Enhanced carbon dioxide gas compositions within mine waste storage facilities: implications for kinetic test methods and mine waste geochemical characterisation

MEM

The science behind success

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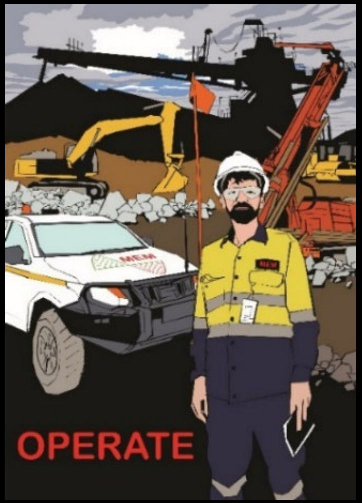

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Study location and experimental materials

The waste rock being used within this study has been provided by Boliden AB. The material comes from their active Kevitsa mining operation.

The material is a low sulfide ultramafic rock type and has potential for carbonation weathering reactions to occur as a result of exposure to ambient conditions

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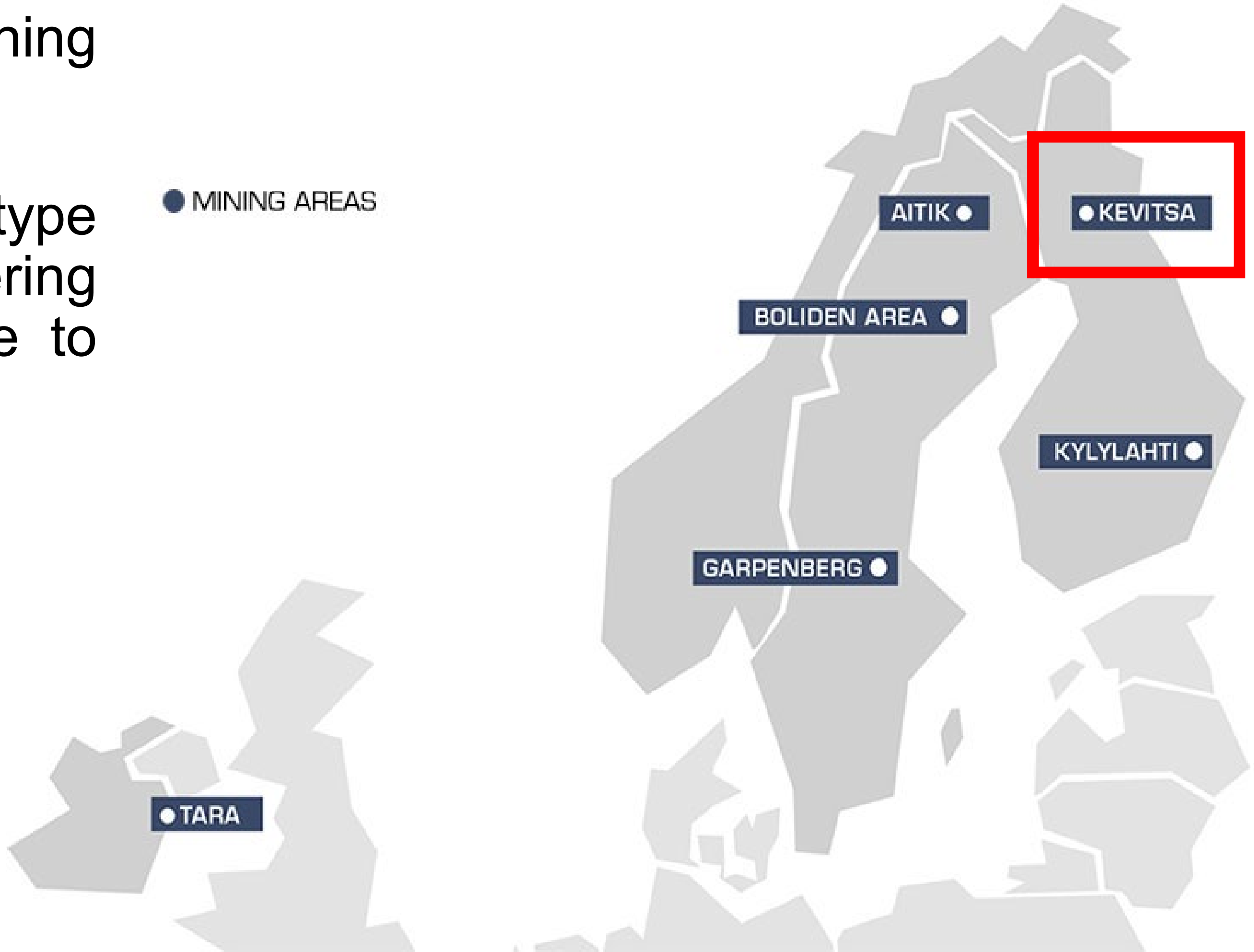

CO_2 compositions in mine waste storage facilities

Above atmospheric or 'Enhanced' CO_2 concentrations have been demonstrated in multiple studies assessing pore gas compositions in mining waste storage facilities. CO_2 generation relates to organic carbon oxidation (coal deposits) or sulfide oxidation and carbonate dissolution reactions in hard rock metalliferous deposits.

- Lorca et al., 2016 – Cu-Zn Polymettalic Skarn Deposit - **>2% CO_2 seasonally** (limited by detection limit of reader)

- Lahnira at al., 2014 – Zn-Pb-Fe Sulphide Deposit (Sullivan mine, BC) – **4-5% CO_2**

- Vriens, 2018 – Sulphide rich, Skarn and Carbonate rich waste (Antamina mine, Peru) - **>2.2% CO_2** (above detection limit). Other studies at this site have shown hot spots with **>7% CO_2**.

Waste rock monitoring data from the Boliden Kevitsa mine:

		Spring 2019		Summer 2019		Autumn 2019		Winter 2019	
Place	Port	O2 %	CO2 %	O2 %	CO2 %	O2 %	CO2 %	O2 %	CO2 %
Trial 1	A	7.8	5.6	6.8	6.3	12.8	7.5	14.1	3.3
	B	7.7	6.2	5.7	7.9	11.6	7.9	17.5	1.4

Why is CO_2 important to kinetic test methods and mine waste geochemical characterisation?

- The presence of above atmospheric or ‘enhanced’ CO_2 concentrations in mine wastes is generally not considered in standard testing methodology which are carried out under atmospheric conditions

- Sulphide oxidation and dissolution of carbonates may result in varied internal gas compositions in waste facilities

- Enhanced CO_2 internal waste atmospheres will ultimately have implications for the weathering of certain mineral species e.g. carbonation of silicates

- CO_2 concentrations effect the pore water chemistry as a result of generation of carbonic acid due to CO_2 dissolution

- Degassing of CO_2 at seepage outlets can effect pH of seepages reporting to environment

- The covering and encapsulation of waste and long term changes in pore as composition will ultimately affect waste pore gas and pore water geochemical development and AMD predication

<u>Site specific data including internal gas compositions suggested to be considered as part of standard testing protocols</u>

Kinetic testing for mine wastes

- Typical laboratory based kinetic tests include columns and humidity cell tests (HCT's).
- The HCT test is designed to assume an unlimited water and oxygen supply and availability condition (i.e. atmospheric pore gas and flushed pore water state).
- Generic methods like these are therefore not site specific in their test parameters (temperature, water content, flushing rate, gas composition)

All experiments were carried out at our industrial partner **Geochemic Ltd**, located in South Wales

Geochemic Ltd
www.geochemic.co.uk

Other considerations

- **Potential for future utilization of mine waste as part of large scale carbon capture and storage (CCS) projects increases the potential that CO_2 may be <u>added</u> to mine waste**
- **Green mining practices**
- **Enhanced closure planning systems and waste management**

Kaivosvastuu (Mining Responsibly Standard): The Finnish Towards Sustainable Mining

Commitments 4 (Water) and 5 (Energy & GHG)

Water management

1. Maintain water balance model
2. Aware of risks
3. Provision for climate change
4. Work with stakeholders to develop and implement responsible policies and practices
5. Openness and transparency
6. Commit to continuously improving

Energy & Greenhouse gas emissions

1. Implement energy use and GHG emissions management systems
2. Identify key issues and significant areas for improvement
3. Monitor and report energy use and emissions
4. Set KPIs
5. Decision making includes energy consumption and emission sources
6. Reduce their dependence on fossil fuels

FINNISH TOWARDS SUSTAINABLE MINING (TSM) STANDARD

Experimental set ups

Treatment Method	Test Information
CO_2 reactor columns	This experiment was designed to determine the carbonate formation potential of a variety of materials exposed to pure CO_2 marginally above atmospheric pressure All the columns were set-up and run at room temperature (20°C) with 10% moisture content. The columns ran for twelve months.
Altered Humidity Cells (HCT)	This experimental set up was designed based on an altered version of the ASTM D5744 standard for humidity cell tests. The aim was to assess how the introduction of CO_2 into a standard humidity cell may affect drainage quality prediction – Are rates of metal leaching suppressed or enhanced due to potential changes in pore-water pH?

Small Scale CO_2 Reactor Columns

CO_2 enriched column tests (non-leached)

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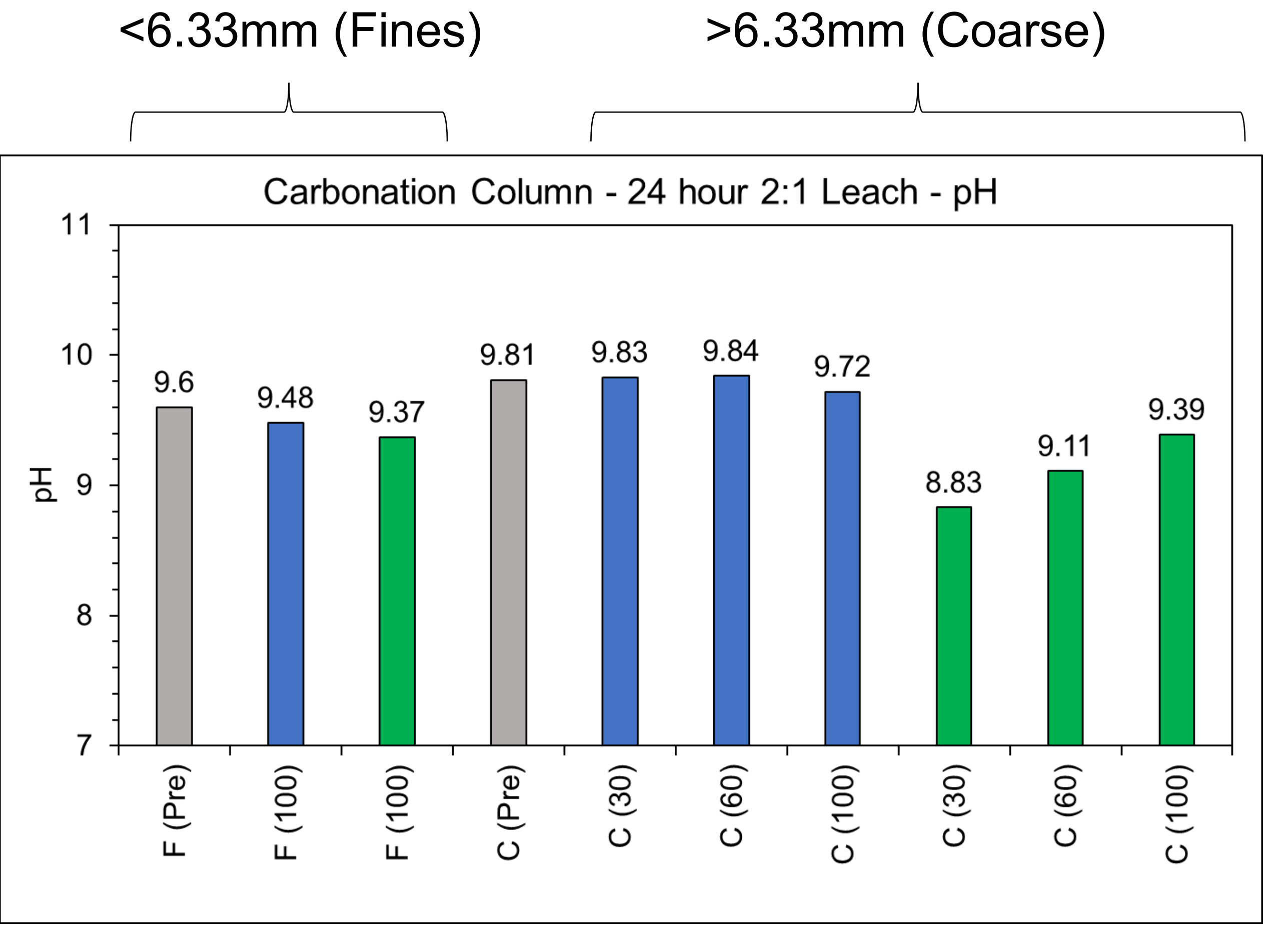
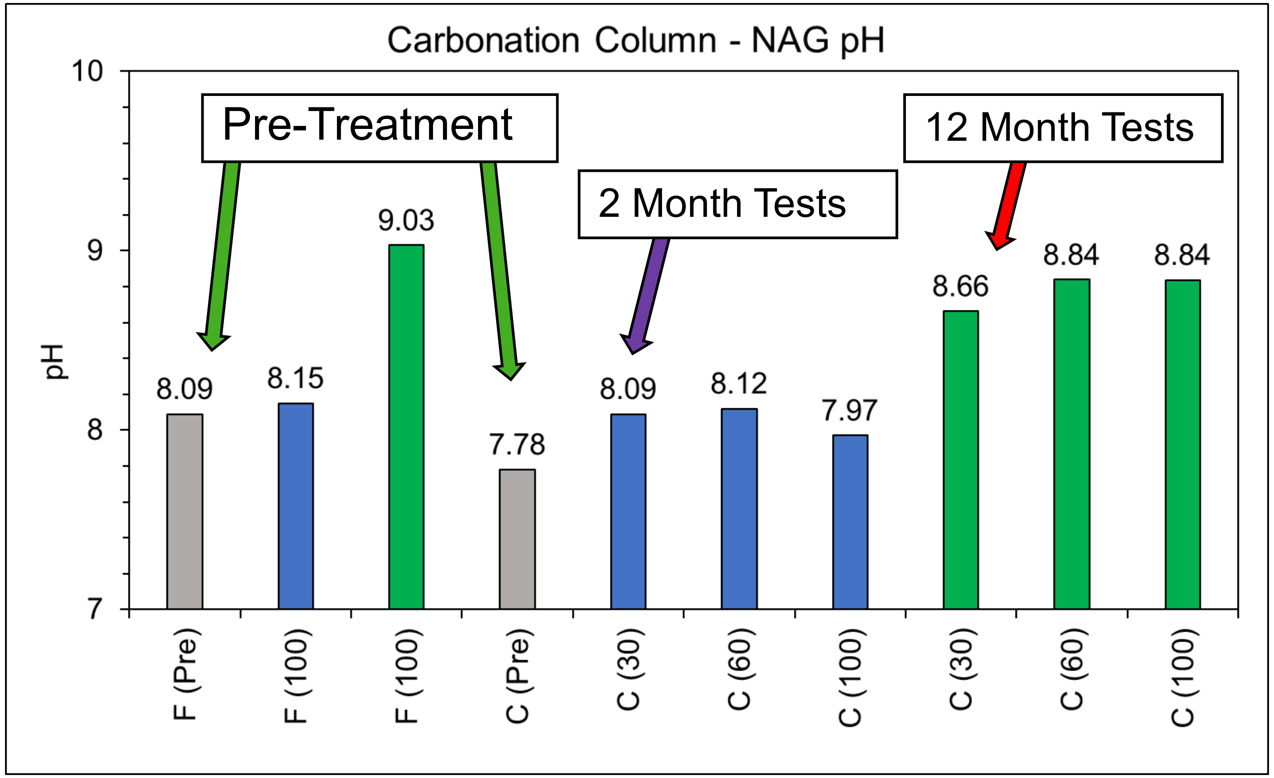
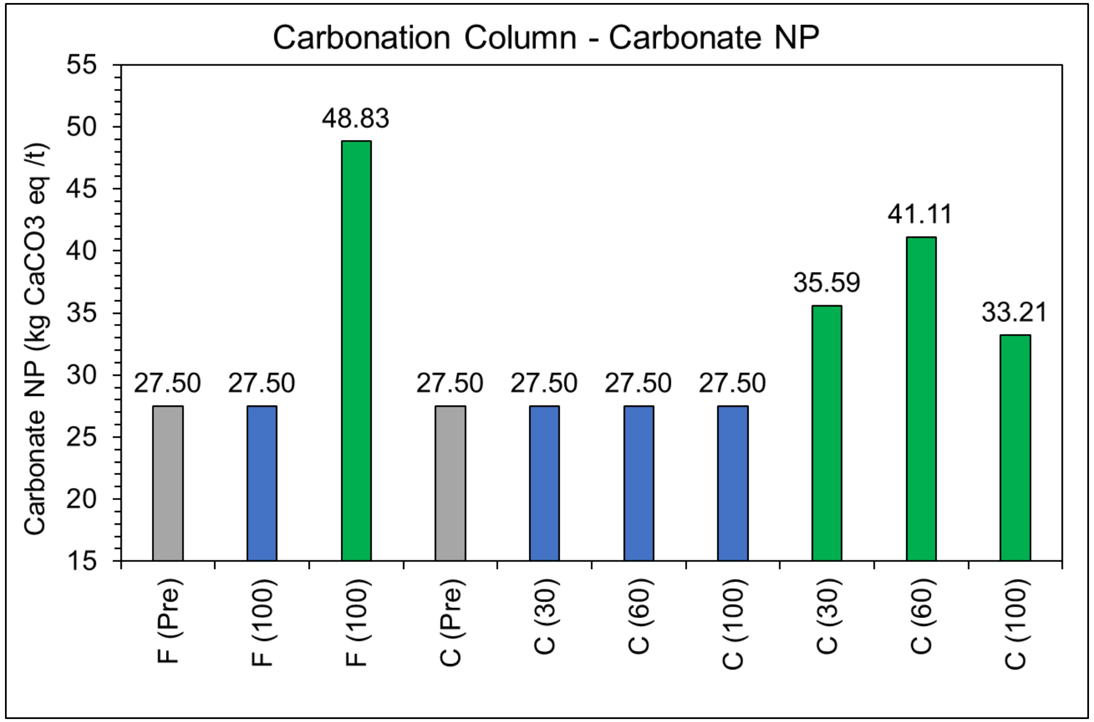
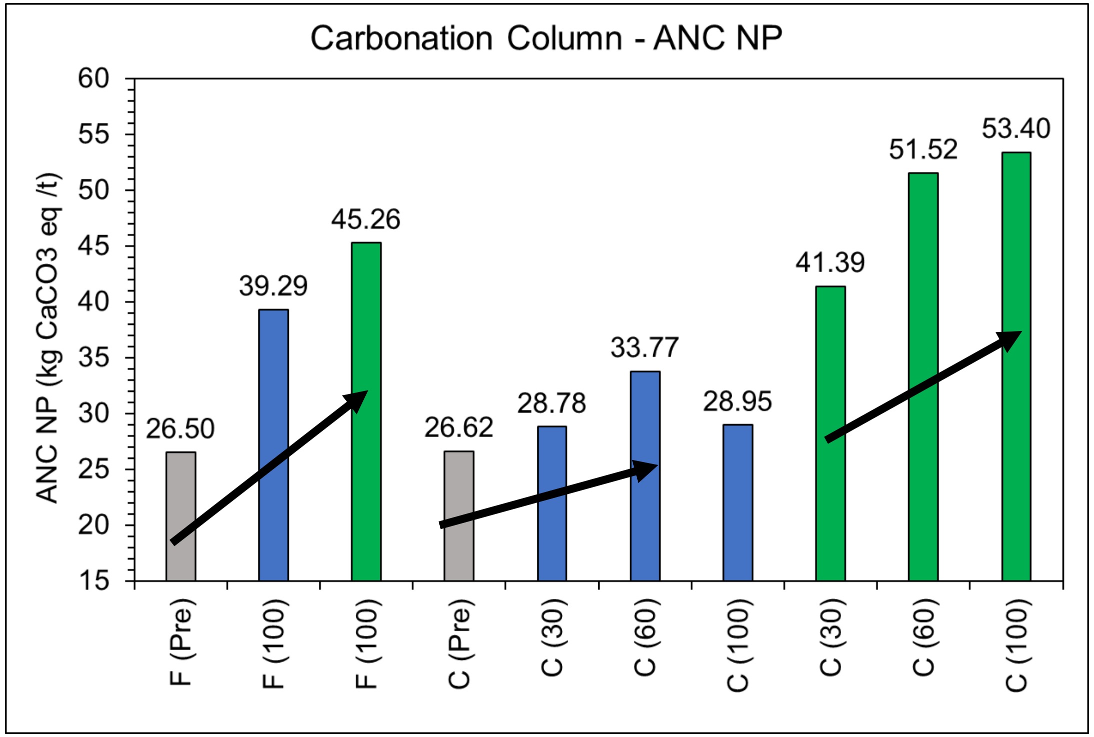




- Over 12 months NAGpH increased in CO2 columns implying ABA balance has changed over time to be more buffering
- 24 hour leach pH condition decreased over same period which likely relates to dissolved CO_2

CO_2 enriched column tests (non-leached)

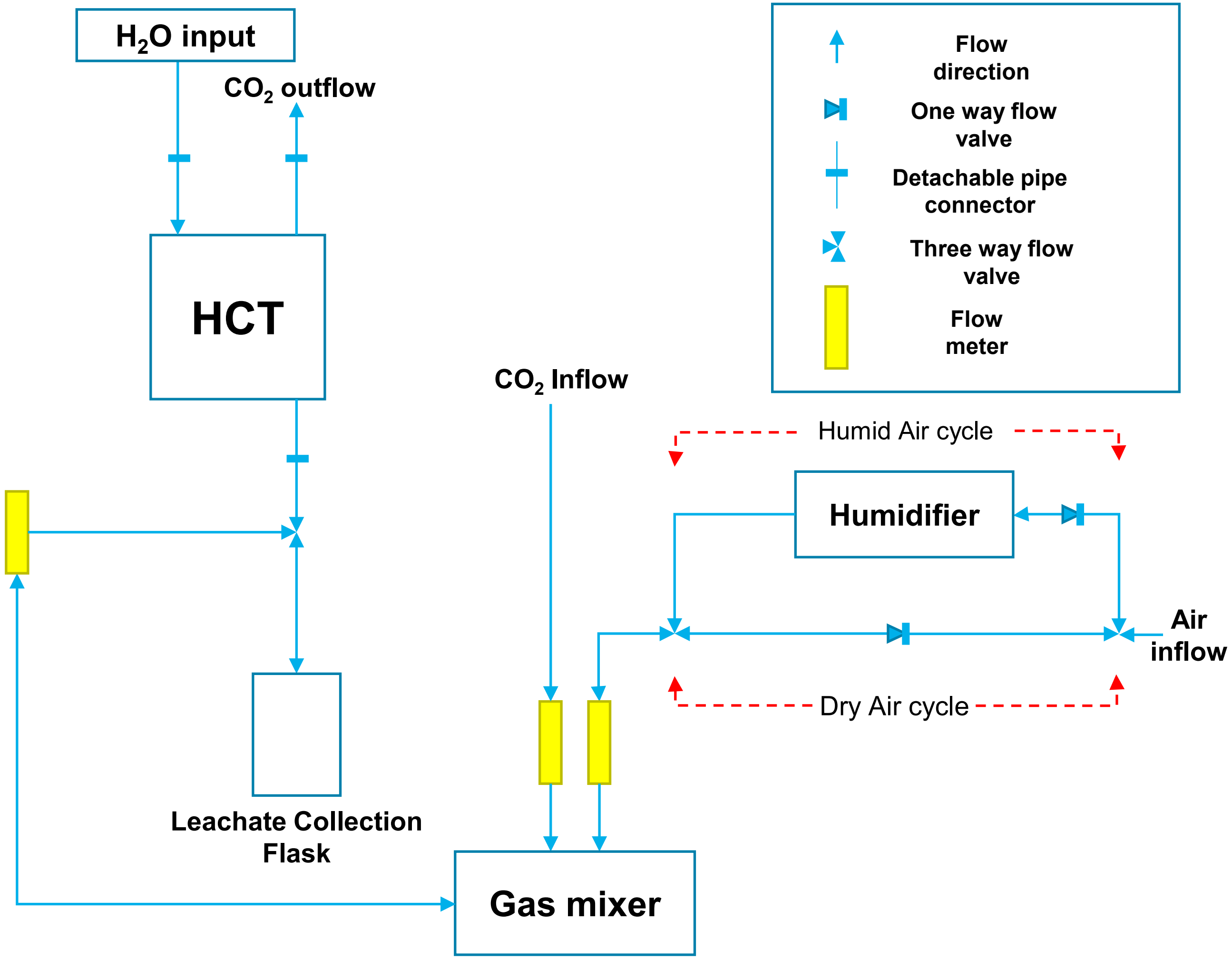


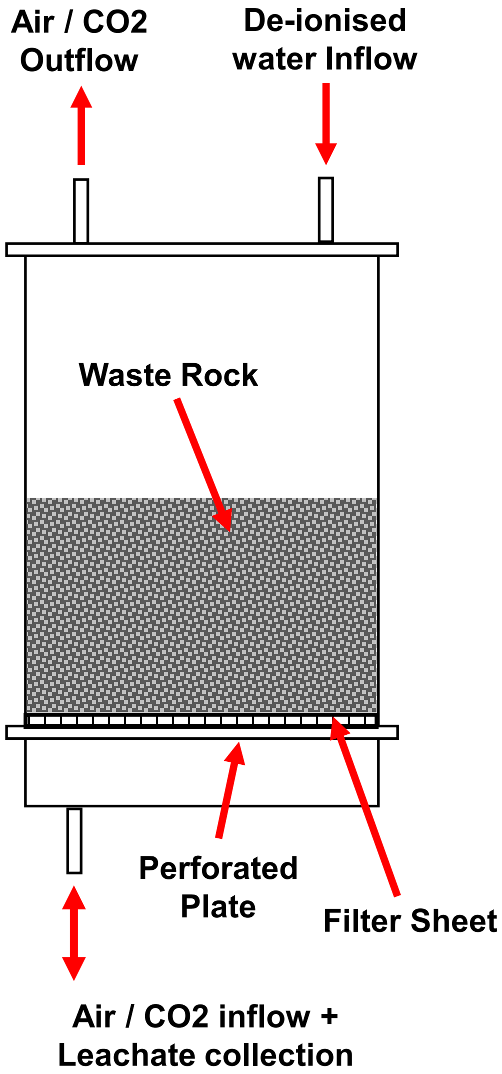


- Marked increases in ANC over time related to columns with higher CO2 concentrations. Empirical evidence that buffering potential is impacted by pore gas CO2 concentrations
- Some evidence for increase in carbonate content over longer 21 month tests which may explain ANC results (less conclusive results than ANC).

Removed total C as same as carbonate C to declutter the slide

Altered Humidity Cells (HCT) – Set up

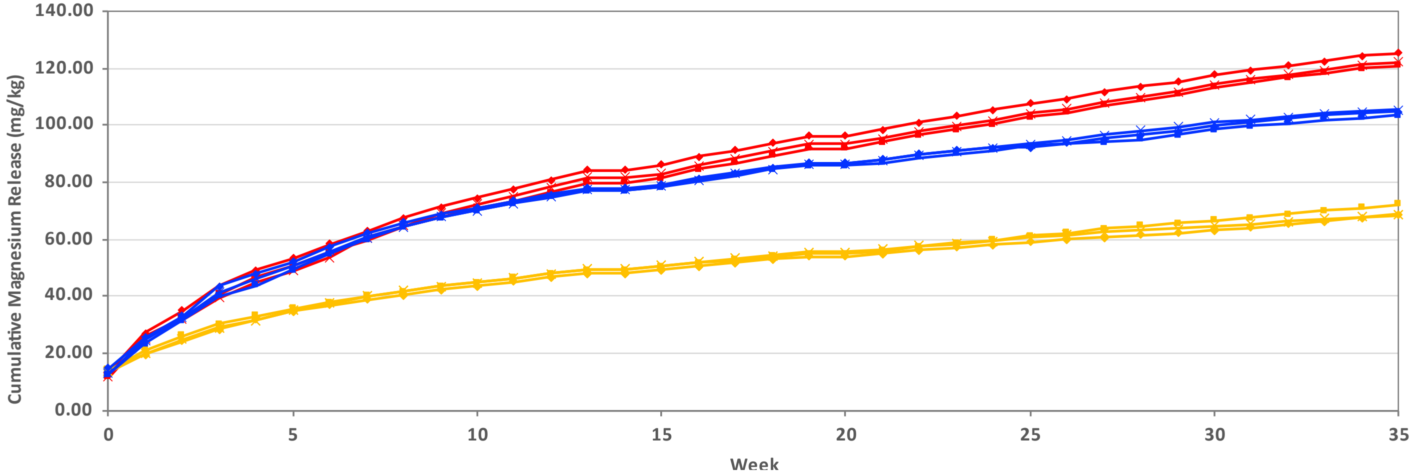


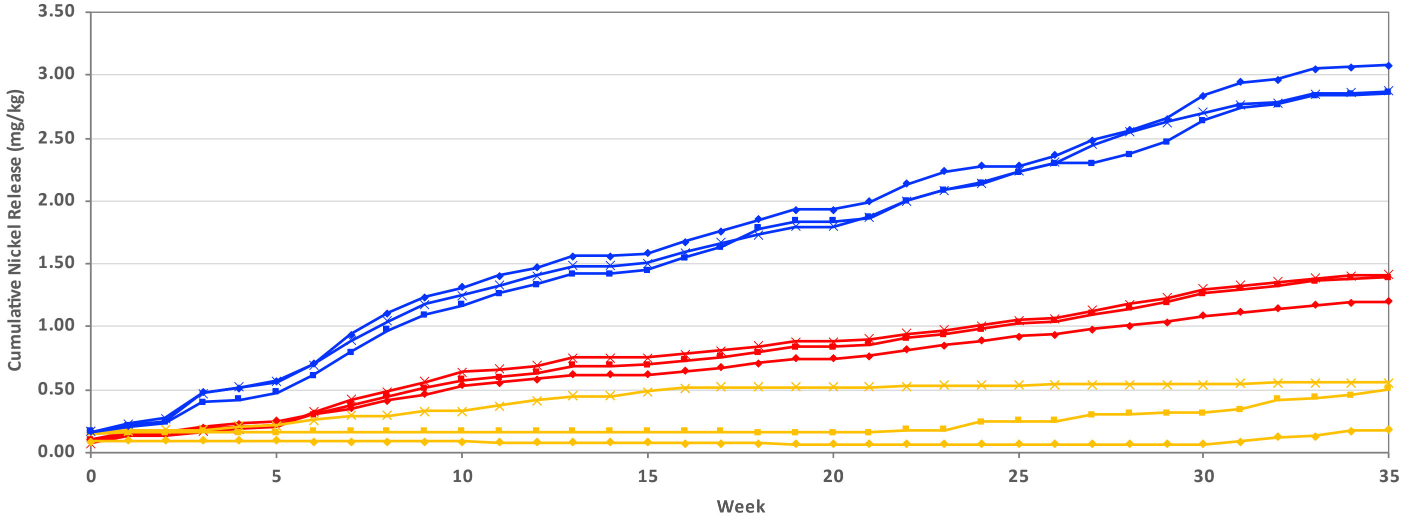


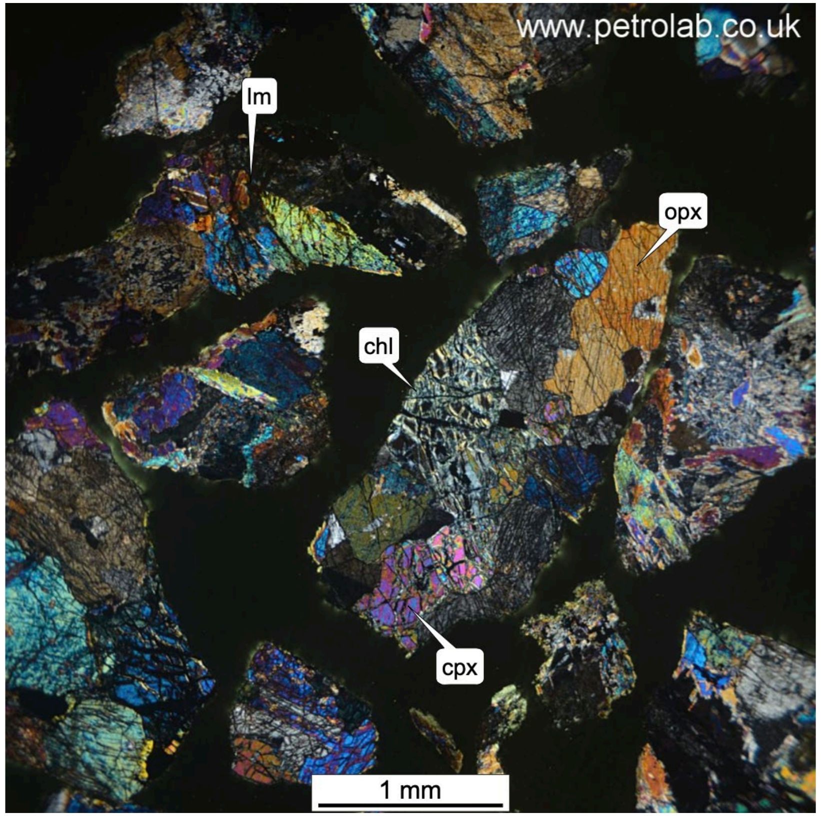
Altered Humidity Cell Tests (HCT's)

Warm Room CO_2 = 10% / 25^{O}C Cold Room CO_2 = 10% / 10^{O}C Warm Room N_2 = 10% / 25^{O}C

Petrolab
Mineralogy · Petrography







Cross polarised light image of sample showing abundant fragments of gabbro mostly composed of clinopyroxene (cpx) and orthopyroxene (opx). Fractures in weathered pyroxenes and residual olivine are infilled with limonite (lm) and chlorite (chl) respectively.

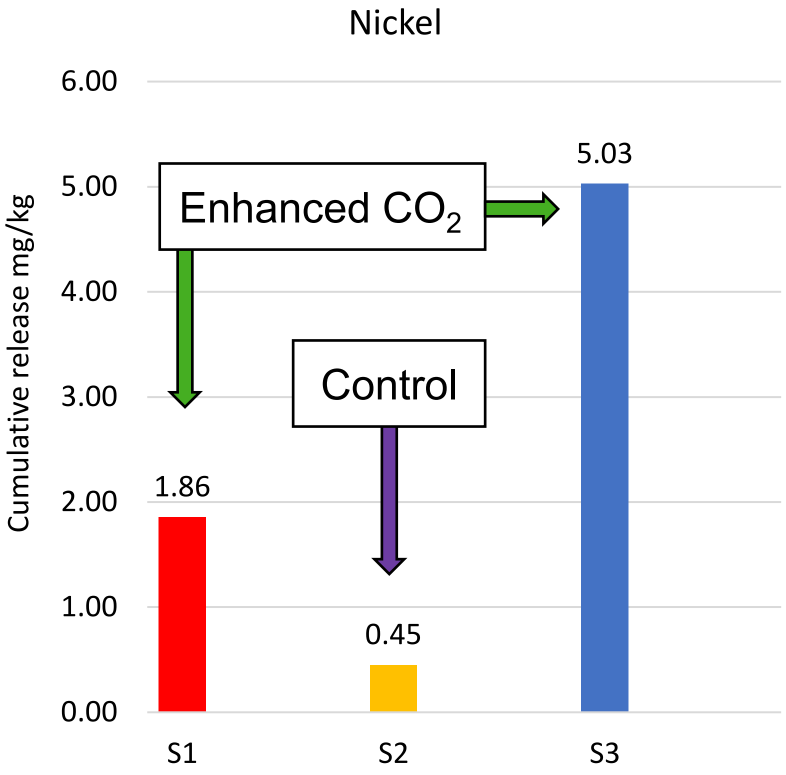
Altered Humidity Cell Tests (HCT's)

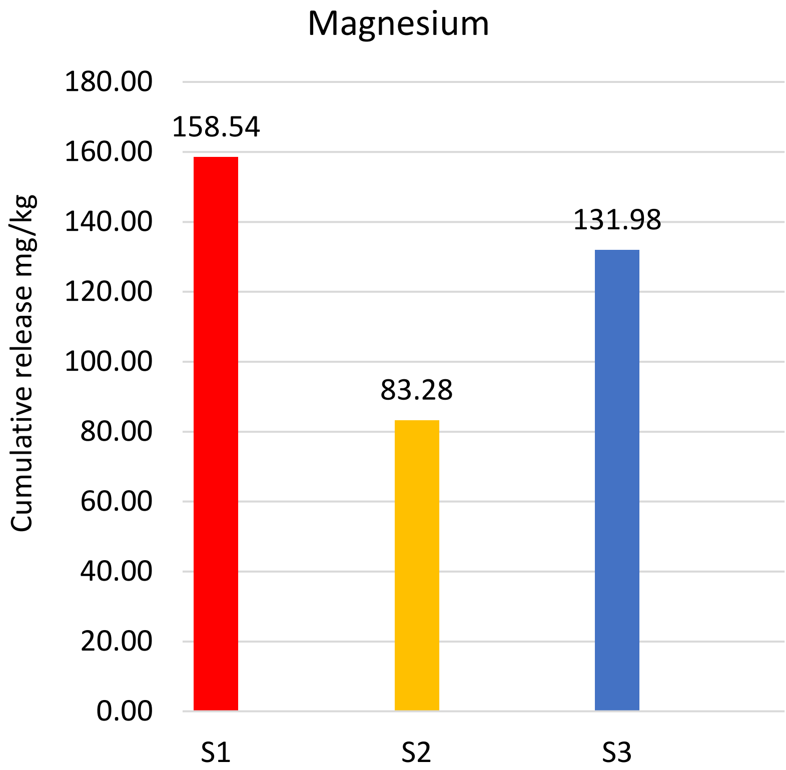
Warm Room CO_2 = 10% / 25^{O}C

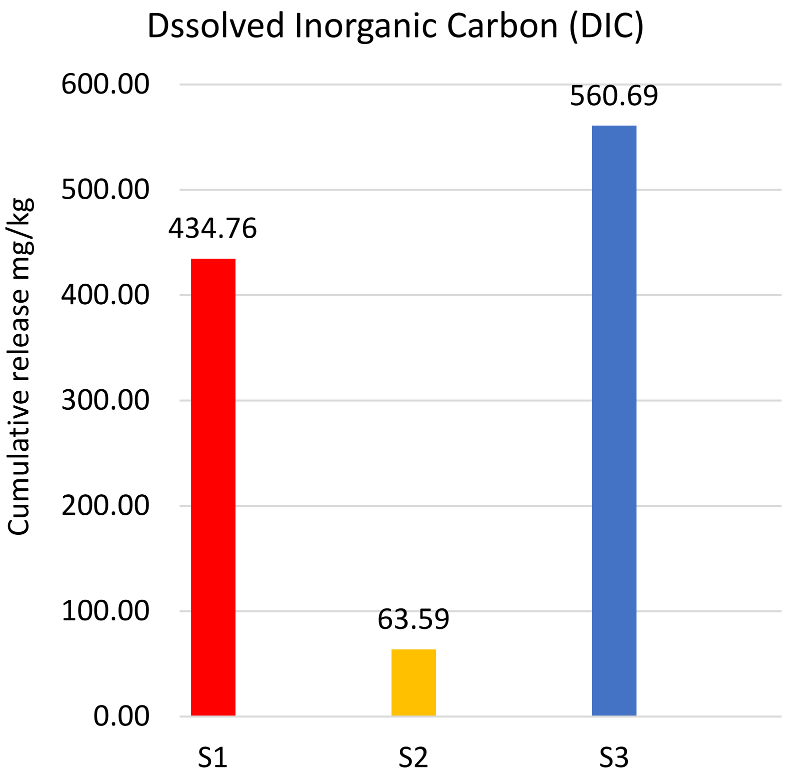
Cold Room CO_2 = 10% / 10^{O}C

Warm Room N_2 = 10% / 25^{O}C

Clear differentiations are shown between CO_2 enhanced and 'standard' HCT experiments. Reduced temperature HCT's with enhanced CO2 concentrations show greater release of Ni as well as Mg when compared to standard cells under STP.







Study limitations

- Column test humidity and water content was difficult to maintain once in place.
- Column design is being reviewed to address the potential for preferential gas flow as the waste materials ‘cement’, reducing gas permeability.
- The flushing frequency of HCT experimental cycles mean that secondary carbonate formation could not be measured post test.
- The lack of ‘cold’ temperature HCT control limits some comparisons between the initial test control and the enhanced CO_2 cold room tests

Key findings

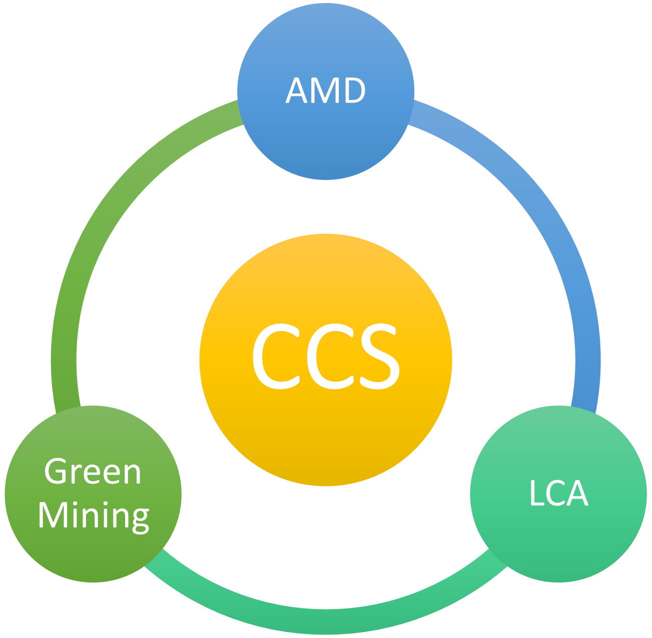
- What did we find out that relates to testing methods as the title says
  - Where CO_2 concentrations are elevated in pore gas, carbonation weathering reactions can occur where “vulnerable” mineral species are present (e.g. olivine). Over time this may result in increase in carbonate content and ANC (i.e. buffering potential) which means the ABA of waste material is not static over time and buffering potential may increase (acid potential decrease).
  - Elevated CO_2 concentrations increase potential for pore water geochemical changes compared to atmospheric conditions, for example dissolved CO_2 may increase carbonic acid generation which may result in increased metal release
  - Standard test methods can be amended to account for site specific gas composition considerations however it is better scientific approach to design test methods based on simulation if site conditions (e.g. customised kinetic testing).

Implications

- To date no standardised kinetic or static tests have been developed to assess environmental implications of enhanced CO2 pore gas condition and related carbonation reactions on mine drainage quality

- Appropriate method development allows the assessment of the dual opportunity of capturing carbon dioxide in mine waste as part of carbonation reactions and the potential reduction in environmental impacts related to acid mine drainage

- Preliminary results demonstrate the benefit of assessing the impact of enhanced CO_2 concentrations on mine waste geochemistry and AMD prediction.



Viewing mine waste in a new way

Traditional thinking

Asset → Ore processing → Ore Extraction → Waste Production → Liability

A new approach to waste management

Asset → Ore processing → Ore Extraction → Waste Production → Passive / Enhanced Carbonation + Metals recovery → Value realisation → Asset

Thank you for listening!

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