Remediation of mercury in contaminated lakes: The Newcastle Reservoir demonstration project

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OUTLINE

♦ Problem
♦ Pre-deployment monitoring/modeling
♦ Pump deployment and operation
♦ Post deployment results
Hg IN UTAH RESERVOIRS

Problem • Pre-pumping • Model results • Remediation
Utah regulatory agencies can’t do much about controlling atmospheric sources of mercury, but may be able to do something about managing Hg methylation.


**Problem**

- **Pre-pumping**
- **Model results**
- **Remediation**

**Does lake thermocline depth affect methyl mercury concentrations in fish?**

- Decreased volume of water with high methyl mercury
- Decreased surface area of low oxygen sediment
DECREASE IN METHYL Hg

(Rask and others, 2011)

Fish tissue

(70-80 mm)

Thermocline pumping

Hals

Vako

MeHg, ng/L

Before pumping

During/after pumping

0.6

0.5

0.4

0.3

0.2

0.1

0.0

2004

2005

2006

2007

Exp.

Control

Exp.

Control

Exp.

Control

Exp.

Control

Water

(epilimnion)

X = 0.54

X = 0.16

Problem • Pre-pumping • Model results • Remediation
July 2010

NCR-2

MEHg:THg (MASS)

0.0 0.2 0.4 0.6 0.8 1.0

DO, IN MG/L

NCR-3

MEHg:THg (MASS)

0.0 0.2 0.4 0.6 0.8 1.0

DO, IN MG/L

NCR-4

MEHg:THg (MASS)

0.0 0.2 0.4 0.6 0.8 1.0

DO, IN MG/L

Problem  ♦  Pre-pumping  ♦  Model results  ♦  Remediation

MeHg:THg = 0.28

Outflow gage

NCR-2

NCR-3

NCR-4

Newcastle Reservoir

Inflow gage
NUTRIENT POOL AT DEPTH

July 2010
Site NCR-2

CHLOROPHYLL A, IN \( \mu \text{G/L} \)

0 10 20 30

CHLOROPHYLL a
Temperature

Orthophosphate
Ammonia
Nitrate + Nitrite

July 2010
Site NCR-2

CONCENTRATION, IN MG/L

0.00 0.05 0.10 0.15 0.20

Outflow gage
NCR-2

Newcastle Reservoir

Inflow gage
PO$_4$ = 0.09; NO$_3$ = < 0.04

Problem ✦ Pre-pumping ✦ Model results ✦ Remediation
Hg SPECIES IN SEDIMENTS

Problem

Pre-pumping

Model results

Remediation

Great Salt Lake wetlands

Naftz and others, in review

Typical ratio in most sediments
(Ulrich and others, 2001)

Hg total

Hg methyl

Anoxic sediments

2.6%

2.7%

2.8%

2.1%
Hg SPECIES IN SEDIMENTS

Great Salt Lake wetlands

Naftz and others, in review

Typical ratio in most sediments
(Ulrich and others, 2001)

Enterprise

Newcastle

Problem • Pre-pumping • Model results • Remediation

Hg total

Hg methyl
SESTON PROFILES (Hg$_{\text{total}}$) July 2010

Plankton net

Problem • Pre-pumping • Model results • Remediation

MeHg$_{\text{water}}$ = 0.16 ng/L

MeHg$_{\text{water}}$ = 0.53 ng/L

MeHg$_{\text{water}}$ = 0.20 ng/L

MeHg$_{\text{water}}$ = 0.40 ng/L

MeHg$_{\text{water}}$ = 0.21 ng/L

MeHg$_{\text{water}}$ = 0.62 ng/L

MeHg$_{\text{water}}$ = 0.86 ng/L

MeHg$_{\text{water}}$ = 4.50 ng/L
Model Objectives

- Simulate pumping of near bottom water to surface
- Simulate area of influence under different (1) pump rates; (2) pump positions; and (3) reservoir outflows
BOUNDARY CONDITIONS

- 15-minute weather station data (Enterprise, Utah)
- Daily water-level data (regression model)
- Inflow from Pinto Creek gage (15-minute data)
- Hourly reservoir outflow data
- Pump locations and rates inserted at various model grid points

Problem  ♦  Pre-pumping  ♦  Model results  ♦  Remediation
PUMPING INFLUENCE

No wind, pump inlet in bottom layer, reservoir outlet at bottom, vertical pipe inflow and outflow?

Position pump to the NE and migrate up reservoir (take advantage of bottom water removal from reservoir outflow)?

Position closer to reservoir outflow for Hg removal?

Problem • Pre-pumping • Model results • Remediation
Wind forcing off 1500 gpm pump rate
Surface layer

Simulation time

Wind forcing on 1500 gpm pump rate
Surface layer

Simulation time

Dye concentration

20 day simulation

20 day simulation

Problem • Pre-pumping • Model results • Remediation
Profile “fences”

Solar pump

THERMOCLINE IMPACTS

Profile “fences”

Solar pump

20-day pumping cools upper water column and warms lower water column relative to “pump off” simulation

20-day pumping cools upper water column and warms lower water column relative to “pump off” simulation

Problem ♦ Pre-pumping ♦ Model results ♦ Remediation
Hg REMOVAL PROJECT

- Solar-powered pump (SolarBee, Inc.) 1,500 gpm
- Reverse water flow (bottom → up)
- Oxygenate bottom water, photodegrade MeHg, export nutrients, and ??

Problem • Pre-pumping • Model results • Remediation
SOLAR PUMP INSTALLED
July 2011

Assembly
Launch
Positioning
Attachment

Problem
Pre-pumping
Model results
Remediation
SOLAR PUMP OPERATION

- 1,500 gpm total flow
- Operates 24-7, 365 days/year
- Remove algae from outflow

- Small surface footprint
- Low-noise operation
- Hazard light and perimeter chain
- Sulfide odor

Problem • Pre-pumping • Model results • Remediation
THERMISTOR STRING

15-min sampling intervals

Thermistor string, Newcastle Reservoir

Problem • Pre-pumping • Model results • Remediation
POST-INSTALL TEMPERATURE
Temperature increase near bottom

Pump impacts thermal gradient

Problem ♦ Pre-pumping ♦ Model results ♦ Remediation
• **Low redox water moving to surface**

• **Penetration of higher ORP water near pump**

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**Problem**  •  **Pre-pumping**  •  **Model results**  •  **Remediation**