Protecting Human Health and the Environment on Sioux Tribal Lands: A Partnership of EPA and Tribal EPD

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Abstract

Through environmental sampling performed by EPA and Cheyenne River Sioux Tribe Environmental Protection Division personnel, mercury contamination in managed pond systems in South Dakota was characterized and risk reduction recommendations were made to protect subsistence fisherman and their families. However, scientific uncertainty remains with regard to the mechanisms of methylation and demethylation within the pond systems, as well as the means of mitigating the biomagnification occurring in aquatic food webs across the region. In a previous model evaluation of the Regional Mercury Cycling Model (R-MCM), it was discovered that models based on the current science underpredict both total mercury concentrations as well as the percent of total mercury present as methylmercury. This suggests that current models are not adequately capturing the processes governing the total loading of mercury to the system or the transformation processes governing methylmercury production. Continued monitoring of managed farm ponds is focused on reducing temporal and spatial uncertainty in model predictions, as well as uncertainty associated with model parameters such as mercury loading (atmospheric and watershed-based) and transformation. To address these key areas of scientific uncertainty, a model comparison is also underway, involving a new Excel spreadsheet-based application based on the science in the Mercury Report to Congress and expanded to include the current state-of-science.

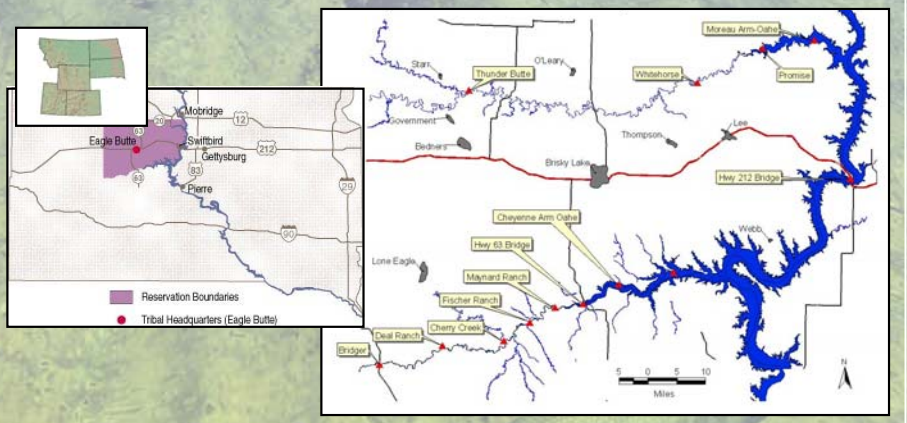
Experiences in the First Year

- Loss of three ponds due to excessive evaporation during drought.
- Winter fishkills
- Loss of groundwater piezometers and benthic Hester-Dendy
- Birds love to perch on new structures: atmospheric samplers

Second Year Changes

- Three ponds selected for more intensive sampling effort
  - Spatial sampling of mercury in sediments increased
  - More frequent temporal sampling of ponds in Spring during flooding
- Fish population and community sampling continue with shocking
  - Ideal sample a range of size classes and smaller prey fishes
- Improved design for groundwater samplers
- Analysis for elemental mercury in surface water (Hg0) for complete speciation
- Tribal Assistance Program: education and outreach

Cheyenne River Basin Sample Stations



Spreadsheet-based Ecological Risk Assessment for the Fate of Mercury

Watershed Characteristics

	Value	Units	Notes
Watershed Area (as Contributing Area)	4,266,478	m2	
Percent Impervious	40%	--	
Percent Wetland	20%	--	
Percent Riparian	0%	--	
% with Known Contaminated Soil	0%	--	
Percent Upland	40%	--	1
Lake Area	186,235	m2	
Epilimnion Depth	2	m	
Hypolimnion Depth	0.1	m	2
Anoxic Hypolimnion	NO	--	3
Hydraulic Residence Time	1	yr	4
Inflow	3.72E+05	m3/yr	
Outflow	3.72E+05	m3/yr	
Water pH	9	--	
Epilimnion Water Temp	27	C	
Hypolimnion Water Temp	4	C	
Air Temp	35	C	
Annual Precipitation	43	cm/yr	
DOC Epilimnion	24	mg/L	
DOC Hypolimnion	24	mg/L	
Color (as PtCo)	0	PtCo	5
Trophic Status	Eutrophic		6

Inflow Mercury Concentrations		
Hg0	0	g/m3
HgII	0	g/m3
MeHg	0	g/m3

Exposure Concentrations

		Predicted Concentrations	
Epilimnion	Hg0 Filtered	0.11	ng/L
	HgII Filtered	0.00	ng/L
	MeHg Filtered	0.00	ng/L
	HgT Filtered	0.12	ng/L
	Hg0 Unfiltered	0.11	ng/L
	HgII Unfiltered	0.86	ng/L
	MeHg Unfiltered	0.05	ng/L
	HgT Unfiltered	1.02	ng/L
Hypolimnion	Hg0 Filtered	0.04	ng/L
	HgII Filtered	0.00	ng/L
	MeHg Filtered	0.00	ng/L
	HgT Filtered	0.04	ng/L
	Hg0 Unfiltered	0.04	ng/L
	HgII Unfiltered	0.90	ng/L
	MeHg Unfiltered	0.06	ng/L
	HgT Unfiltered	1.01	ng/L
Sediment	Hg0 porewater	0.04	ng/L
	HgII porewater	0.00	ng/L
	MeHg porewater	0.00	ng/L
	HgT porewater	0.04	ng/L
	Hg0 bulk	0.00	ug/g
	HgII bulk	0.00	ug/g
	MeHg bulk	0.00	ug/g
	HgT bulk, dry	0.001	ug/g
Fish	Trophic Level 3	0.09	ug/g
	Trophic Level 4	0.36	ug/g

Rate Constants

Process	Media	Value	Units
Methylation	Epilimnion	0.001	per day
	Hypolimnion	0.001	per day
	Sediment	0.001	per day
Demethylation	Epilimnion	0.0001	per day
	Hypolimnion	0.001	per day
	Sediment	0.002	per day
Biotic Reduction	Water Column	0.03	per day
Photo-Degradation (MeHg --> Hg0)	Water Column	0.002	per day per E.m2-day
Photo-Reduction (HgII --> Hg0) Visible Light	Water Column	0.03	per day per E.m2-day
Photo-Reduction (HgII --> Hg0) UV-B	Water Column	28.25	per day per E.m2-day
Photo-Oxidation (Hg0 --> HgII) UV-B	Water Column	58.85	per day per E.m2-day
Dark Oxidation	Water Column	1.44	per day

Trophic Level 1 BAF: Phytoplankton	Phyto	4.94E+05
Trophic Level 2 BAF: Zooplankton	Zoo	1.61E+06
Trophic Level 2 BAF: Benthos	Benthos	2.48E+06
Trophic Level 3 BAF: Fish	Fish	1.60E+06
Trophic Level 4 BAF : Fish	Fish	6.80E+06

Livestock ponds pose challenges for mercury models

- High pH, high conductivity, hyper-eutrophic, high surface area to volume ratio
- High degree of water level fluctuations within year– possible "reservoir effect"
- Ponds retain surface flows with little to no flushing or outflow
- Shallow and well-mixed, no evidence of stratification in Summer
- Losses through volatilization (evasion) likely to be high
- Particulate and dissolved organic matter critical to speciation in model
- Comparison of D-MCM and Excel spreadsheet model necessary
  - Access database of all samples to date

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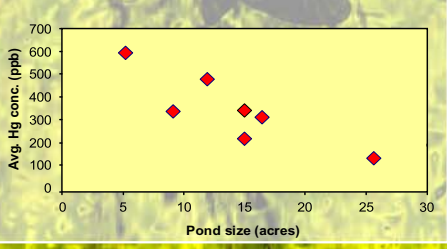
What We Know Now

- Regional study completed for nine ponds (500 square miles of land)
  - Each pond is an island
  - Variability in mercury between ponds and through seasons is high
  - Western ponds received much less rainfall
- Ponds flood to capacity in Spring and dry considerably though Summer
- Water column methylmercury concentrations are high
- Mercury atmospheric inputs are higher than anticipated
- Mercury storage in sediments not found
- Smaller ponds pose greater risk to human health due to higher average body burdens

Piscivores - Common Sportfish



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