Field trials for passive treatment of circum-neutral metal mine drainage in mid Wales, UK

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Introduction

- Mine drainage from abandoned metal mine sites can continue for centuries after extraction ceases
- There are over 1300 abandoned metal mines in Wales
- Chemistry of mine drainage dependent on:
  - Chemistry of ore deposit
  - Host rock and gangue minerals
  - Weathering conditions

Circum-neutral mine drainage

- Many former mining areas in the UK have drainage with a circum-neutral drainage pH, owing to:
  - Absence of pyrite within the ore
  - Presence of a carbonate host rock or gangue
  - Weathering of sulfide minerals without release of acidity or iron

- Sphalerite: ZnS + 2O2 → Zn2+ + SO4^{2-}
- Galena: PbS + 2O2 → Pb2+ + SO4^{2-}

- Often high levels of dissolved Zn / Pb / Cd


...all surface waters and groundwaters within defined river basin districts must reach at least ‘good’ ecological and chemical status by 2015...

An estimated 9% of rivers in England and Wales fail WFD standards because of mining-related pollution (Johnston and Rolley, 2008)

Remediation of circum-neutral mine drainage

- Low Fe content not possible to remove metals by pH buffering and co-precipitation with Fe-oxyhydroxides.

Acid mine drainage (pH 2.5, 500 mg/L Fe) + limestone → Circum-neutral mine drainage (pH 6.5, <5 mg/L Fe) + ???

Novel approach required

Waste materials as reactants

- Waste materials = a popular option for mine water treatment
- Five materials chosen for treatment trials:
  - Waste shell material
  - Basic oxygen furnace (BOS) slag mixed with blast furnace slag
  - Peat fly ash *
  - Iron ochre *
  - Compost *

* Mixed with sand to ensure adequate permeability

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Bwlch mine, Mid Wales (UK)

- Former Pb/Zn mine
- Mineralisation:
  - Galena
  - Sphalerite
  - Quartz gangue
  - No pyrite

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Bwlch mine</th>
<th>EU WQS</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>S.U.</td>
<td>6.3</td>
<td>6 - 9</td>
</tr>
<tr>
<td>Zn</td>
<td>mg/L</td>
<td>20 - 40</td>
<td>0.008</td>
</tr>
<tr>
<td>Fe</td>
<td>mg/L</td>
<td>&lt; 0.2</td>
<td>1</td>
</tr>
<tr>
<td>Pb</td>
<td>µg/L</td>
<td>500 - 1000</td>
<td>50</td>
</tr>
<tr>
<td>Cd</td>
<td>µg/L</td>
<td>50 - 100</td>
<td>1</td>
</tr>
</tbody>
</table>

Treatment tank design

- Inflow control
- Distribution tank allow water to drip onto reactive material
- Head control and outflow of treated water
- Mine water from reservoir
- Treated water drips through bed and base of inner tank
- Perforated stainless steel sheet
- Bed of reactive material (10 cm)
- Flow rate: up to 1 L/min
- Residence time: ~15 minutes

Results

- Order of material performance:
  - Peat fly ash > compost > waste shell material > BOS/BFS slag
- Peat fly ash removes Zn, Pb and Cd removed to below detection limits from 1000 litres of mine water = 10.5 mg/L
- Order of breakthrough for all reactive materials: Zn = Cd > Pb
- High influent Zn concentrations = saturation of all reactive materials with Zn after less than 2 weeks.

Zn removal
**Fly ash metal removal mechanisms**

- Rise in pH causes precipitation of metal hydroxides (e.g. Zn(OH)₂) – confirmed by geochemical modelling

  \[
  \text{CaO} + \text{H}_2\text{O} \rightarrow \text{Ca}^{2+} + 2\text{OH}^-
  \]

**Permeability constraints**

- Flow rates controlled by material permeability
  - Whelk shells
  - BOS slag
  - Compost
  - Fly ash
  - Iron ochre

- Iron ochre cell discontinued after 1 day due to low permeability and very low flow rate

**Scaling**

- Results scaled to determine size of treatment cell required to remove 90% of metal load over 1 year.

<table>
<thead>
<tr>
<th>Material</th>
<th>Mass required (tonnes)</th>
<th>Area of treatment cell (metres)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peat fly ash</td>
<td>7.5</td>
<td>2.7 x 2.7</td>
</tr>
<tr>
<td>Compost</td>
<td>57</td>
<td>9.7 x 9.7</td>
</tr>
<tr>
<td>Waste shell material</td>
<td>8,333</td>
<td>81.6 x 81.6</td>
</tr>
<tr>
<td>BOS/BFS slag</td>
<td>18,718</td>
<td>144 x 144</td>
</tr>
</tbody>
</table>

* Assuming a bed thickness of 1 metre

**Trials using Acid Mine Drainage**

- Additional trials carried out at Cwm Rheidol, mid-Wales UK:
  - pH: 3.2
  - Zn: ~21 mg/L
  - Fe: > 36 mg/L in solution

- Rapid decrease in flow rates due to precipitation of Fe-(oxy)hydroxides

- Trials terminated prior to breakthrough after 8 days
Conclusions

- Remediation of circum-neutral metal mine discharges not hindered by precipitation of Fe-(oxy)hydroxides and armouring of reactive materials.
- However, zinc removal very difficult as it remains soluble over a wide pH range.
- Peat fly ash removed over 99.9% of Zn, Pb and Cd from 1000 litres of mine water.
- A treatment cell as small as 2.7 x 2.7 x 1 metre could be used to remove 90% of metal load from Bwlch mine (flow rate = 10 L/min, 23.5 mg/L Zn).
- Conclusion: It is possible to treat small, circum-neutral discharges from disused metal mines for very little cost.

Thank you