



Field Trials of Dispersed Alkaline Substrate to Passively Treat Highly Polluted Acid Mine Drainage at two Emblematic Abandoned Mines in Wales

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SCLF 2023 - 25 August 2023



The problem

- Acid Mine Drainage - global issue
- Conventional treatment expensive and often remote / closed mines and prone to clogging and passivation
- Historical treatment - solution was to over-engineer (land-take, costs and maintenance) to prolong treatability: to a point.
- Dispersed Alkaline Substrate (DAS) aims to over-come clogging and passivation whilst optimising engineering issues.
- DAS is a patented technology, involving University of Huelva (and University Free State)



Trial sites

- PARYS MOUNTAIN, ANGLESEY

Parameter	Unit	Parys Mountain
Flow	l/s	8.4
pH	s.u.	2.48
Al	mg/l	73.4
Cd	mg/l	0.15
Cu	mg/l	41.6
Fe	mg/l	645.8
Pb	mg/l	0.02
Mn	mg/l	16.5
SO ₄	mg/l	2263.1
Zn	mg/l	66.8



- The world's largest source of copper in the 18th Century
- Massive sulphide deposit
- Opencast mine
- High Fe, Zn, Al, Cu, sulphate, etc.

Trial sites

- CWM RHEIDOL, MID-WALES



- Warm brine epigenetic vein type lead zinc deposit
- Several connected underground mines
- Two discharges:
 - Adit 6: high flow, low metal concentrations
 - Adit 9: low flow, high metal concentrations

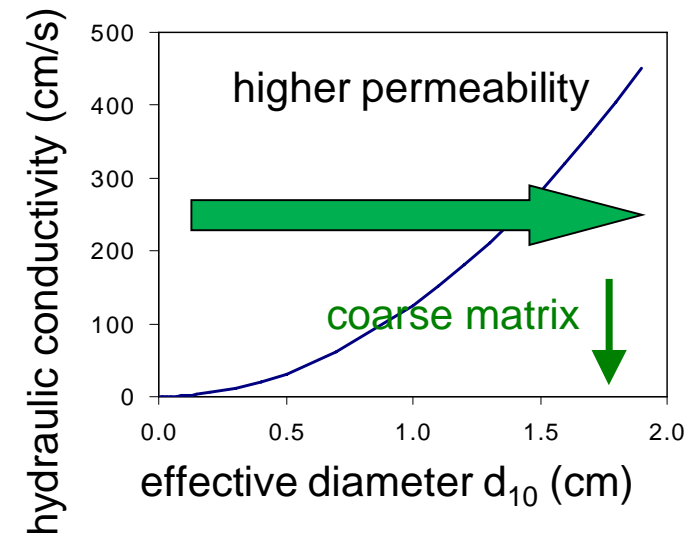
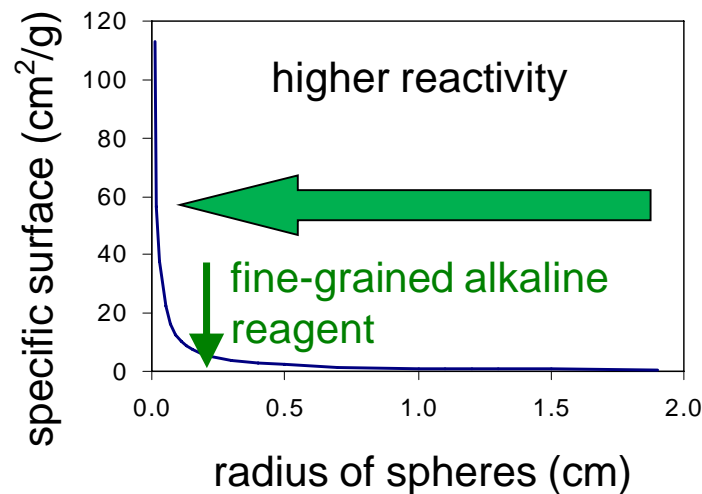
Parameter	Unit	Cwm Rheidol Mine		
		Adit 6	Adit 9	Adit 6+9
Flow	l/s	8.08	0.84	8.9
pH	s.u.	4.16	3.02	~3.5
Al	mg/l	2.73	29.0	5.54
Cd	mg/l	0.03	0.12	0.04
Cu	mg/l	0.04	0.1	0.05
Fe	mg/l	7.0	126.1	17.8
Pb	mg/l	0.66	0.01	0.62
Mn	mg/l	0.59	4	0.95
SO ₄	mg/l	146.0	824.3	216.4
Zn	mg/l	12.5	85.5	20.3

Concept of Dispersed Alkaline Substrate

DAS combines:

1. a fine-grained alkaline material

- **high reactivity** to produce mineral alkalinity
- **higher fraction** of reactive material **dissolves** before coating (reduced passivation)



2. a coarse supporting material (matrix)

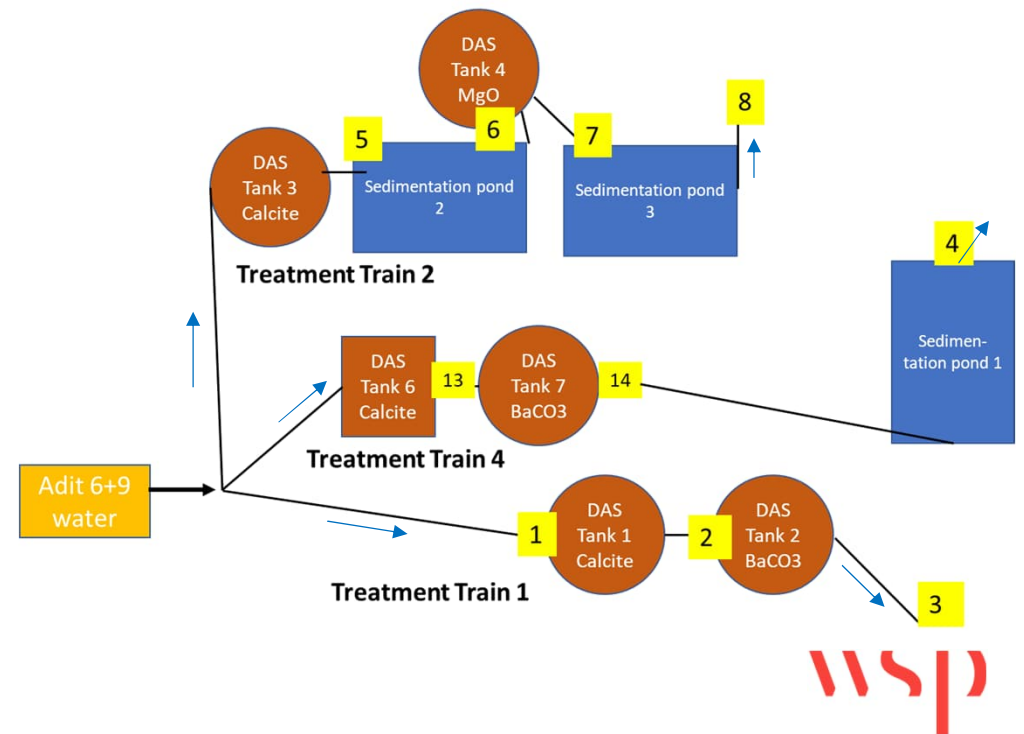
- provides a **large pore space** where precipitates can accumulate **without affecting permeability** (reducing clogging and by-pass flow)

Cwm Rheidol

- FIELD TRIAL - FINAL CONFIGURATION

Three treatment trains:

- Train 1: CaCO_3 DAS + BaCO_3 DAS (Ash tree wood chips)
- Train 2: CaCO_3 DAS + MgO DAS (Pine wood chips)
- Train 4: CaCO_3 + DAS + BaCO_3 DAS (Pine wood chips)



Cwm Rheidol main challenge:

- Microbial reactions in fresh wood cuttings of treatment train 1



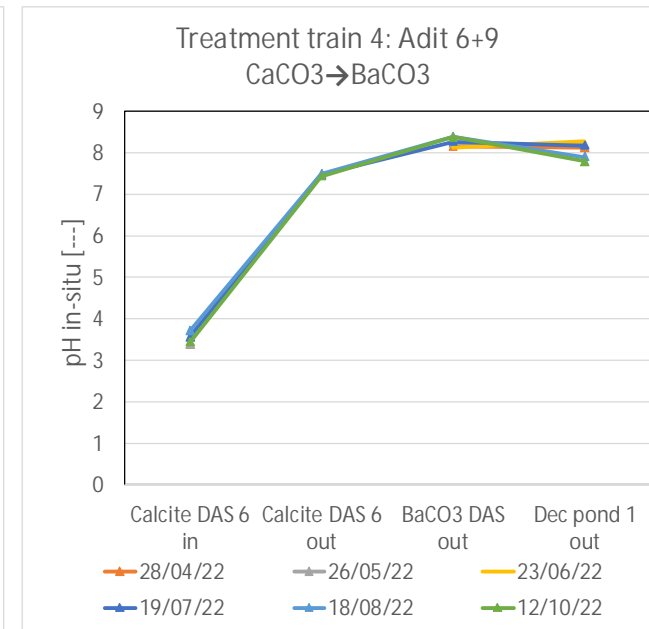
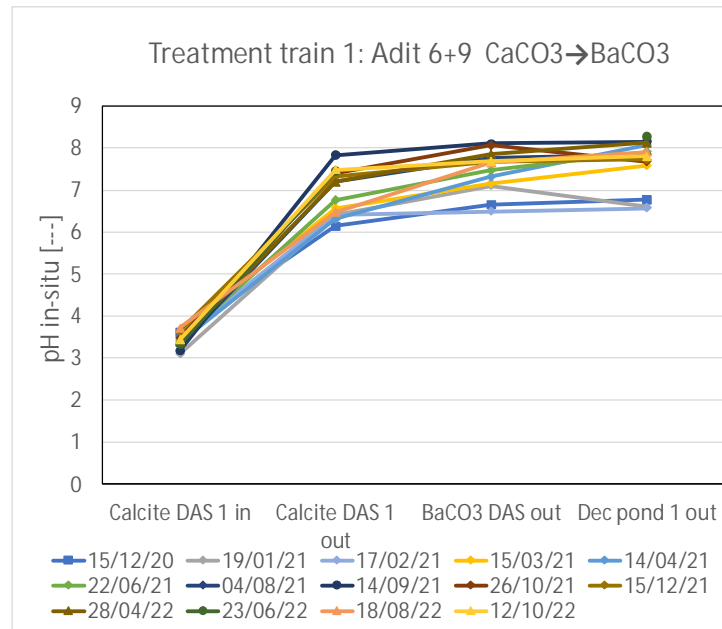
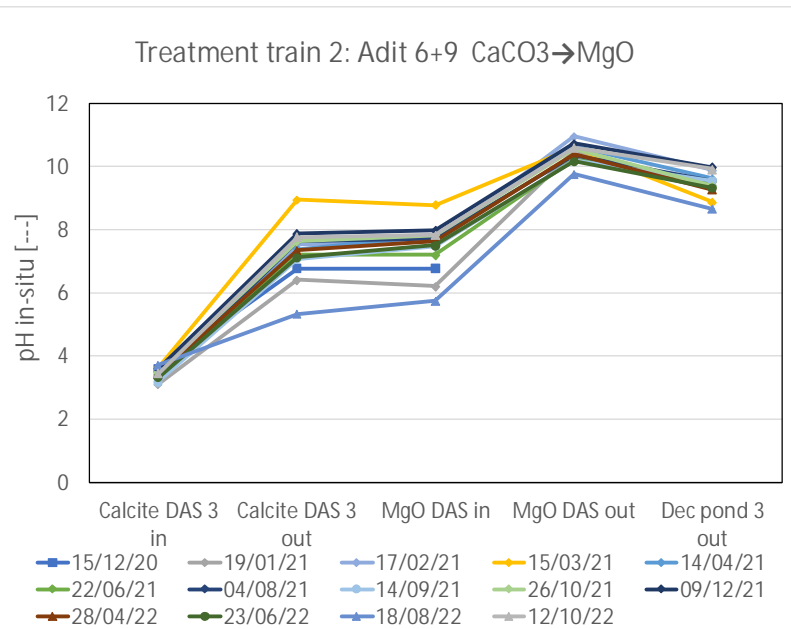
- Train 1:
 - Ash tree wood cuttings:
 - Discolored treated water with unpleasant odour



- Train 2:
 - Pine wood shavings:
 - Crystal-clear treated water

Cwm Rheidol

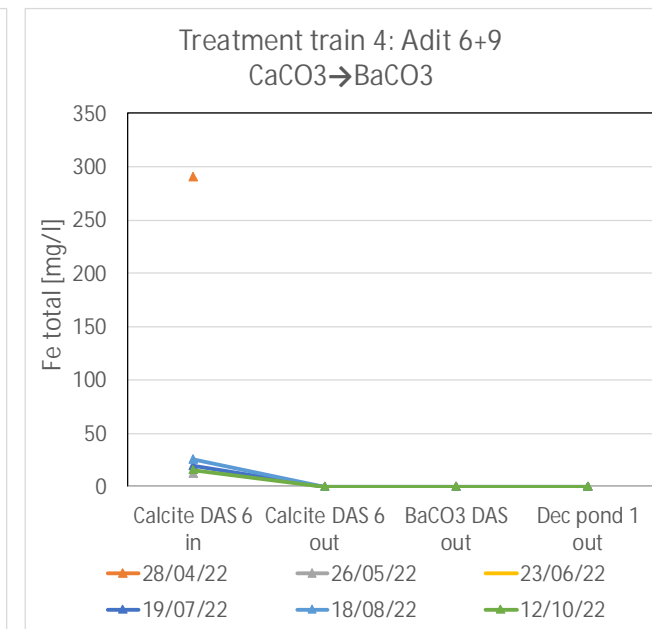
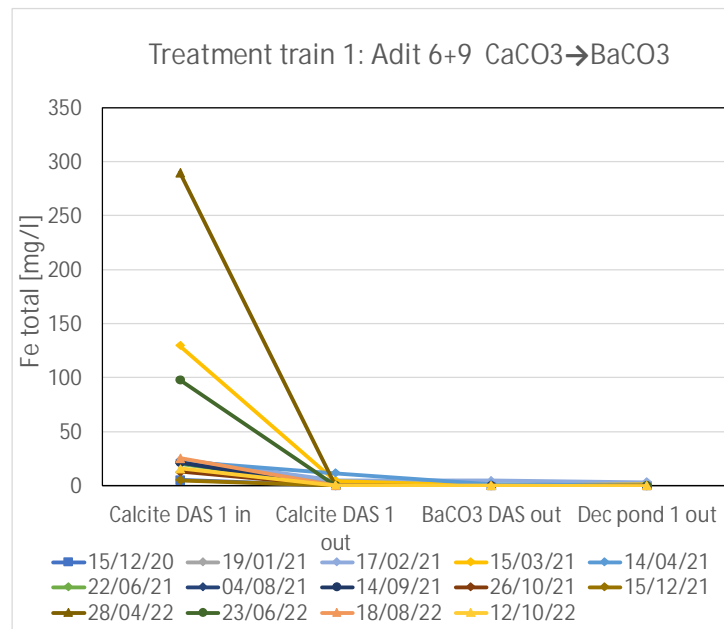
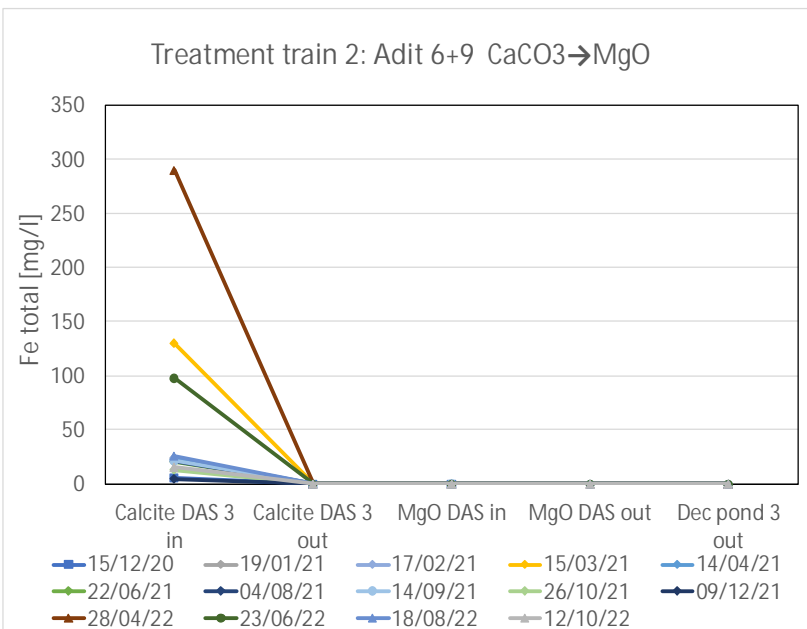
TREATMENT RESULTS - pH



- Calcite DAS produces pH 6 - pH 7.5
- MgO DAS produces pH 9.5 - pH 11.3 and pH 8.3 - pH 10 after final decantation pond
- BaCO₃ DAS produces pH 6.5 - pH 8

Cwm Rheidol

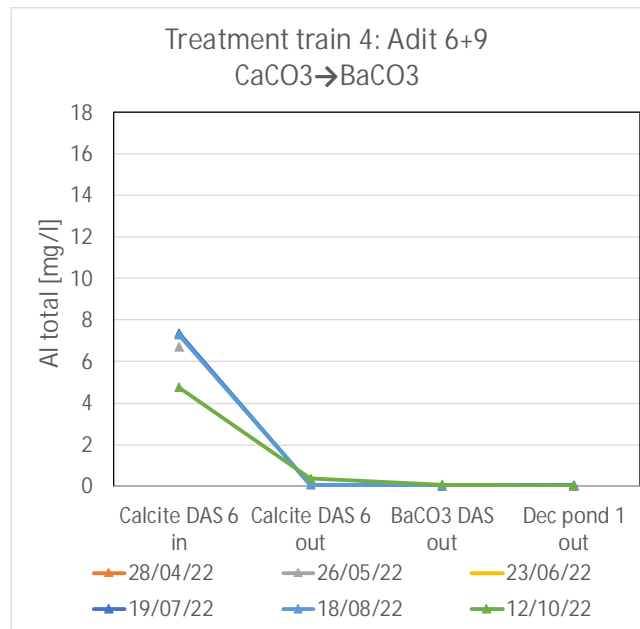
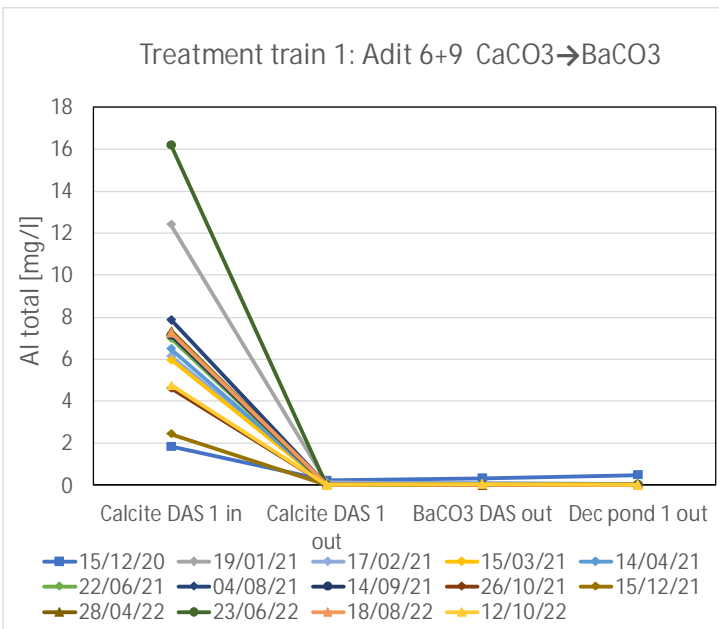
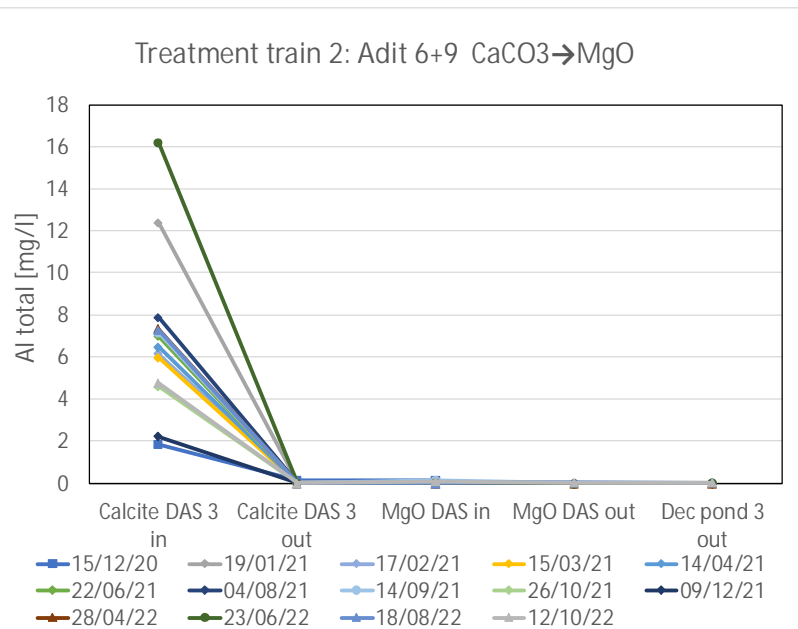
TREATMENT RESULTS - IRON



- Near-complete iron removal from Adit 6+9 water in Calcite DAS

Cwm Rheidol

TREATMENT RESULTS - ALUMINIUM

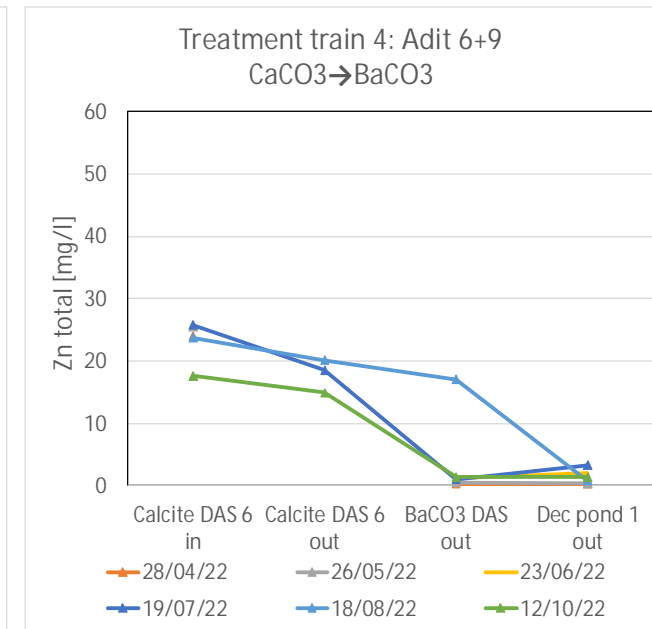
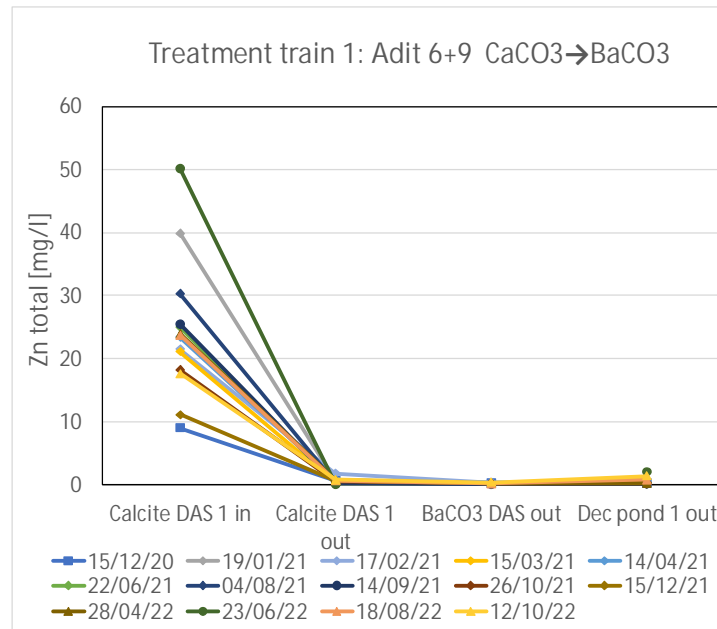
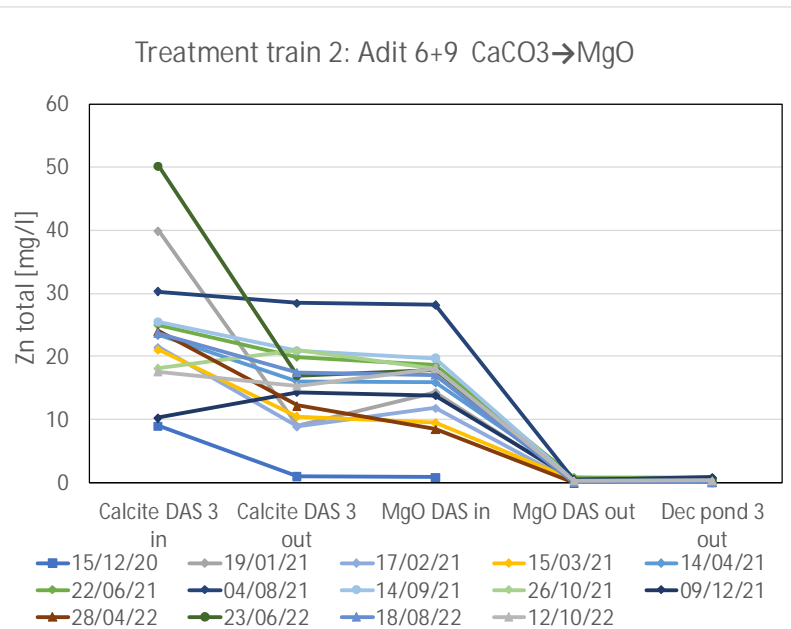


- Near-complete Al removal in Calcite DAS



Cwm Rheidol

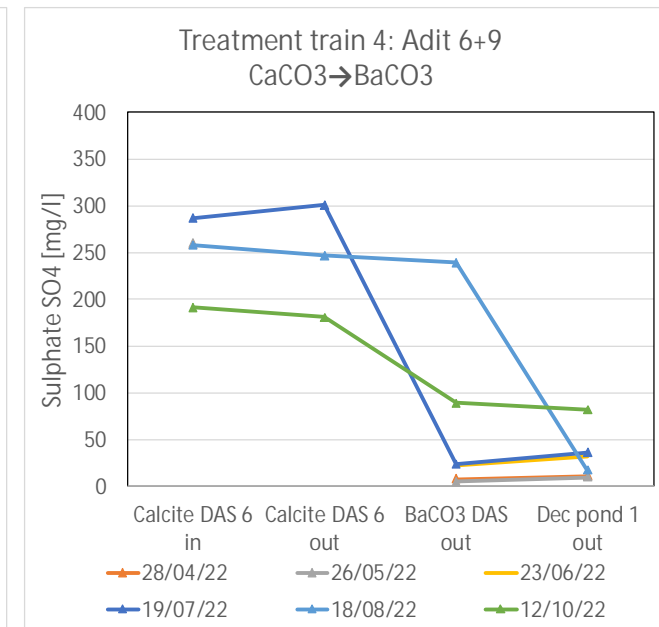
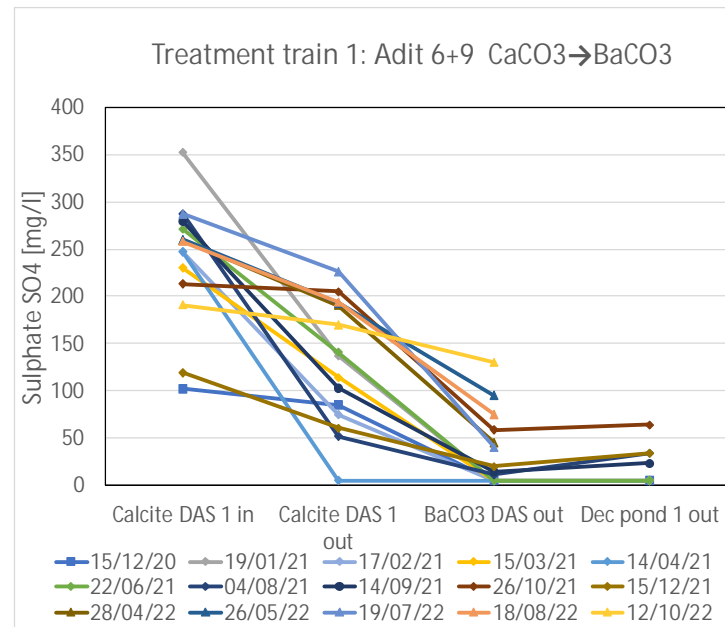
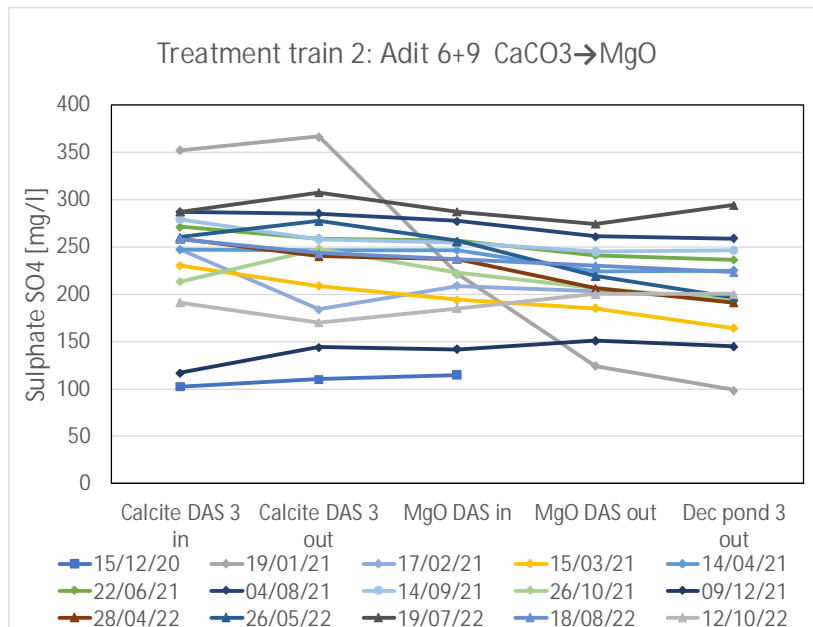
TREATMENT RESULTS - ZINC



- 5-35 mg/l Zn removal in Calcite DAS of treatment train 2, near-complete removal in MgO DAS
- Near-complete Zn removal in Calcite DAS of treatment train 1 (sulphate reduction)
- Around 5 mg/l Zn removal in Calcite DAS of treatment train 4, reduction to 0.3-3.3 mg/l in BaCO₃ DAS

Cwm Rheidol

TREATMENT RESULTS - SULPHATE



- Some sulphate removal in Calcite DAS of treatment train 1 (sulphate reduction)
- No sulphate removal in Calcite DAS of treatment train 4
- Decrease of sulphate to < 100 mg/l in BaCO₃ DAS of trains 2 and 4



Cwm Rheidol

• CONTAMINANT REMOVAL EFFICIENCIES

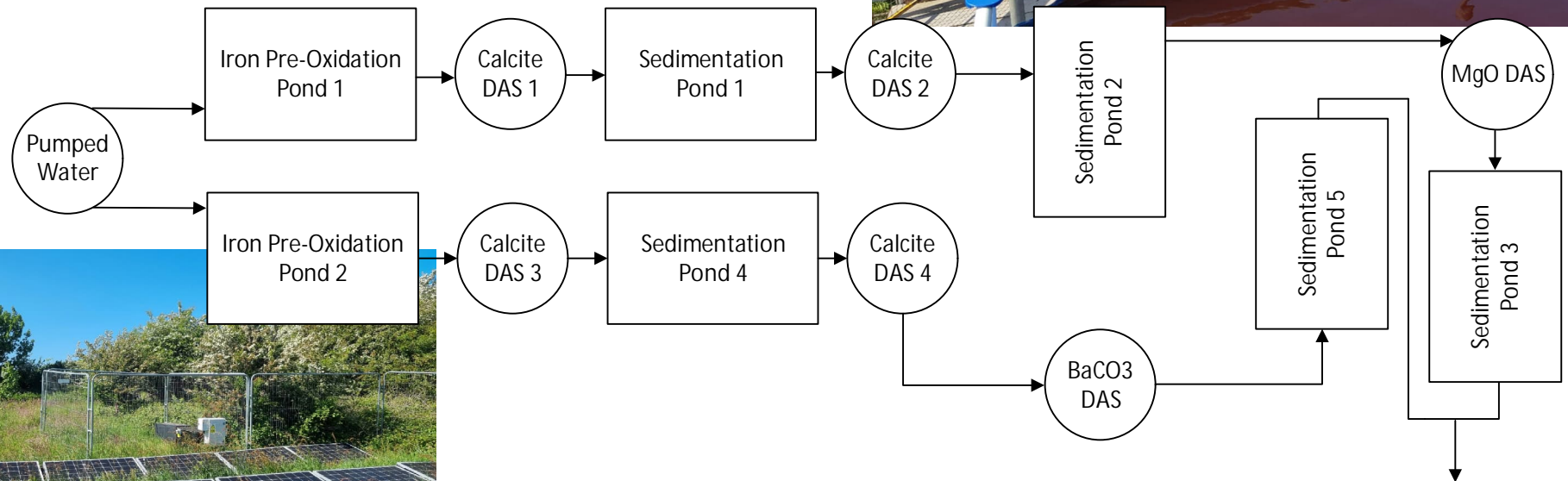
Parameter	Train 1 (CaCO ₃ +BaCO ₃)	Train 2 (CaCO ₃ +MgO)	Train 4 (CaCO ₃ +BaCO ₃)
Al	99.6%	99.8%	99.5%
Cd	99.8%	99.3%	98.4%
Cr	79.2%	79.2%	79.2%
Cu	83.7%	98.1%	97.0%
Fe	99.4%	99.8%	99.8%
Mn	56.1%	99.0%	74.5%
Ni	98.9%	99.3%	79.9%
Pb	99.3%	99.7%	99.7%
SO ₄	97.6%	9.6%	89.3%
Sr	-1442.9% (↑ ~1 mg/l)	57.1%	-557.1% (↑ ~0.5 mg/l)
Zn	99.0%	98.0%	94.8%



Parys Mountain

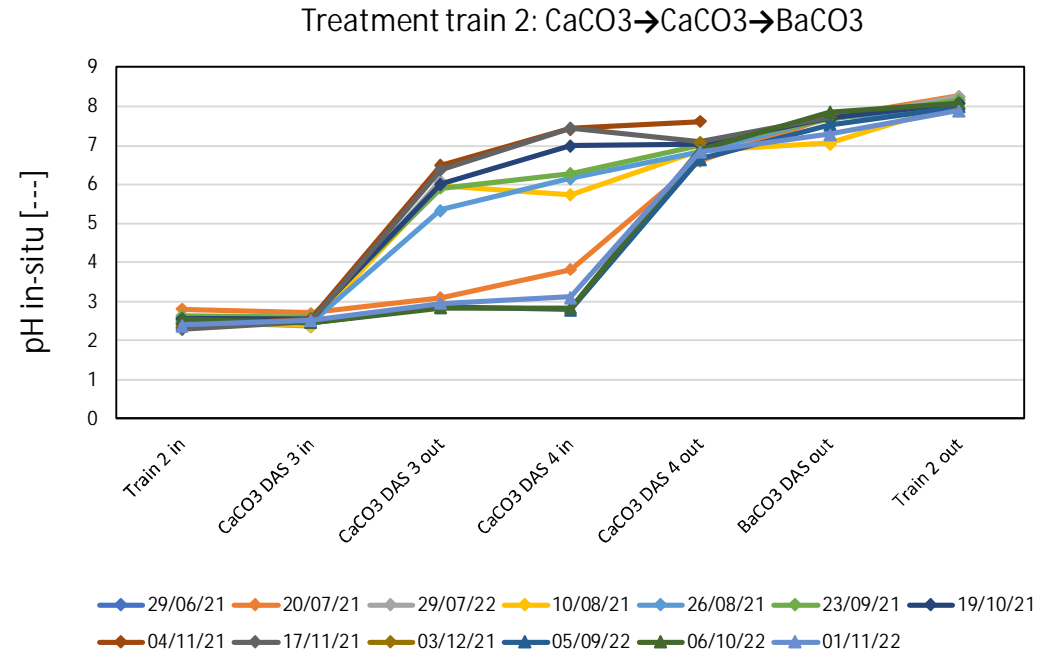
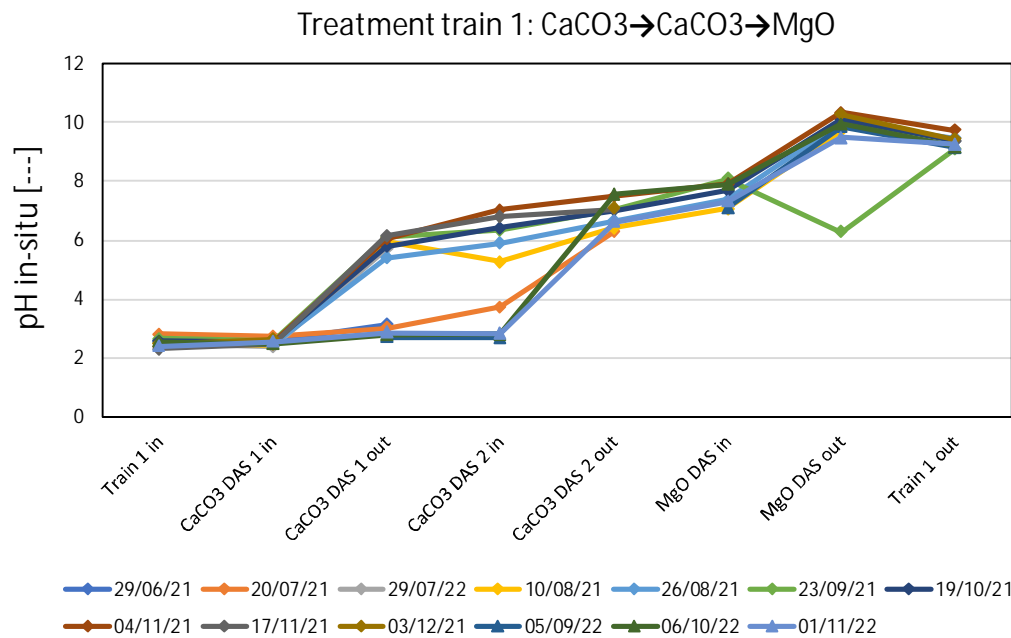
- FIELD TRIAL SETUP

- Two treatment trains
- Powered by solar- and wind- pump system



Parys Mountain

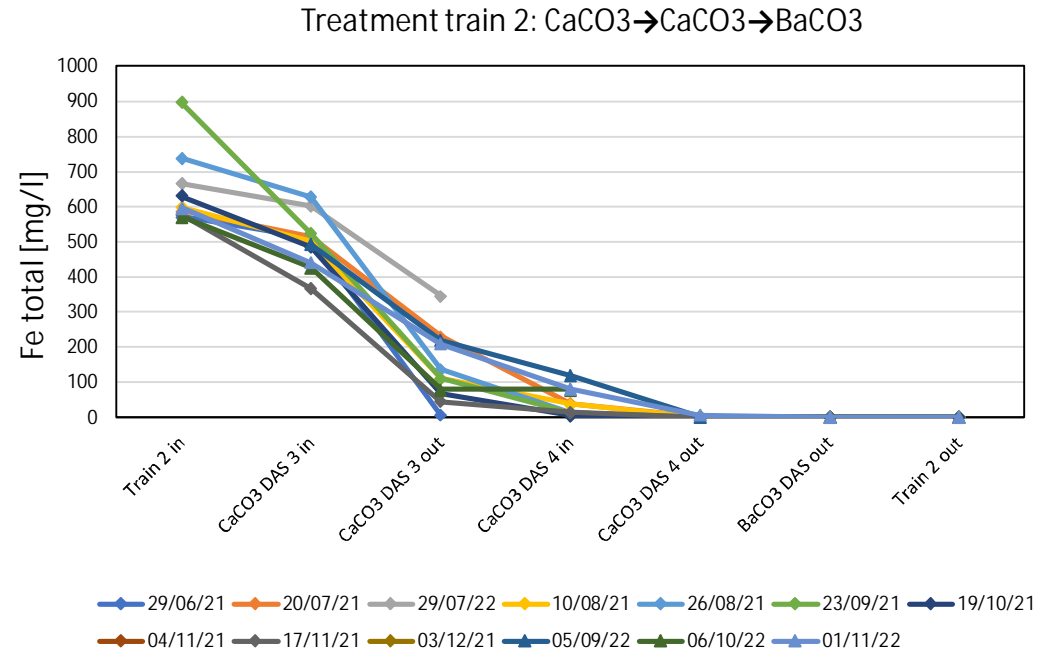
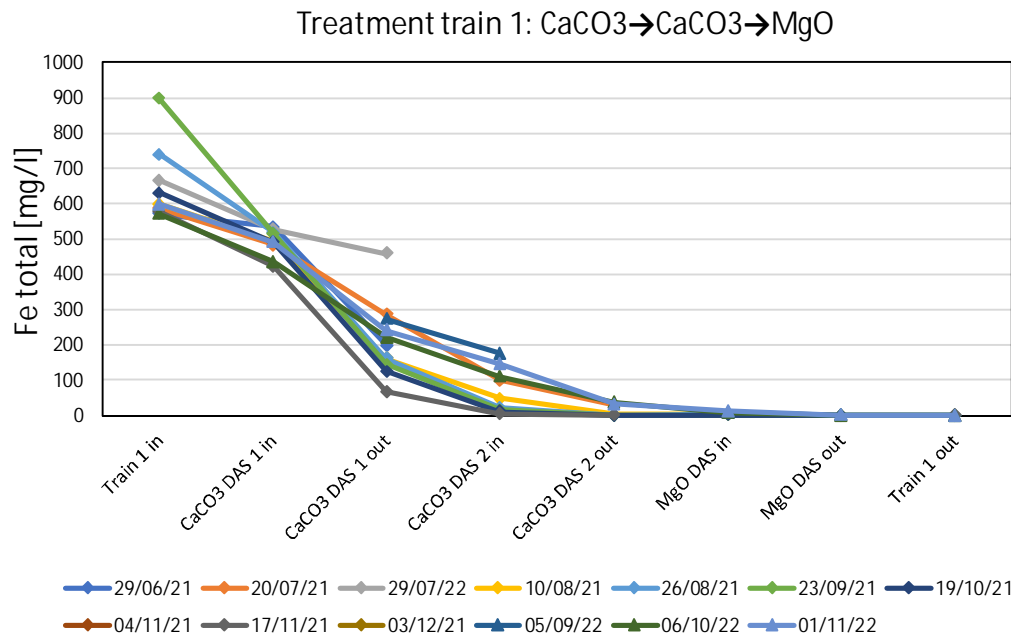
TREATMENT RESULTS - PH



- Increase from pH 2.5 to pH 9.0-9.8 in Train 1 (final MgO DAS)
- Increase from pH 2.5 to pH ~8 in Train 2 (final BaCO₃ DAS)

Parys Mountain

TREATMENT RESULTS - IRON

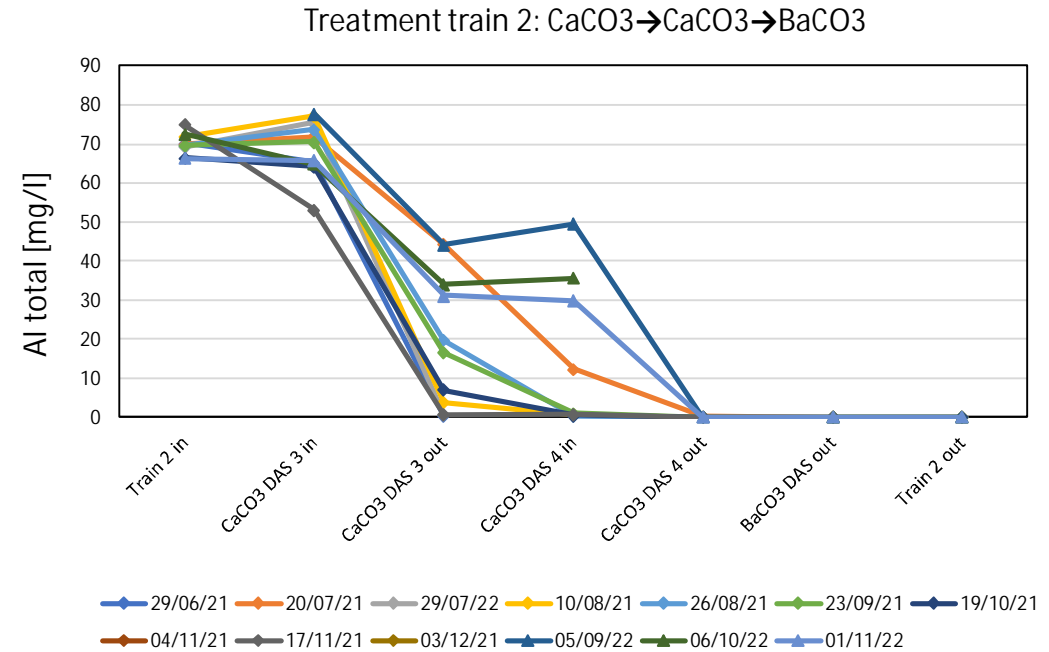
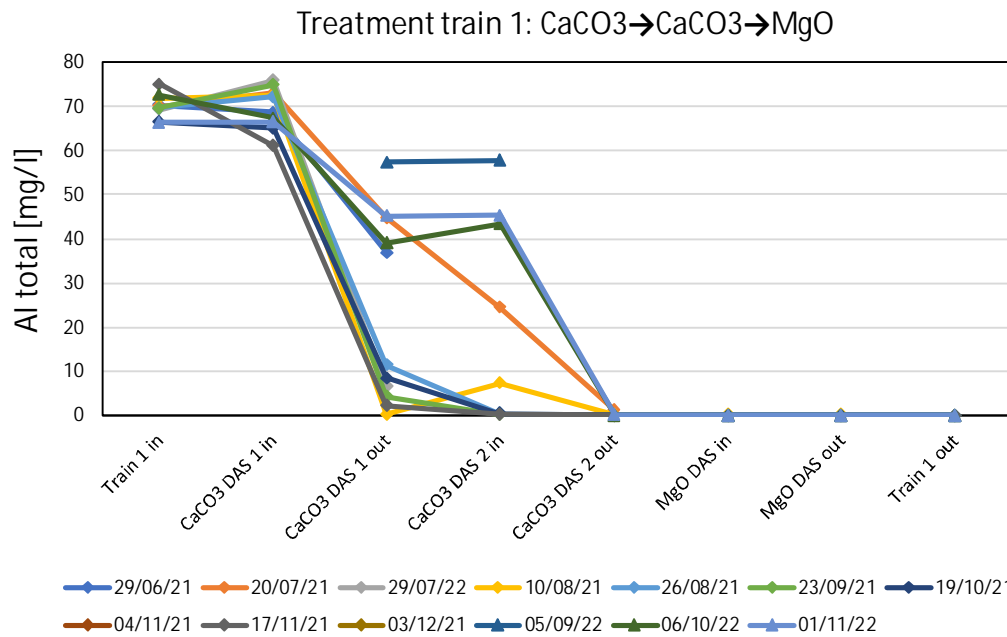


- Near-complete iron removal from inflow concentrations of 550 - 900 mg/l in both treatment trains
- Removal of about 100 - 200 mg/l in the iron pre-oxidation ponds.



Parys Mountain

TREATMENT RESULTS - ALUMINIUM

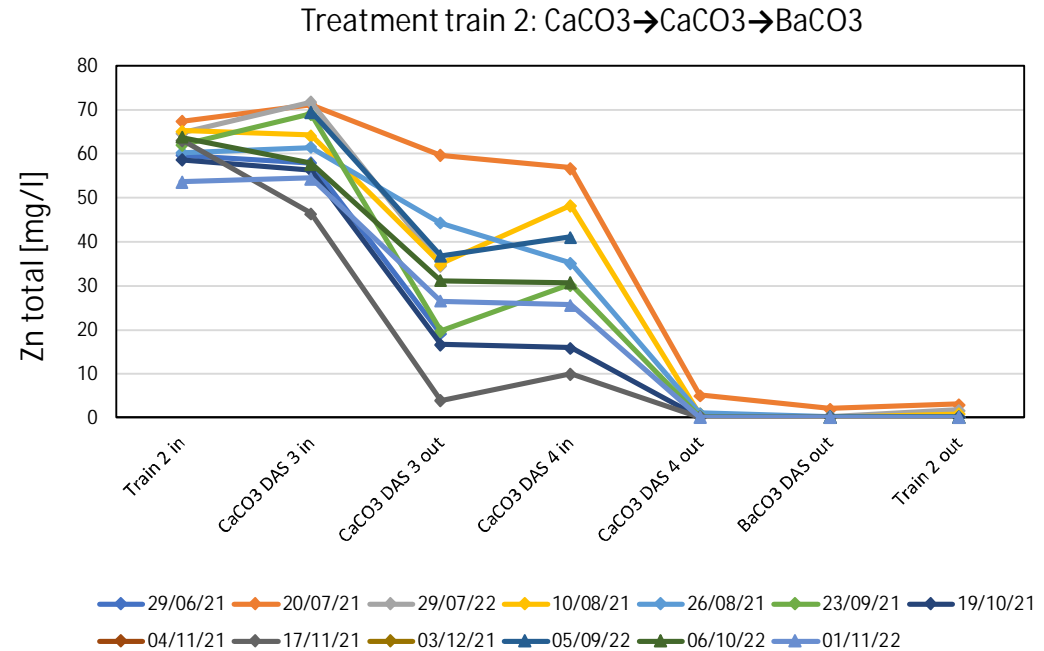
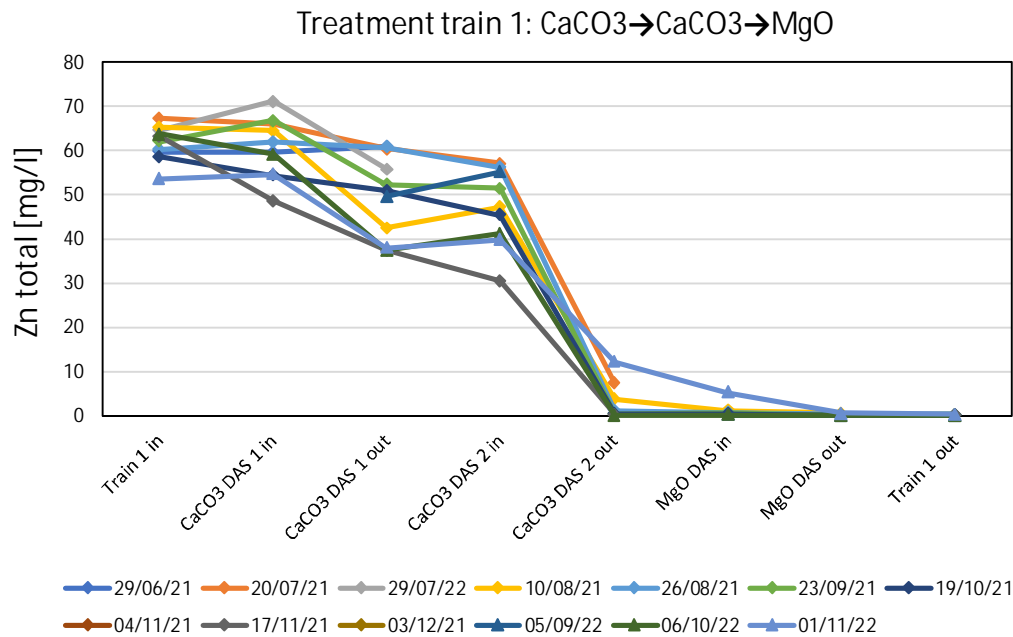


- Near-complete Al removal in Calcite DAS in both treatment trains



Parys Mountain

TREATMENT RESULTS - ZINC

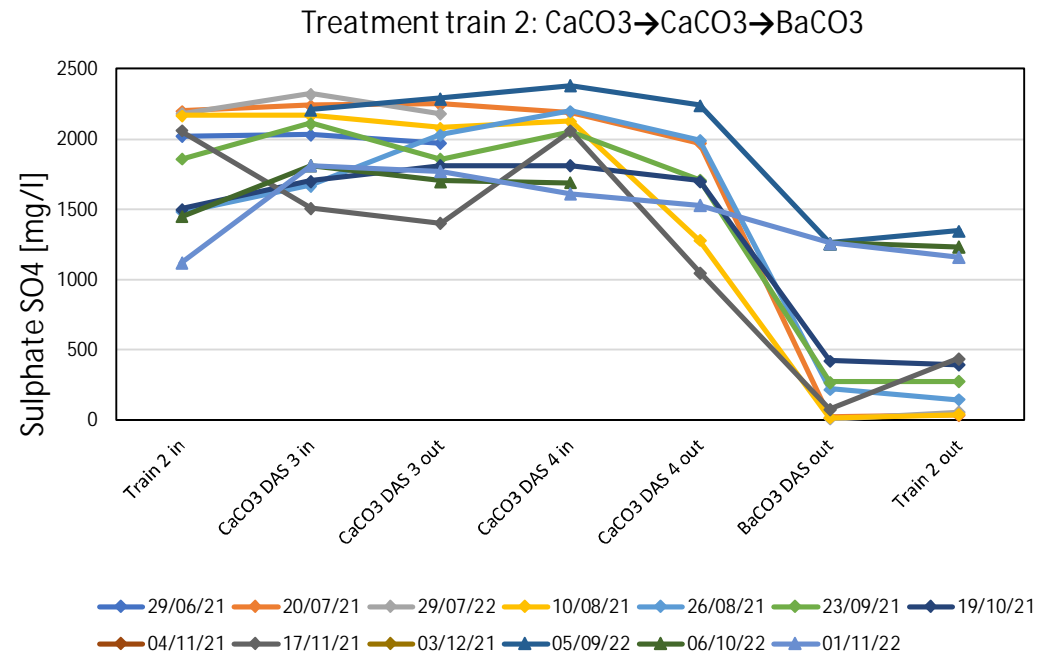
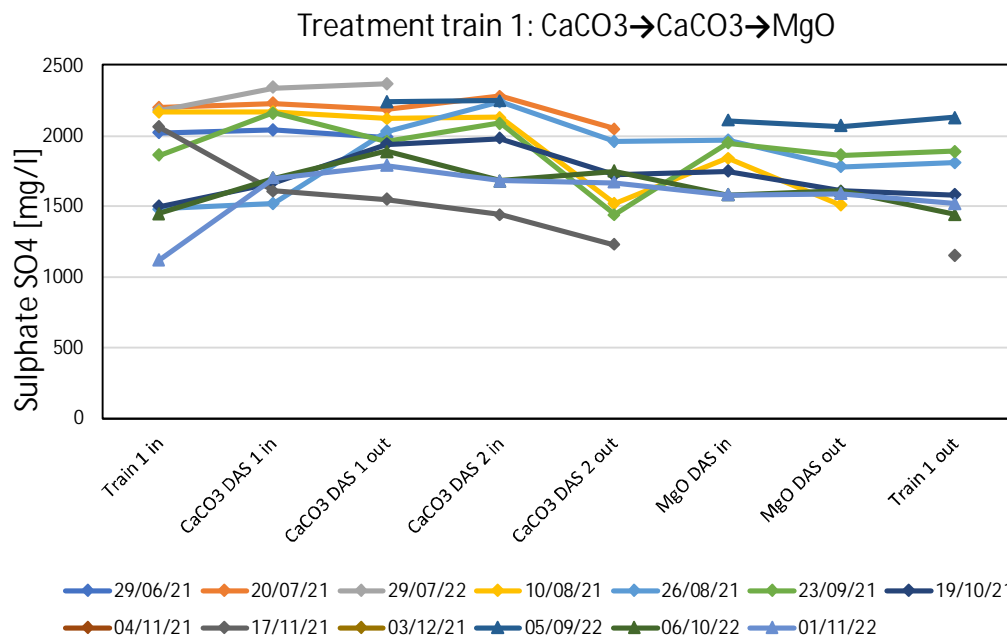


- Near-complete Zn removal in Calcite DAS of both treatment trains (sulphate reduction)



Parys Mountain

TREATMENT RESULTS - SULPHATE

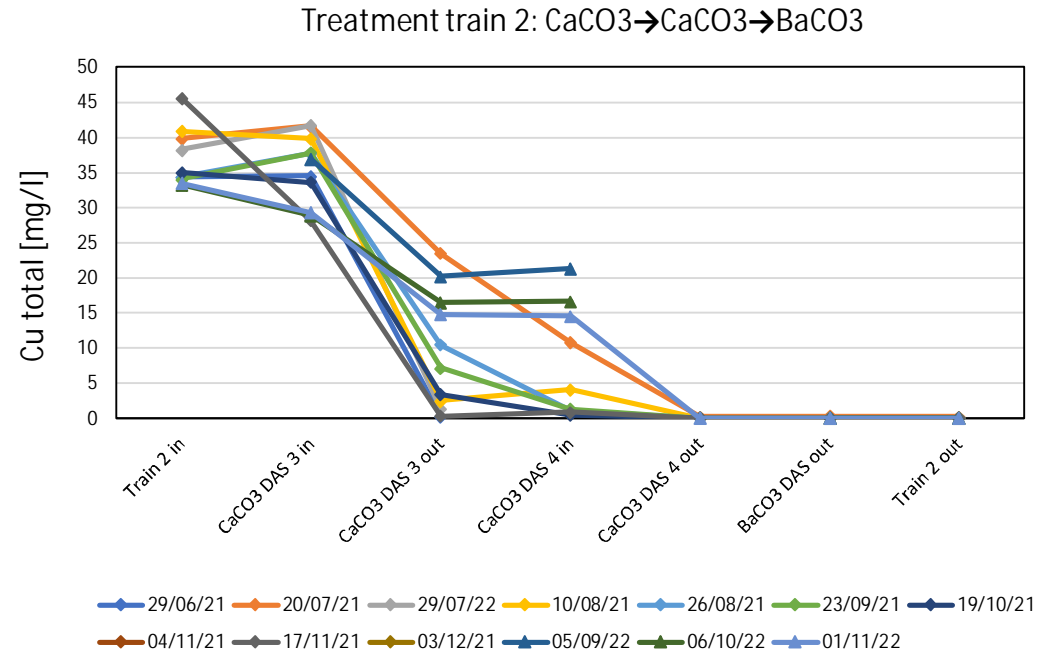
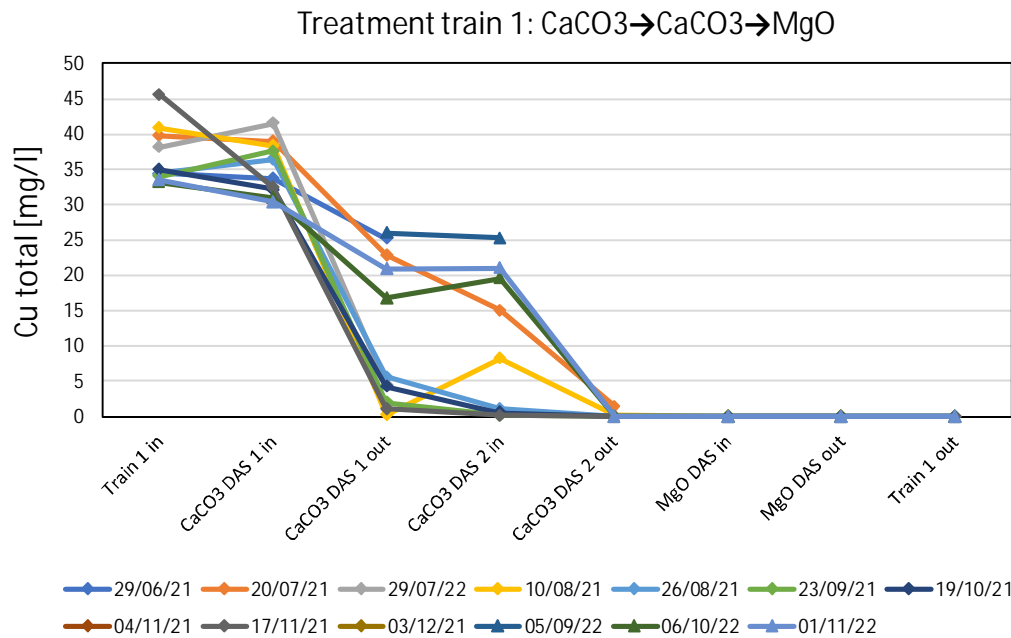


- Little sulphate removal in treatment train 1
- Decrease of sulphate to < 500 mg/l in BaCO₃ DAS of treatment train 2 in 2021, but only to < 1300 mg/l in 2022 (exhaustion of BaCO₃)



Parys Mountain

TREATMENT RESULTS - COPPER



- Near-complete copper removal in both treatment trains from inflow concentrations of up to 46 mg/l



Parys Mountain

• CONTAMINANT REMOVAL EFFICIENCIES

Parameter	Unit	Inflow	Train 1 Outlet conc.	Train 1 removal	Train 2 Outlet conc.	Train 2 removal
Al	mg/L	69.85	0.013	100.0%	0.022	100.0%
Cd	mg/L	0.146	0.00015	99.9%	0.00033	99.8%
Cr	mg/L	0.015	0.0005	96.7%	0.0005	96.7%
Cu	mg/L	36.6	0.006	100.0%	0.012	100.0%
Fe	mg/L	615	0.4	99.9%	0.26	100.0%
Mn	mg/L	17.4	0.27	98.4%	2.2	87.4%
Ni	mg/L	0.151	0.006	96.0%	0.002	98.7%
Pb	mg/L	0.02	0.002	90.0%	0.002	90.0%
SO₄	mg/L	2040	1695	16.9%	145	92.9%
Sr	mg/L	0.13	0.14	-7.7%	2.15	-1553.8%
Zn	mg/L	62.65	0.11	99.8%	0.24	99.6%



Conclusions

- At both sites, DAS achieved very significant metal removal and pH increase.
- Good long-term hydraulic performance with little clogging problems.
- MgO DAS as final treatment step shows excellent contaminant removal and steady performance, except for sulphate.
- BaCO₃ DAS as final treatment step also shows excellent contaminant removal including sulphate, but performance decreases with time.
- Compliance against GWFD - approximately half of metals meet EQS Freshwater (Tier 1 conservative review)

Thank you!

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