Passive Treatment of Coal Mine Drainage

By Robert S. Hedin, Robert W. Narin, and Robert L. P. Kleinmann
Effective Passive Treatment of Coal Mine Drainage

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Hedin Environmental
Pittsburgh, PA
Hedin Environmental

- Formed in 1994
- specialize in AMD assessments and passive treatment
- Clients include watershed associations, non-profits, PADEP, mining companies, engineering companies, bonding companies
- 50 installed passive treatment systems based on our designs
Components of an Effective Passive Treatment System

- Proper selection of technology (IC 9389)
- Proper sizing (IC 9389)
- Consideration/mitigation of possible problems
- Proper construction
- Routine maintenance and sampling
- Major maintenance
Figure 12.—Flow chart showing chemical determinations necessary for the design of passive treatment systems.
Characterize Mine Water

Net alkaline:
- DO, Fe$^{3+}$, Al all < 1 mg/L (high Fe$^{2+}$)
- Anoxic Limestone Drain
- Net Alkaline
  - Ponds
  - Wetland
  - Mn
  - Oxic Limestone Bed
  - Mn

Net acid:
- DO, Fe$^{3+}$, Al any > 1 mg/L
- Vertical Flow Pond
  - Ponds
  - Wetland
  - Oxic Limestone Bed (drainable)
  - Fe < 10 mg/L

Final Discharge

Repeat As Needed
Passive Technologies Used by HE

• **Ponds**
  – oxidize Fe, settle solids, mixing (IC 9389)

• **Wetlands**
  – polishing, Mn and solids removal; (IC 9389)

• **Anoxic limestone drains**
  – alkalinity generation (IC 9389)

• **Oxic limestone beds (new)**
  – alkalinity generation, metal removal, polishing

• **Vertical flow ponds (SAPS, Anaerobic Wetlands) (new)**
  – alkalinity generation and metal removal
Four Examples of the Reliable Use of these Technologies
Characterize Mine Water

Net alkaline

- Anoxic Limestone Drain
  - DO, Fe$^{3+}$, Al all < 1 mg/L (high Fe$^{2+}$)
  - Ponds
  - Wetland
  - Oxid Limestone Bed

Net acid

- DO, Fe$^{3+}$, Al any > 1 mg/L
  - Vertical Flow Pond
  - Ponds
  - Wetland
  - Ponds
  - Oxid Limestone Bed (drainable)

Final Discharge

Mn
Marchand Mine Passive System

Ponds and Wetlands
Fe$^{2+}$ + HCO$_3^-$ + O$_2$ $\rightarrow$ FeOOH + H$_2$O
Marchand system, average conditions, 2006 - 2013

<table>
<thead>
<tr>
<th></th>
<th>Flow</th>
<th>pH</th>
<th>Alk</th>
<th>Fe\textsuperscript{T}</th>
<th>Mn</th>
<th>Al</th>
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<td>&lt;0.1</td>
<td>1,160</td>
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### Fe, mg/L

- **Influent**
- **Effluent**

![Graph showing Fe concentrations over time](image-url)
Maintenance of the Marchand System

Fe sludge accumulation

• 575 ton/yr Fe solids
• 575,000 gallons/yr Fe sludge
• 7.5% loss of storage volume per year
• In June 2012 the system’s theoretical retention had decreased from 74 hr to 46 hr
• June 2012 sludge in first three ponds was removed
influent
Sewickley Creek
Pond
A
Pond
B
Pond
C
Pond
D
Pond
E
Pond
F
FeOOH recovered in 2012
Characterize Mine Water

Net alkaline

- DO, Fe$^{3+}$, Al all < 1 mg/L (high Fe$^{2+}$)
- Anoxic Limestone Drain

Net Alkaline

Ponds

Wetland

Net acid

DO, Fe$^{3+}$, Al any > 1 mg/L

DO, Fe$^{3+}$, Al any > 1 mg/L
Fe < 10 mg/L

Vertical Flow Pond

Repeat As Needed

Ponds

Oxic Limestone Bed (drainable)

Oxic Limestone Bed

Mn

Final Discharge

Mn
SR-114D Passive System

Anoxic Limestone Drain
1,300 ton limestone
120 gpm flow with 35 mg/L Fe$^{2+}$
SR 114D System,
Butler County, PA

\[
\text{Fe}^{2+} + \text{Mn}^{2+} + \text{H}^+ \xrightarrow{\text{limestone anoxic}} \text{Fe}^{2+} + \text{Mn}^{2+} + \text{Ca}^{2+} + \text{HCO}_3^-
\]
Limestone Dissolution in ALD 1995-2014

• ALD has generated 375 ton CaCO$_3$
• ALD has dissolved 416 tons limestone
• 32% of original 1,300 tons
• Theoretical average retention time has decreased from 10.8 hr to 7.4 hr
SR-114D ALD Maintenance

• No maintenance to date (19 years)
• ALD will need rehabilitated in next 5-10 years
  – Clean remaining limestone
  – Replaced dissolved limestone
Characterize Mine Water

Net alkaline

DO, Fe$^{3+}$, Al all < 1 mg/L (high Fe$^{2+}$)

Anoxic Limestone Drain

Ponds

Net Alkaline

Wetland

Oxic Limestone Bed

Mn

Net acid

DO, Fe$^{3+}$, Al any > 1 mg/L

Vertical Flow Pond

High Fe$^{2+}$

Repeat As Needed

Ponds

Oxic Limestone Bed (drainable)

Fe < 10 mg/L

Ponds

Mn

Wetland

Final Discharge
Anna S Mine
Passive Treatment Complex

Vertical Flow Ponds
# Anna S passive systems, 2004 - 2014

<table>
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<th></th>
<th>Flow</th>
<th>pH</th>
<th>Alk</th>
<th>Acid</th>
<th>Fe</th>
<th>Al</th>
<th>Mn</th>
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<td>mg/L</td>
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<td>1</td>
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Alkalinity, mg/L

Hunters system final discharge
Anna System final discharge
Major Maintenance

• Rehabilitate substrates that contribute to system’s effectiveness (alkalinity generation)
• Alkaline Organic Substrate: replenish
• Limestone Underdrain: clean and replenish
Characterize Mine Water

Net alkaline

- DO, Fe$^{3+}$, Al all < 1 mg/L (high Fe$^{2+}$)
- Anoxic Limestone Drain

Net alkaline

- Ponds
- Wetland
- Oxic Limestone Bed

Net acid

- DO, Fe$^{3+}$, Al any > 1 mg/L
- Vertical Flow Pond

Net acid

- Ponds
- Wetland
- Oxic Limestone Bed

DO, Fe$^{3+}$, Al any > 1 mg/L
- Oxic Limestone Bed (drainable)

Repeat As Needed

Final Discharge
Tangascootack #1 Passive System

Oxic Limestone Bed (drainable)
Water Level Control box with bottom gate valve

Computer

Solar Panel
Tangascootack #1 system, Nov 2010 – Apr 2014

<table>
<thead>
<tr>
<th></th>
<th>Flow</th>
<th>pH</th>
<th>Alk</th>
<th>Acid</th>
<th>Fe</th>
<th>Al</th>
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Solids Management

• Routine draining removes portion of solids
• Infrequent cleaning of stone removes remaining solids
Pittsburgh Botanic Garden DLB solids basin during end of draining
Pittsburgh Botanic Garden DLB solids basin during end of draining

71% of the Al retained in the DLB during routine operations released during draining
Major Maintenance

• Clean limestone aggregate every 3-10 years
• Established procedures and costs
Summary

• Highly successful passive treatment of discharge with large range of flow rates and chemical conditions
• Effective treatment obtained year-round
• All systems require O&M, but the needs are modest and with planning can be implemented cost-effectively
A graph showing Mn, mg/L concentrations over time from August 2010 to August 2014. Two lines are shown: blue for influent and red for DLB effluent. The influent line shows fluctuations from approximately 0 to 35 mg/L, while the effluent line is mostly close to 0.
<table>
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<tr>
<th></th>
<th>Al</th>
<th>Fe</th>
<th>Mn</th>
<th>Al</th>
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<th>Mn</th>
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<td>13.8</td>
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<td>0.2</td>
<td>0.4</td>
<td>0.09</td>
<td>0.14</td>
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<td>Retained</td>
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<td>13.4</td>
<td>0.35</td>
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<td>Removal</td>
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<td>0.2-0.8</td>
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<td>% removed</td>
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<td></td>
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<td>71%</td>
<td>99%</td>
<td>13%</td>
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<tr>
<td>% retained</td>
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<td>29%</td>
<td>1%</td>
<td>87%</td>
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**Pittsburgh Botanic Garden DLB**

- Poured concrete tank
- 100’ X 20’ X 5’
- 450 ton limestone
- Agri Drain SDS system
- Drains empty once/week

**Routine conditions**

<table>
<thead>
<tr>
<th></th>
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<td>Al, mg/L</td>
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<tr>
<td>Mn, mg/L</td>
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<tr>
<td>Fe, mg/L</td>
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