Solving mine drainage problems at the Soudan Mine

The final answer

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Minnesota’s oldest and deepest iron mine
- Began in 1882
- Ended 1962

US Steel donated mine to state
- DNR developed a state park 1965

Becomes Paul’s career project
1994
The Problem

- Mine never had a discharge permit
  - Began in 1882
  - Ended 1962
- DNR applied for permit early 90’s
- Neutral drainage
  - Elevated copper and cobalt
    - Total copper ~ 0.1-1 mg/l
      - standard 0.020 mg/l
    - Total cobalt ~ .01-.04 mg/l
      - standard 0.005 mg/l
A Little? Background....

- Long and sordid story complete with numerous plot twists
  - (and endless ASMR papers)
- Cliffs Notes Summary:
  - Compliance 2009
  - Ion exchange treatment

Small unit in the mine
Major source
Large unit on surface
Entire discharge
Current Treatment System

Surge tank → Filters → Break tank → Carbon → IX resin → IX resin
So what’s the problem?

- Unfiltered copper removal problematic
  - TSS ~ 5 mg/l
  - 75% of copper in discharge is in particulate form
  - Some suspended copper moves through system
  - Plugging of ion exchange tanks
Particle Size Analysis, Input

Particles per mL

Particle diameter

0.5-1.0 1.0-2.0 2.0-4.0 4.0-6.0 6.0-8.0 8.0-10.0 10.0-15.0 15.0-20.0 20.0-30.0 30.0-40.0 40.0-50.0 50-100 100-200
So what’s the problem?

- Particles generally < 4 microns
- Only about 20% of the removal capacity utilized
  - 4-5 million gallons treated

Is there a better approach?
Physical filtration

Coagulants, Flocculents and Clarifiers (oh my)
- Low solids
- Chemical and O&M concerns

Sand filters
- Nominal removal: 10-20 micron

Multimedia filters
- Nominal removal: 5-10 micron
APTsorb™

- Patented peat based sorption media
- Hardened granule
- High hydraulic conductivity (~1 cm/sec)
  - Can be used in active or passive approach
- High metal affinity (1-15% max dry wgt)
Approach

- Use tank with APTsorb as pretreatment
- Treatment tank
  - 1000 gallon
  - 500 gallons media
  - Design for periodic backwash
  - 30 – 100 gpm
Bed Volume = Volume of reactive media in treatment tank or system (gallons)  500 gallons

Empty bed contact time (min) = \[
\frac{\text{Volume of reactive media (gallons)}}{\text{Flow rate (gallons/min)}}
\]

5-20 minutes
Copper, unfiltered (μg/L)

Input, site A
n=15

After filters, site B
n=13

After carbon, site C
n=12

After tank 1, site G
n=9

After tank 2, site D
n=15

Input, site E
n=27

After APT, site F
n=27

Existing System

American Peat System

Mean
Median
Permit
Total copper

Cu (µg/L)

Bed volumes

Influent

Effluent
Total copper

Cu (µg/L) vs Bed volumes

Influent
Effluent
The graph illustrates the concentration of copper (µg/L) against bed volumes for both influent and effluent conditions. The x-axis represents bed volumes, while the y-axis shows copper concentration. The graph highlights failure in the mine treatment process, with peaks indicating increased copper levels. The influent line starts with a lower concentration and fluctuates, while the effluent line shows a decrease over time, indicating a decrease in copper concentration after treatment.
Failure in mine treatment

Total copper

Cu (µg/L)

Bed volumes

Influent
Effluent
Total copper

Failure in mine treatment

In mine treatment restarted

Cu (µg/L)

Bed volumes

Influent
Effluent
Conclusions

- Effective removal of copper
  - Average 74% suspended
  - Average 60% dissolved

- 12 months operation:
  - 16 million gallons treated
  - 32,000 bed volumes
  - Minimal maintenance
    - Backwash every 4-6 weeks
  - Treatment cost < $0.00025/gallon
- Can simplify treatment system
System Comparison

Existing System

Surge tank → Filters → Break tank → Carbon → IX resin → IX resin

APT System

Surge tank → APTsorb → IX resin

APTsorb replaces filters, break tank, pump, carbon tank and first IX tank
Total Copper, ug/l

Bed Volumes

Influent
Effluent
After Siemens Tank
<table>
<thead>
<tr>
<th>Bed Volumes</th>
<th>Cobalt influent</th>
<th>Cobalt, after APTsorb</th>
<th>Cobalt after Siemens</th>
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<tr>
<td>577</td>
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<td>0.47</td>
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</tbody>
</table>

All concentrations in ug/l; Permit limit 4 ug/l
Estimated Annual Operating Costs

- Existing system: $163,000<sup>a</sup>
- Proposed APTsorb system: $70,000<sup>b</sup>

<sup>a</sup>4 exchanges per year
<sup>b</sup>2 exchanges per year
Next Steps

- Proposal for implementation submitted
- Additional issues
  - Mercury
  - Typical discharge 40-60 ng/l
  - Standard 6.9 ng/l
  - 90% suspended
- Other applications
  - Treated coal mine drainage
  - Total aluminum exceeds limit
    - Most is suspended
Looking for Answers?

Ask a question!

“There are no rules here. We’re trying to accomplish something.”

Thomas Edison
Cobalt Results

![Graph showing Cobalt Results]

- **Cobalt, µg/l**
- **Bed Volumes**
- **Permit limit**

- **Cobalt in**
- **Cobalt out**