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: $ZnS + 2O_2 \rightarrow Zn^{2+} + SO_4^{2-}$

Galena: $PbS + 2O_2 \rightarrow Pb^{2+} + SO_4^{2-}$

- Often high levels of dissolved Zn / Pb / Cd

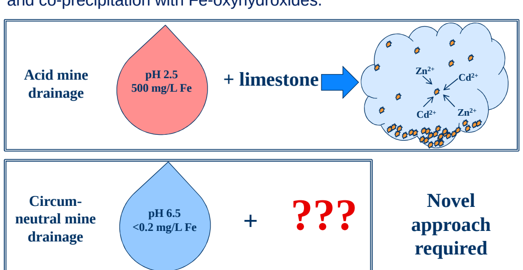
Water Framework Directive (2000/60/EC)

...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.



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 *
- Sourced locally where possible

* Mixed with sand to ensure adequate permeability

Bwlch mine, Mid Wales (UK)

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

Parameter	Units	Blwch mine	EU WQS
pH	S.U.	6.3	6 - 9
Zn	mg/L	20 - 40	0.008
Fe	mg/L	< 0.2	1
Pb	µg/L	500 - 1000	50
Cd	µg/L	50 - 100	1

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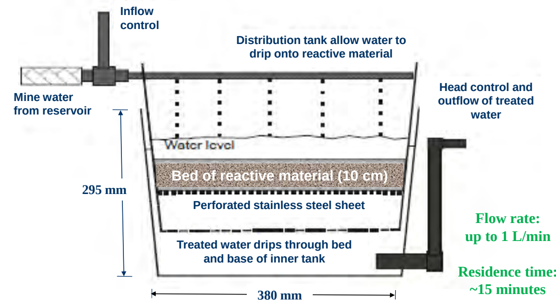
Treatment tank design



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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/g
- 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.

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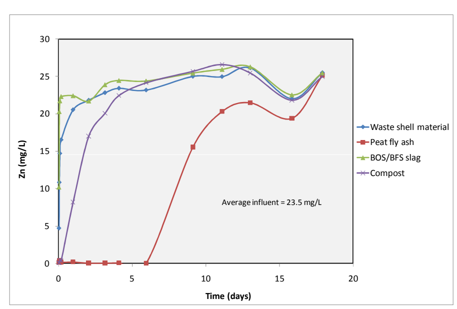
Zn removal



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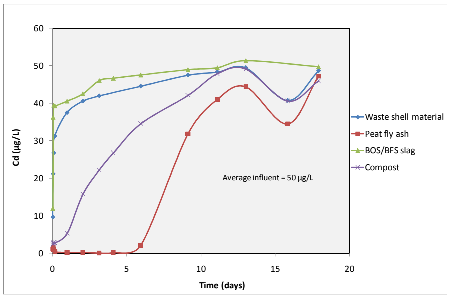
Cd removal



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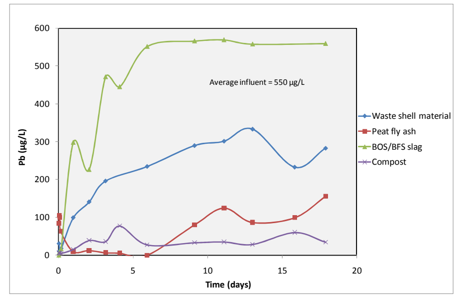
Pb removal



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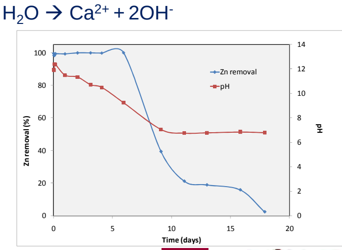
Fly ash metal removal mechanisms

- Rise in pH causes precipitation of metal hydroxides (e.g. $Zn(OH)_2$) – confirmed by geochemical modelling
- $CaO + H_2O \rightarrow Ca^{2+} + 2OH^-$



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Permeability constraints

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

0.89 L/min → 0.0002 L/min

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

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Scaling

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

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

* Assuming a bed thickness of 1 metre

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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

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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