



Attenuation of metals in tailings

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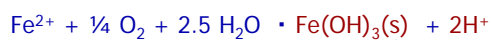
Background – Oxidation of sulphide minerals releases metals and acidity

Weathering (oxidation) of **sulphidic** mine waste produces acidity and releases metal ions and sulphate.

Limited access to O₂ (within tailings) (di)sulphide is oxidised



(In contact with air: Fe(II) is oxidised)





The acidity is partly or completely neutralised and metal ions may be removed from water

- in weathered tailings
- in unweathered tailings
- in the underlying ground
- in the discharge area
- in downstream surface waters

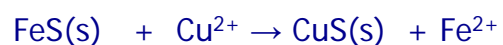
all depending on geochemical conditions



Several geochemical processes removing metals from water are possible

e.g.

- FeS and FeS₂ in tailings
 - **adsorption** of Me²⁺/As(III, V) to mineral surfaces
 - formation of **secondary sulfides** (e.g. CuS, FeAsS)



- **Precipitation** of sulphates (e.g. CaSO₄ and PbSO₄)
- **Precipitation** of carbonates and hydroxides (e.g. ZnCO₃(s), CuCO₃(s) and Cu(OH)₂(s))



Goals of the present project

The main goals are to:

- identify the minerals in mining waste able to contribute metals in short and long term, and to
- facilitate prediction of the quality of discharging ground water by quantifying the metal retardation capacity of tailings of different composition.



Methods

- Sampling - *Core drilling*
- Chemical analysis of tailings and pore water
- Physical characterisation of tailings
- Mineralogical characterisation
- Structural investigations
- Quantification of uptake capacity – *Column and batch experiments*
- Literature study of relevant geochemical processes
- Construction of a spreadsheet model for metal retention in tailings considering chemical and mineralogical composition.

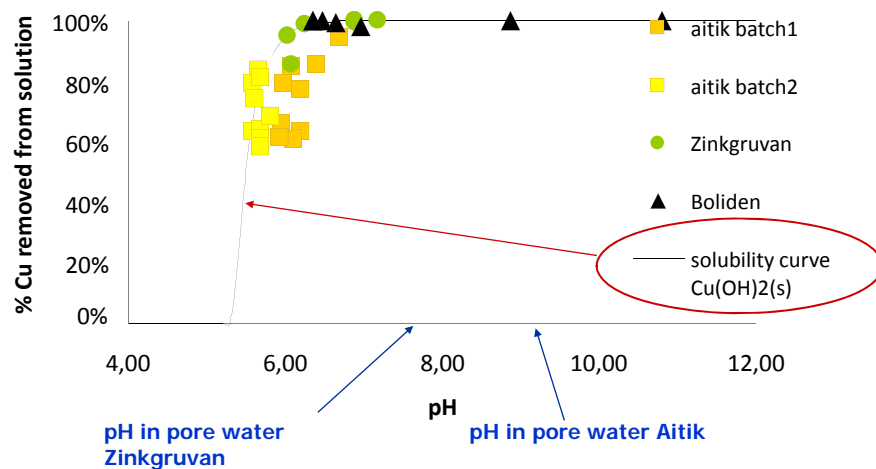


Sampling sites

- **Kristineberg**: High content of FeS_2 (ca. 30%).
- **Zinkgruvan**: Low sulphide content. Not net acid producing.
- **Aitik**: Low sulphide content (<1%), but net acid producing.
- **Boliden**: Fresh tailings from the concentrator; high in sulphide.

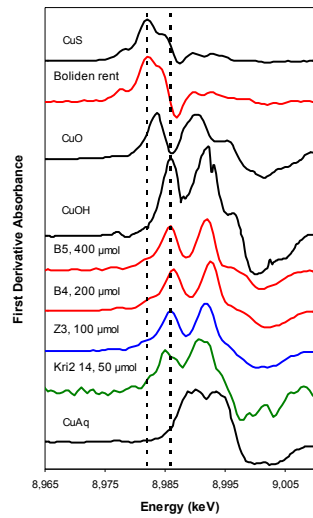


Copper uptake by tailings in batch experiment





XANES measurements indicate "Cu(OH)₂(s)"



Copper sulphide – pure substance

Fresh tailings from Boliden

Copper oxide – pure substance

Copper hydroxide – pure substance

Fresh tailings from Boliden + Cu added

Tailings from Zinkgruvan + Cu added

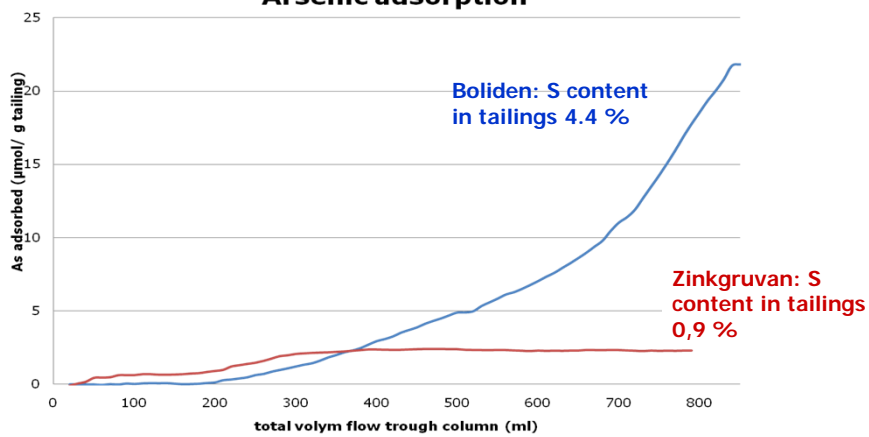
Tailings from Kri-berg + Cu added

Copper dissolved in water – pure substance



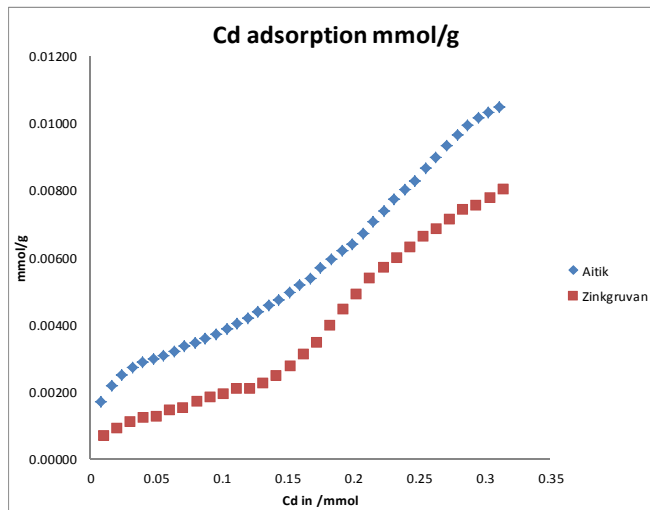
Arsenic removal at pH 8

Arsenic adsorption





Results from column experiments Cadmium removal in tailings at pH 6.5

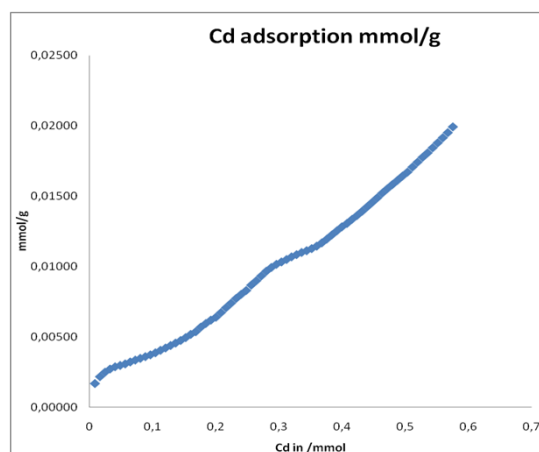


Only a small fraction (c.a. 5-6%) of the injected Cd is taken up by the tailings.

But



Uptake of Cd(II) to tailings exceeds adsorption at monolayer level



Tailings from Aitik

pH 6.5

Specific surface area of tailings
2.5 m²/g

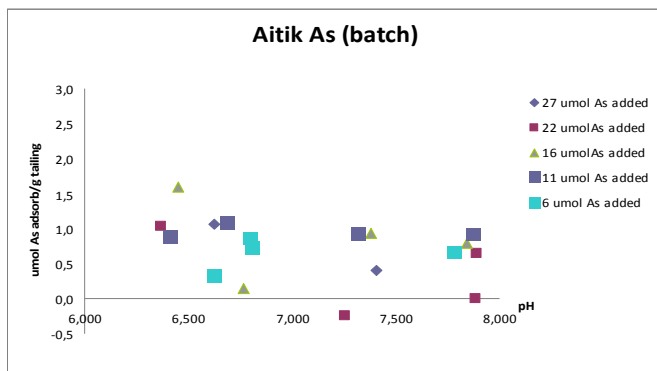
Uptake normalised to surface
area:

0,020 mmol/g →

ca. 8 μmol/m² which exceeds
theoretical surface site
concentrations (ca 5 μmol/m²)



Capacity of arsenic(III) uptake to tailings from Aitik is lower than uptake of Cu(II)



Specific surface area of tailings 2.5 m²/g

Uptake normalised to surface area:

0.8 μmol/g →

ca. 0.3 μmol/m² which is lower than theoretical surface site concentrations (ca 5 μmol/m²)

Sulphide minerals seems to play a greater role for As uptake.



An estimate of adsorption capacity of tailings minerals in Kristineberg

Assumptions:

Silicates active in metal adsorption (65 %), sulphides (25 %) and other minerals (10 %).

Density of wet tailings: 2 400 kg/m³

Porosity: 40 % (pores are saturated with H₂O: 400 kg)

Mineral phases constitute 2 000 kg/m³

Silicates (model substance: kaolinite):

Amount of silicates in 1.0 m³ of tailings: 0.65 * 2 000 kg = 1 300 kg

Specific surface area: 3 m²/g

Density of metal binding surface sites: 5.5 μmol/m²

(Angove et al., 1997)

Amount of surface sites: **21 mol/m³**



An estimate of adsorption capacity of tailings minerals in Kristineberg

Sulphides (pyrite):

Fraction of minerals composed by pyrite: 25%

Amount of pyrite in 1.0 m³ of tailings: 0.25*2 000kg = 500 kg

Specific surface area: 0.90 m²/g (Axelsson, 2002)

Density of metal binding surface sites: 4.3 μmol/m²
(Kornicker and Morse, 1991)

Amount of surface sites: **1.9 mol/m³**

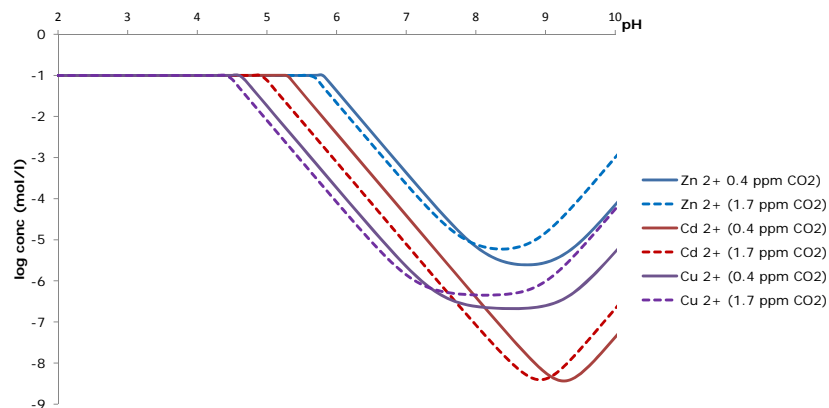
Amount of metals in tailings from Impoundment 1 (Holmström et al., 2001)

Zn: 0.9 % of 2000 kg/m³ = 18 kg/m³ → 275 mol/m³

Cu: 0.1 % of 2000 kg/m³ = 2.0 kg/m³ → 31 mol/m³



Solubility of carbonates of Cu(II), Cd(II) and Zn(II) atmospheric and enhanced of CO₂ pressure





High bicarbonate concs. in tailings groundwater - Saxberget

Alkalinity (HCO_3^-) calculated from charge balance

Anions: $[\text{OH}^-] + [\text{HCO}_3^-] + [\text{CO}_3^{2-}] + 2[\text{SO}_4^{2-}]$

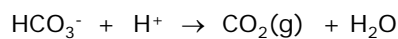
Cations: $[\text{H}^+] + [\text{Na}^+] + [\text{K}^+] + 2[\text{Mg}^{2+}] + 2[\text{Ca}^{2+}] + 2[\text{Fe}^{2+}] + 2[\text{Mn}^{2+}] + 2[\text{Ni}^{2+}]$

pH 6.45 at point of discharge

pH ca 6.8 at a point 15 m downstream

Calculated a alkalinity ca 3.5 meq./l

→ Pressure of $\text{CO}_2(\text{g}) >$ atmospheric



→ High potential of forming carbonate minerals with $\text{Cu}(\text{II})$, $\text{Cd}(\text{II})$, $\text{Zn}(\text{II})$ and $\text{Pb}(\text{II})$



Conclusions

- The uptake of metal cations ($\text{Cu}(\text{II})$, $\text{Cd}(\text{II})$ (and $\text{Zn}(\text{II})$) to tailings at neutral pH exceeds adsorption at monolayer level.
- XANES spectroscopy indicate that sorbed $\text{Cu}(\text{II})$ is bound in a form resembling $\text{Cu}(\text{OH})_2(\text{s})$.
- The uptake capacity with respect to As relates to the tailings content of sulphide minerals.
- Several of the tailings sampled in the field exhibit a high pH and all samples show large acid neutralising capacities.
- Relatively large concentrations of bicarbonate ions in tailings pore water makes formation of carbonate phases of e.g. $\text{Cu}(\text{II})$, $\text{Cd}(\text{II})$ and $\text{Zn}(\text{II})$ likely.



Axknövelgements

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