Mercury Reduction Plan evaluations including:
  - Hg removal rates,
  - Technical feasibility,
  - Adverse environmental impacts, and
  - Corrosion effects.
- Testing included refined data collection and stack testing methodology.

Mercury Reduction Plan Evaluations

Best Available Mercury Reduction Technology

Mercury Reduction Plan - Best Available Mercury Reduction Technology

- The operating taconite facilities conducted an evaluation of potential mercury control technologies (control equipment, processes, materials or work practice standards) to determine if a 72% mercury reduction is technically achievable.
- Similar process as other regulatory technology evaluations:
  - Best Available Retrofit Technology (BART) analysis - utilized by EPA and MPCA
  - Best Available Control Technology (BACT) analysis – utilized by EPA and MPCA
  - Mercury Best Available Control Technology (MBACT) analysis, utilized by Idaho
- Incorporated adaptive management criteria as included in 2009 TMDL Implementation Plan and 2014 Mercury Rule development.
  - the control technology must be technically feasible;
  - it must be economically feasible;
  - it must not impair pellet quality; and
  - it must not cause excessive corrosion to pellet furnaces or associated ducting or emission control equipment

Mercury Reduction Plan - Potential Control Technologies Evaluated

Control Technology		Basis of Technology
Mercury Capture by Wet Scrubber and Solids Disposal		Oxidized mercury can be captured in wet scrubbers. To prevent captured mercury from re-entering the system, the scrubber solids need to be disposed.
Mercury Oxidation for Capture by Wet Scrubber	Halide Injection	Halide injection increases mercury oxidation and subsequent capture.
	High Energy Dissociation Technology (HEDT)	Generation of reactive halogens at high temperatures outside of the process prior to injection downstream of the furnace, which aid in mercury oxidation and subsequent capture.
Activated Carbon Injection		Injection of powdered activated carbon (PAC) adsorbs mercury and is then removed by particulate control equipment. Several injection locations and PAC types, including brominated PAC (which also aids mercury oxidation), have been tested.
Fixed Bed Carbon Adsorption		Flue gas from the wet scrubber is routed through a carbon bed which adsorbs the mercury.
GORE^{TM}		GORE^{TM} technology is a fixed sorbent polymer composite, which doesn't require injection of powder sorbents or chemicals, capturing both elemental and oxidized mercury in particulate and gas phase.

Mercury Reduction Plan - Best Available Mercury Reduction Technology

- Step 1 – List potentially available control technologies
- Step 2 – Is the technology commercially available?
- Step 3 – Does the technology operate without impairing pellet quality or production?
- Step 4 – Does the technology cause excessive corrosion to pellet furnaces, associated ducting or emission control equipment?
- Step 5 – Does the technology present unacceptable environmental impacts?
- Step 6 – Can the technology consistently meet the 72% reduction per the rule?
- Step 7 – Is the technology cost effective?
- Step 8 – Determine BAMRT
- Step 9 – If Steps 1-7 are not satisfied, conduct Alternative Mercury Emissions Reduction evaluation

Summary – Taconite Mercury Technology Evaluation

Sources of Hg in Mn

- 90% of Hg deposition in Minnesota originates from international and out-of-state sources
- 10% of Hg deposition from Minnesota sources, with Taconite contributing approx. 2%
- Taconite furnaces emit primarily elemental Hg which does not deposit locally

Hg – R&D

- Taconite R&D efforts on-going since 1997
- Millions of Taconite dollars invested in R&D as well as thousands of staff hours
- Detailed engineering evaluations performed using EPA BACT/BART-like top-down analysis

Results

- Each Taconite facility submitted detailed reports in December 2018 (~1,400 pages each)
- 72% reduction via control technology is not technically achievable
- Some incremental reductions are feasible (e.g., NSM 72% red.; scrubber solids removal at Minorca)

Context

- Taconite furnaces are unique and not comparable to EGUs
  - Indurating furnaces have a high volume of hot gases with low concentrations of Hg
- Reduction technology using ACI or oxidizing chemicals in scrubbers would cause adverse environmental impacts through local deposition
- Reducing mercury emissions must be addressed on a national and global level. Even if Hg emissions from all Minnesota sources were eliminated, the TMDL goal (remove Hg impairments from MN waters) would not be achieved

Conclusion