ENHANCED NATURAL REMOVAL OF CYANIDE AND AMMONIA IN TAILINGS LAKE AND ZONE 2 PIT LAKE AT COLOMAC, NWT

REMTECH 2006

by

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Laboratory Analysis:
ALS Environmental
Taiga Environmental
PRESENTATION OVERVIEW

- Treatment Of Mine Water At Colomac
- Description of Monitoring Programs
- Results & Treatment Evaluation for Tailings Lake and Zone 2 Pit
HISTORY

- 1990 Mine operations begin
- 1997 Ore processing & milling ceases
- 1999 Water transfers begin
- 1999 INAC assumes responsibility of abandoned site
- 2001 Construction of diversion ditches begins
- 2002 Water treatment begins
- 2004 Remediation Plan approved by MWL&W Board
ISSUES

• Water Management
  Tailings Lake expected to exceed licenced freeboard limit by 2006

• Water Quality
  Natural degradation of cyanide and related compounds insufficient
- Add phosphate for ENR
  2002: 11 tonnes of MAP
  2003: 9 tonnes of MAP
- Divert runoff to increase storage time
- Discharge Fuscum Lake annually
- First discharge of TLk via north spillway: 2008 - 2009
WATER TRANSFER 1999 – 2002

3.4 M m³ from TLk to Z2P
Diversion Ditches
Construction 2001 to 2004
WATER TREATMENT OPTIONS

Enhanced Natural Removal (ENR)

- Preferred Option
- Phosphorus Deficient
- Bench Scale Tests

Pilot Plant

- Alkaline Chlorination
- Rotating Biological Contactor
ENR LAB BENCH TEST Oct 2001
MAP fertilizer on melting ice
Staging of MAP
PHOSPHATE ADDED BY HELICOPTER AT BREAKUP
Zone 2.0 Pit  Water Treatment & Management Strategy

- Add phosphate for ENR
  
  2002: 22 tonnes of MAP  
  2003: 9 tonnes of MAP  

- If required, induce artificial circulation in 2006  

- Reach regulated level in 2011  
  Seepage to Baton 2014
Colomac Technical Advisory Committee
ENR Monitoring Program

• **Physical**: lake limnology
  
  (depth profiles – Temp, DO)
  
• **Biological**: algae identification, biomass and diversity
  
• **Chemical**: major ions, nutrients, metals
  
  targets: cyanide, ammonia
Challenges - TCA is filling up; water is of unacceptable quality; exposed tailings.

North Station

Middle Station

Tailings Lake
Zone 2 Pit Sample Locations

- Z2P-S
- Z2P-NW

Pieter’s Monitoring Raft
Twice under ice

Monthly open water
Dissolved Oxygen % vrs Depth TLK 2005

Physical Monitoring indicated:

- lake stratifies in summer:
  - active, warm, oxygenated epilimnion
  - cold, anoxic hypolimnion
- strong wind can overturn or cause mixing
- Mixing is important to supply P to the surface where it is needed for SCN & NH$_3$-N removal
- lake is anoxic in winter
Biological Monitoring Component

- Physical changes in water – colour, clarity
- Algal productivity levels (biomass)
- Algae identification & diversification
Predominant algal assemblage in TLK 2003-04 (typical of wastewaters)

- small flagellate and colonial Chlorophyta (top row)
- large heterotrophic flagellates (left)

Cryptophyte dominated 2005
Similar biomass range

Predominated by green algae

2005 increase in flagellates (Cryptomonads)
TLK-M
MICROZOOPLANKTON & HETEROTROPHS

→ LOWER ABUNDANCE IN 2005
First Appearance of Macrozooplankton in 2005

Daphnia pulex

Cyclops vernalis
Monitoring Water Chemistry

Monthly sampling of the water column indicated:

• Trends in contaminant removal from season to season

• Greatest removal rates related to biological activity in the epilimnion (above thermocline layer)
THIOCYANATE REMOVAL in TLK

Thiocyanate (mg/L)

Epilimnion Thiocyanate
Hypolimnion Thiocyanate

SCN mg/L
THIOCYANATE REMOVAL

\[ \text{SCN}^- + 2\text{H}_2\text{O} + \frac{5}{2}\text{O}_2 \rightarrow \text{SO}_4^{2-} + \text{HCO}_3^- + \text{NH}_3 \]

Biological oxidation
Produces ammonia
AMMONIA REMOVAL in TLK

Epilimnion
Hypolimnion

5 mg/L license limit

Indian and Northern Affairs Canada
Affaires indiennes et du Nord Canada
AMMONIA-N REMOVAL MECHANISMS

1) DIRECT UPTAKE BY ALGAE

2) MICROBIOLOGICAL NITRIFICATION

\[ \text{NH}_4^+ + \frac{3}{2} \text{O}_2 \rightarrow 2\text{H}^+ + \text{H}_2\text{O} + \text{NO}_2^- \]

\[ \text{NO}_2^- + \frac{1}{2} \text{O}_2 \rightarrow \text{NO}_3^- \]

3) MICROBIOLOGICAL DENITRIFICATION (anoxic)
Nitrate to nitrogen gas
Nutrient Recycling At Bottom 2m of TLk
Sedi trap
Recovery
SEDIMENT TRAP RESULTS

Nutrient Removal From Sedimentation in TLk

- Tot-N
- Tot-P
- VSS (%)

2004
2005

Tonnes

Values for 2004 and 2005 are shown in the bar chart.
Removal Of Total Phosphorus - TLk

- Licence 2008: 0.22
- MAP additions

Graph showing TP mg/L from Jul-01 to Sep-06.
Removal Of Total Metals - TLk

TCu ug/L
TAs ug/L

As 40
Cu 10
Tailings Lake Discharge to North Wetlands

Discharge channel

L Shaped Lake

2004.10.07
SUMMARY FOR TAILINGS LAKE

• ENR with P addition + Water Management was an cost effective and low risk treatment

• Water Quality of Tailings Lake has improved to within licence limits established for discharge in 2008/09
NEXT STEPS for TLk

- Continue to monitor ENR process until discharge in 2008/09
- If necessary, supply depleted phosphorus to active algae layer from lake bottom with a pumping system
- Modify the Tailings Lake discharge wetland to optimize wetland treatment and attenuation
Zone 2 Pit - OVERVIEW

ENR process
Zone 2 Pit morphology and limnology
Artificial circulation option
Design of Zone 2 Pit destratification system
Preliminary results
Next steps
COMPARISON OF TREATED LAKES

Tailings Lake

- 75%
- 12 m deep
- 4 M m3 volume

TLk mixes completely

Zone 2 Pit

- 20%
- 105 m deep
- 7.9 M m3 volume

Z2Pit does not mix
SURFACE BLOOM IN ZONE 2 PIT
ALGAL BIOMASS & MAJOR TAXA 2004-05

Green algae

flagellates (Dinophyta)
ZONE 2 PIT - ISSUES

• SCN and NH$_3$-N remain despite ENR
• Z2P water elevation predicted to reach Baton Lake level in 2011
• Action required if water quality not suitable when Z2P reaches 0.5 m within Baton Lake
Zone 2 Pit Morphology & Limnology

- high depth to length ratio (15.7 ha)
- occurrence of relatively saline water
- lack of natural outlet (220 years retention time)
- protection from prevailing winds
- sampling data indicate the Pit rarely mixes below 50 m, usually ~ 22 m
- no oxygen in lower layers, high concentrations of ammonia and thiocyanate
- Under-ice circulation driven by salt freeze-out
Depth profiles of SCN from Z2PNW Stn 2005

![Graph showing depth profiles of SCN from Z2PNW Stn 2005.](image-url)
Hardware Of Artificial Circulation System
Colomac Zone 2 Pit, NWT Artificial Circulation System for Water Quality Remediation

Compressed Air Destratification System
Diffusers set at 60 m depth

Baton Lake
INSTALLATION OF DIFFUSER INTO RAFT

CHECKING FOR LEAKS IN THE HOSE SECTION JOINS.
Circulation System in Zone 2 Pit

S Diffuser Raft

NW Diffuser Raft

Pieter’s Monitoring Raft

BATON LAKE
Startup – July 12 – Both Diffusers
22 DAYS AFTER STARTUP
Zone 2 Pit Sonar Transect

Figure 6  Raw sounder transect east to west past south diffuser raft

<3m to raft
Preliminary Results

- Temperature
- % Dissolved Oxygen saturation
- SCN
- NH$_3$-N
- NO$_3$-N
Temperature from dataloggers stationed at Pieters Monitoring Raft 2005
Figure 3a  Colomac Zone 2 Pit, Summer, 2006

Aerator ON July 12 10:00

Aerator OFF July 19–23

T dataloggers, Pieters raft 2006 (UBC)
Temp change July 12 – 19, 2006 from Temp dataloggers, Pieters Raft (UBC)
DO Profiles in Zone 2 Pit - 2006

Figure: Percent Dissolved Oxygen Profiles over time in Zone 2 Pit. The graph shows the depth (m) on the y-axis and percent dissolved oxygen on the y-axis. Various dates are indicated on the graph, corresponding to different dissolved oxygen profiles.
Zone 2 Pit – Thiocyanate Inventory

21 July 06, 6.4 mg/L
24 Aug 06, <0.5 mg/L

Apr 06, 40.7 tonnes
Zone 2 Pit – Ammonia Inventory

Ammonia-N Inventory (tonne)

- 21 Jul 06, 17.2 mg/L
- 24 Aug 06, 17.5 mg/L
- 12 Sept 06, 13.0 mg/L
## Z2 Pit Results for NO₃-N (mg/L)

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NEXT STEPS for Z2P

• Review and analyze 2006 data
• Conduct under ice sample program for DO and water chemistry
• Meet with ENR Scientific Advisory Committee and decide on 2007 treatment schedule