MATERIALS RECOVERY SYSTEMS

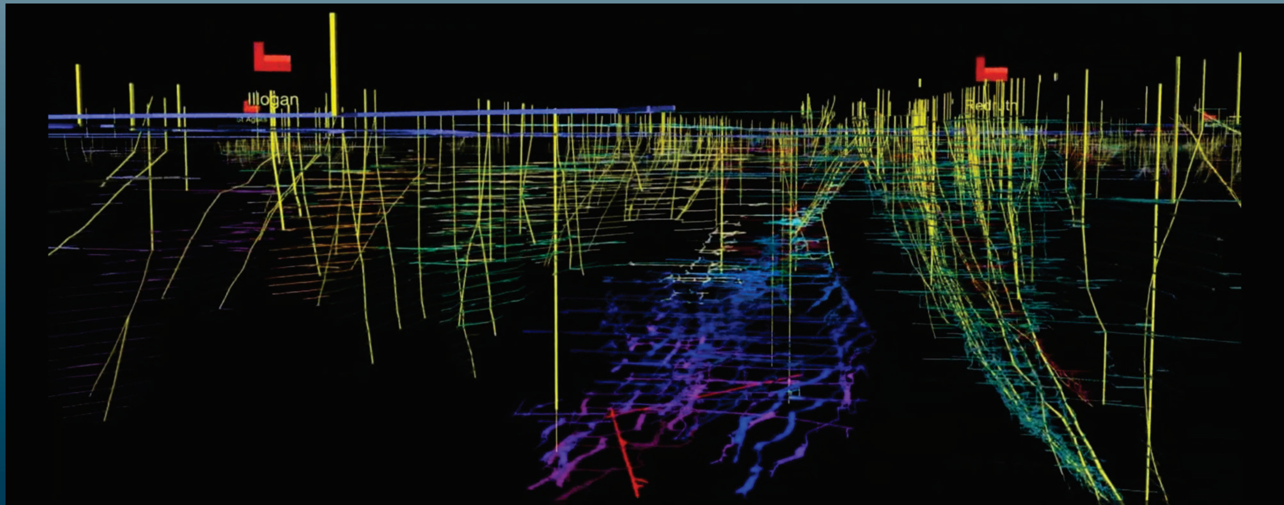
Cornish Metals

Development of a single stage High Density Sludge (HDS) process for the reopening of South Crofty Tin Mine

IMWA Presentation April 2024

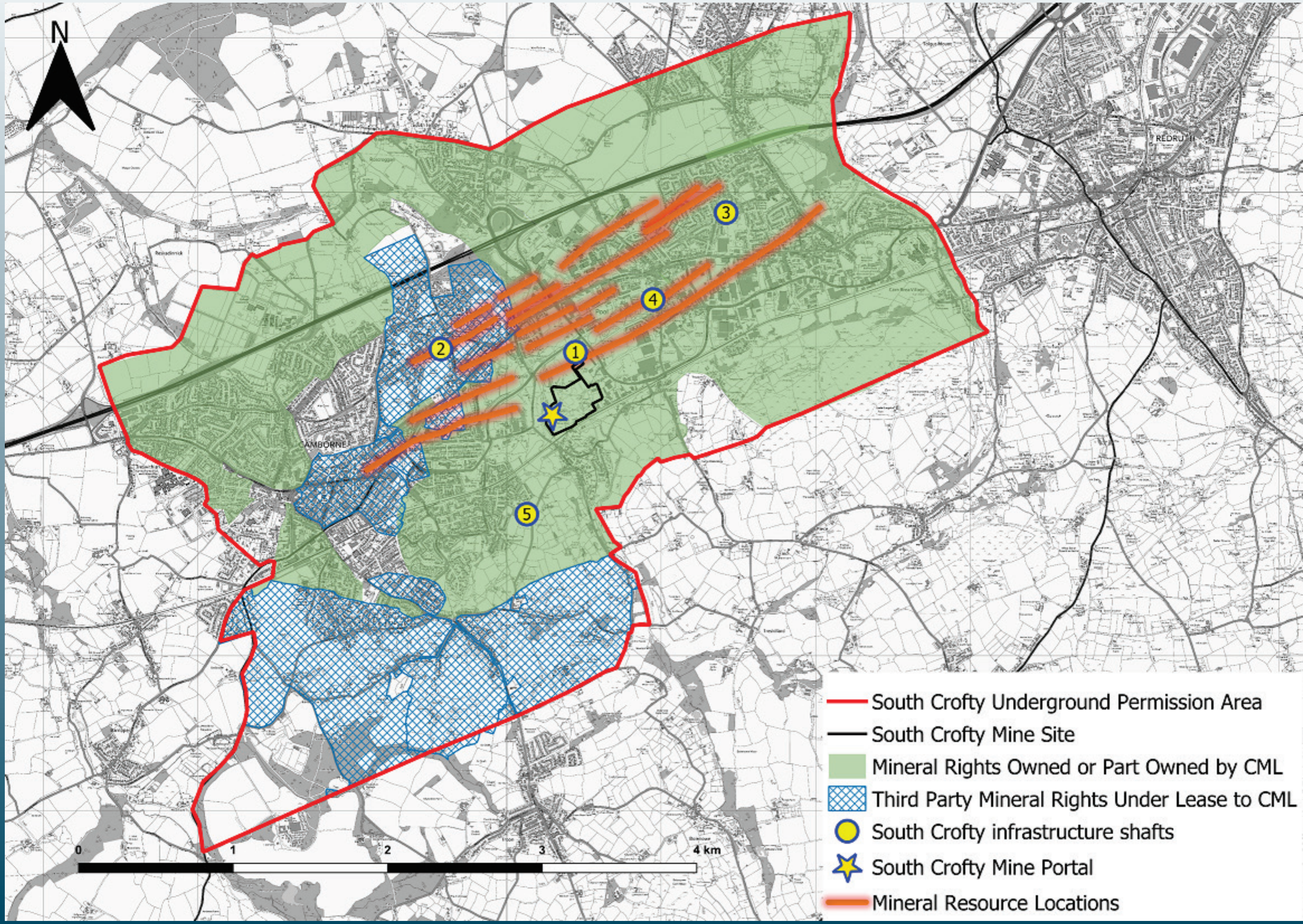
Presenter – Richard Morgan
Authors - Richard Morgan
Dr Richard Coulton
Steve Kingstone
Naomi Watson

WVTF IMWA 2024



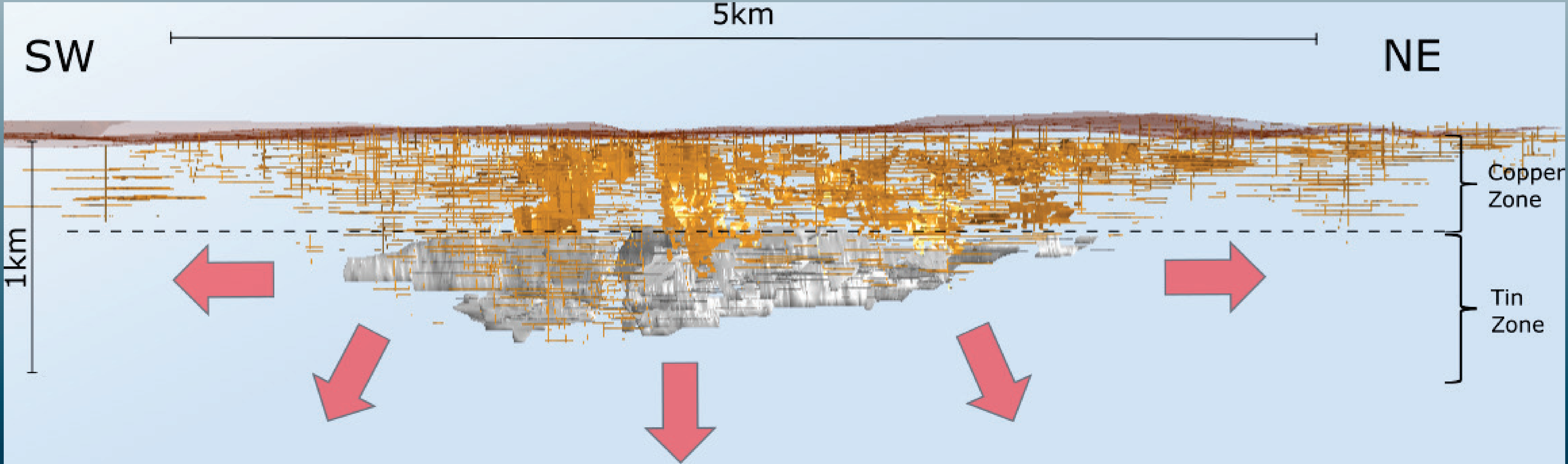
South Croft Tin Mine - Background

- Located in Camborne and Pool, Cornwall. In the South West of the UK
- Historically the Cornwall formed the centre of UK metal mining with:
    - Tin
    - Copper
    - Zinc
    - Tungsten
    - Arsenic



South Croft Tin Mine - Background

- Shallow workings mined for copper, tin, tungsten and arsenic until circa 1900 as individual small mines
- Started to work deeper primarily focusing on Tin
- Mining ended March 1998 (The last tin mine in the UK) due to the prolonged low tin price ending 400 years of mining at the site
- Mine dewatering pumps stopped and ground water allowed to rebound
    - Contaminated mine water decants via the Dolcoath deep adit (60m below shaft collar) in 2001
- Purchased by Cornish Metals 2016 with the aim to dewater and reopen



Mine Water Chemistry & Consents

- Pilot testing system fed continuously via a pump located within the old pump rising main drawing water from 350m below collar level to reduce possibility of stratified water
- Piloting in 2016/17 showed that levels of dissolved arsenic (1.6-3.2mg/L) present within the mine water which presented a challenge for treatment
- Arsenic present as arsenite (As^{3+}) and requires oxidizing to arsenate (As^{5+}) to precipitate as Ferric arsenate
- Alkalinity of 230 mg/L as $CaCO_3$
- Dissolved CO_2 of 90 mg/L

Discharge Consents

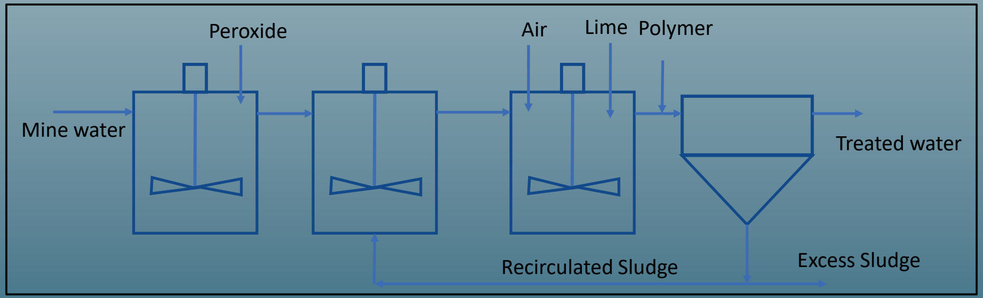
- Environment Agency issued permit to discharge treated water 2018
- Discharge flow limit set at 289 L/s
- Expected consent limits applied to Arsenic and Iron
- Additional consent applied to Manganese discharge limit 20µg/L requiring precipitation at high pH

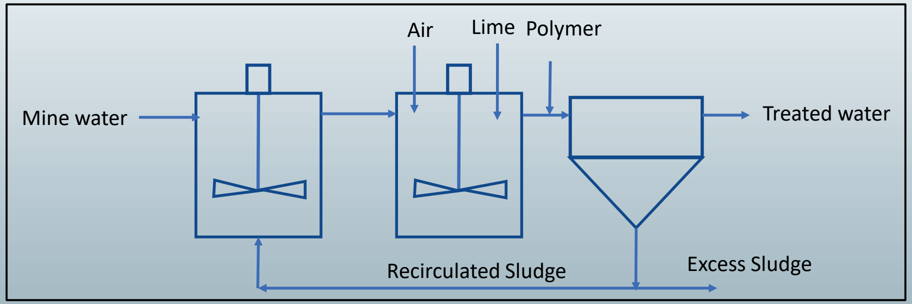
Parameter	**Mine Water**	**Consent**	**Warning level**	**Trigger level**
	2022 Trial Average	Total AA	Dissolved AA	Dissolved AA
pH	6.1	6 to 9	6.5 to 8.5	
Aluminium	890 µg/L		35 µg/L	
Arsenic	2,010 µg/L	50 µg/L	20 to 30 µg/L	40 µg/L
Cadmium	1 µg/L		1 µg/L	
Copper	10 µg/L	10 µg/l	5 µg/L	
Iron	44,156 µg/L		40 µg/L	
Nickel	11 µg/L		5 µg/L	
Manganese	5,140 µ/L		20 µg/L	60 µg/L
Zinc	70 µg/L		10 µg/L	
TSS	5mg/L			20mg/l

Conflicting conditions and implications on HDS operation

- Low pH
  - Oxidation of arsenic
  - Effective degassing of CO2

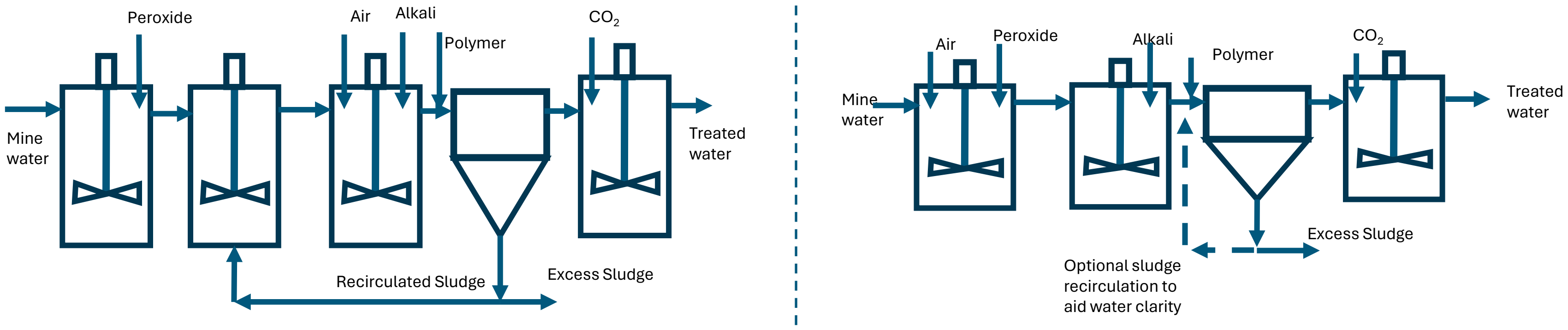
- High pH
  - Precipitation of Manganese Hydroxides





- Recirculation of sludge at high pH impacts the oxidation of arsenic within a conventional HDS plant
- 2017 pilot addressed this by oxidising with hydrogen peroxide in a separate stage
- High operating pH causes large mass of generated sludge
- Attempts to add degassing reduced sludge generation rates but impacted discharge arsenic level consent
- Presence of high levels of arsenic in a high pH reactor with lime alkali allows formation of highly soluble Calcium arsenate

Trial Process Summary



	2017 Process HDS				Single pass peroxide & precipitation			
Alkali reagent	**Caustic**	Caustic	Lime	Lime	**Caustic**	**Caustic**	Lime	Lime
Degassing	**No**	Yes	No	Yes	**No**	**Yes**	No	Yes
As consent	**Yes**	No	No tested	No	**Yes**	**Yes**	Yes	No
Mn consent	**Yes**	Yes	Not Tested	Yes	**Yes**	**Yes**	Yes	Yes
Cu consent	**Yes**	Not tested	Not Tested	Not Tested	**Yes**	**Yes**	Yes	Yes
Sludge Generation	**370 mg/L**	150 mg/L	>475 mg/L Predicted	240 mg/L	**210 mg/L**	**140 mg/L**	475 mg/L	240 mg/L
Alkali Consumption	**320 mg/L**	105 mg/L	>385 mg/L Predicted	160 mg/L	321 mg/L	60 mg/L	385 mg/L	70 mg/L
Clarification & Thickening	Difficult due to mass of sludge being handled (i.e. 26 x precipitated mass)				Low mass but low density Conventional Clarifiers + thickener + centrifuge?			

A different approach is required!

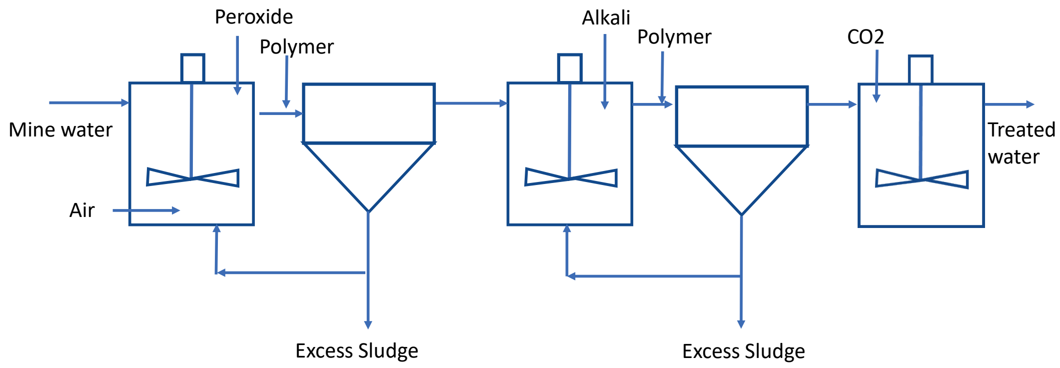
2017 pilot showed consent was achievable, but was inefficient

- Peroxide introduction prior to conventional HDS forces rapid oxidation and precipitation of iron preventing the formation of HDS
- This design would produce 150m3/d of slurry @ 8%w/w
- Research from 2018/19 shows HDS can be formed in a single reactor using hydrogen peroxide

Therefore, treat this as a two-part problem

- Step 1 - Oxidise the arsenic and iron in a single stage HDS plant
- Step 2 - Raise the pH of the supernatant water with lime to precipitate manganese hydroxides

- Trialled in 2022 at 1.3 m3/hr using two pilot plants, one focusing on each step



Step 1 – Arsenic & Iron Removal

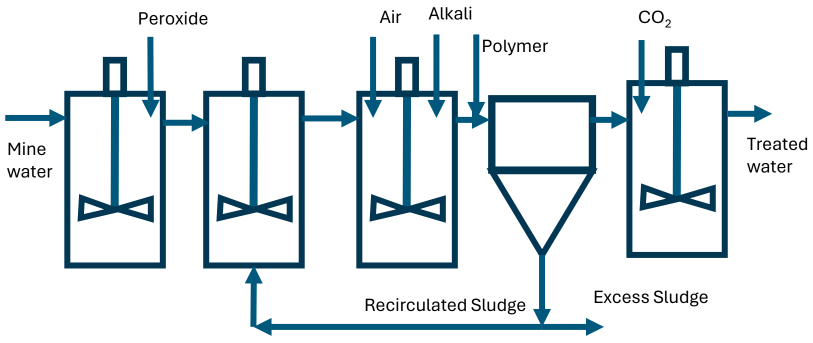
- Mine water pumped into reactor with recirculated sludge added in premix chamber
- Degassing flow of up to 3:1 (air : water) used to remove CO_2
- Hydrogen peroxide added proportionally based on operator calculated dose per litre of mine water
- Reactor operates at pH 5.7-6.1 allowing
  - Rapid oxidation of arsenic
  - Effective degassing of CO_2 from mine water
  - Consumption of bicarbonate alkalinity
- Flocculent added prior to flash mixing and settlement of solids within lamella clarifier
- Sludge generated at a rate of 71 mg/L and is 43% w/w Iron and 2-3% w/w Arsenic

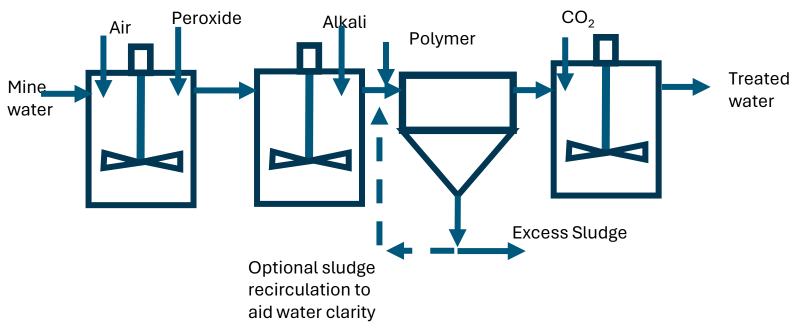
Step 2 – Manganese Removal

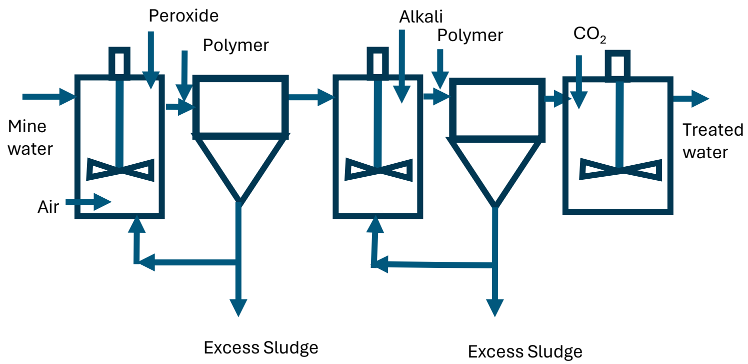
Step 2 – Manganese Removal

- Mine water flows from arsenic removal clarifier overflow into reactor with recirculated sludge added in premix chamber
- Lime slurry (5%w/w) is added to raise the reactor pH
- Reactor operates at pH 9.9-10.3 allowing precipitation of manganese hydroxide below consented discharge level
- Due to reduction of bicarbonate alkalinity in step 1 lime demand is lower
- Flocculent added prior to settlement of solids
- Sludge is generated at 80 mg/L and contains 8 – 11% Manganese w/w
- Supernatant water from the manganese removal clarifier is then pH corrected to pH 8 using CO2

Trial Process Summary







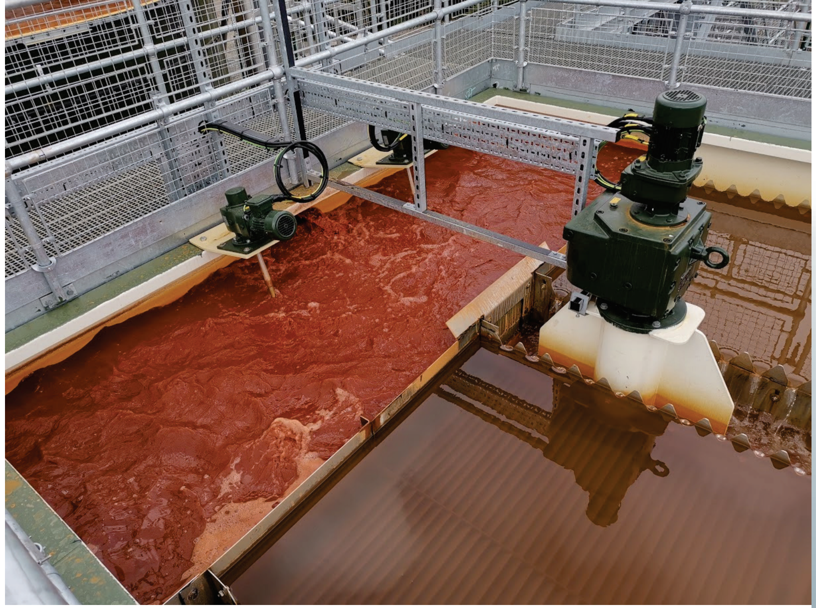
	2017 Process HDS				Single pass peroxide & precipitation				Two stage peroxide HDS
Alkali reagent	**Caustic**	Caustic	Lime	Lime	**Caustic**	**Caustic**	Lime	Lime	**Lime**
Degassing	**No**	Yes	No	Yes	**No**	**Yes**	No	Yes	**Yes**
As consent	**Yes**	No	No tested	No	**Yes**	**Yes**	Yes	No	**Yes**
Mn consent	**Yes**	Yes	Not Tested	Yes	**Yes**	**Yes**	Yes	Yes	**Yes**
Cu consent	**Yes**	Not tested	Not Tested	Not Tested	**Yes**	**Yes**	Yes	Yes	**Yes**
Sludge Generation	**370 mg/L**	150 mg/L	>475 mg/L Predicted	240 mg/L	**210 mg/L**	**140 mg/L**	475 mg/L	240 mg/L	**150 mg/L**
Alkali Consumption	**320 mg/L**	105 mg/L	Not tested	160 mg/L	321 mg/L	60 mg/L	385 mg/L	70 mg/L	**55 mg/L**
Clarification & Thickening	Difficult due to mass of sludge being handled (i.e. 26 x precipitated mass)				Low mass but low density Conventional Clarifiers + thickener + centrifuge?				Low mass forms HDS in both stages

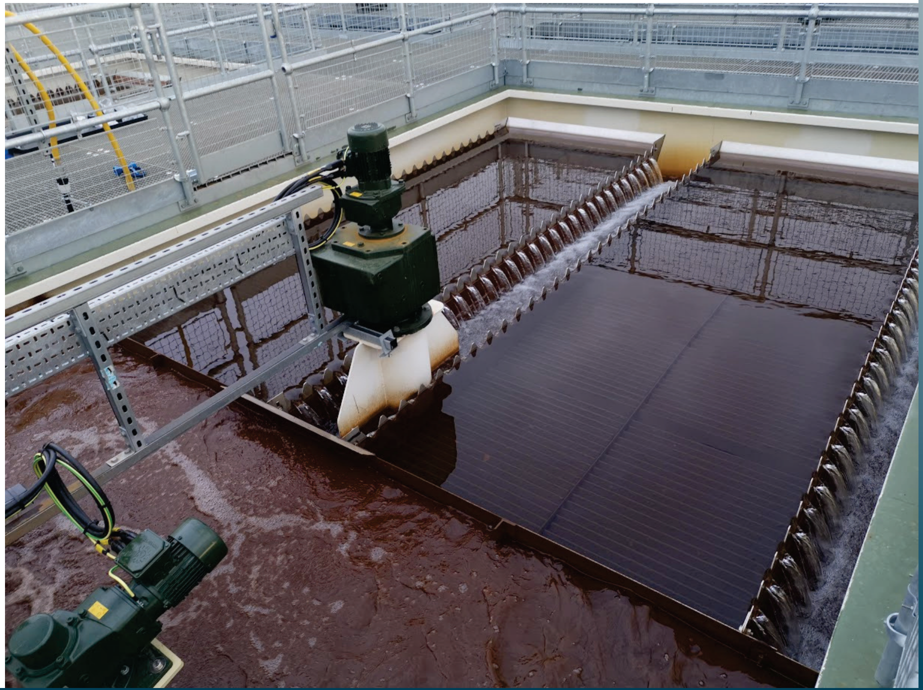
Scaling Up

- Dewatering project given the go ahead in August / September 2022
- Mine to be dewatered from New Cooks kitchen shaft
  - Initially pumped from 350m below collar via 2No. 950 kW submersible borehole pumps
  - Once dewatered to this level a pump station is to be established and the submersible pumps lowered further down the shaft
- Plant to treat 1050 m^3/hr to be constructed using 2 Step Hydrogen peroxide HDS process
  - Plant consists of three identical treatment streams each treating 97 l/s
- Sludge produced to be thickened under gravity
  - Initially tanked to tailings facility at nearby Wheal Jane
  - Once the mine is operational to form part of the paste backfill

Dewatering the Mine

- Commissioning
  - Dry commissioning of control systems late September 2023
  - Process Commissioning October 2023
- Plant official opening 26th October 2023
  - Mine water pumps started and treated watered returned to mine
- Discharge to environment 13th November 2023
  - HDS established and 7 days of compliant running achieved
  - Discharge via adit system now fitted with a 75 kW hydroturbine





Five Months Later

- Mine water treated
  - 2 million cubic meters treated as of April 2024
  - Water level in mine now 280m below shaft collar
  - Pumping rate slowed to allow shaft refurbishment works
- Step 1 – Iron & Arsenic Removal
  - Sludge production 78-92 mg/L with 43% Iron and 3% Arsenic w/w
  - Discharge arsenic level (April 24) averaging 6 µg/L
- Step 2 – Manganese Removal
  - Sludge production 70 mg/L with 8-12% Manganese w/w
  - pH of step 2 reaction tank adjusted to meet manganese target level of 20 µg/L
- Red river quality improving
  - South Crofty no longer decants untreated mine water
  - Treated mine water is diluting pollution from surrounding mines
- Sludge from both Step 1 & 2 thickened under gravity to 32%w/w for disposal

Acknowledgements

Special Thanks to Owen Mihalop, Steve Tarrant and Phil Reynolds and the wider team from Cornish Metals

Thanks are given to fellow authors

- Dr R Coulton
- Steve Kingstone
- Naomi Watson

Any Questions?

WVTF IMWA 2024