Performance of the largest upflow mussel shell bioreactor in New Zealand for the treatment of AMD

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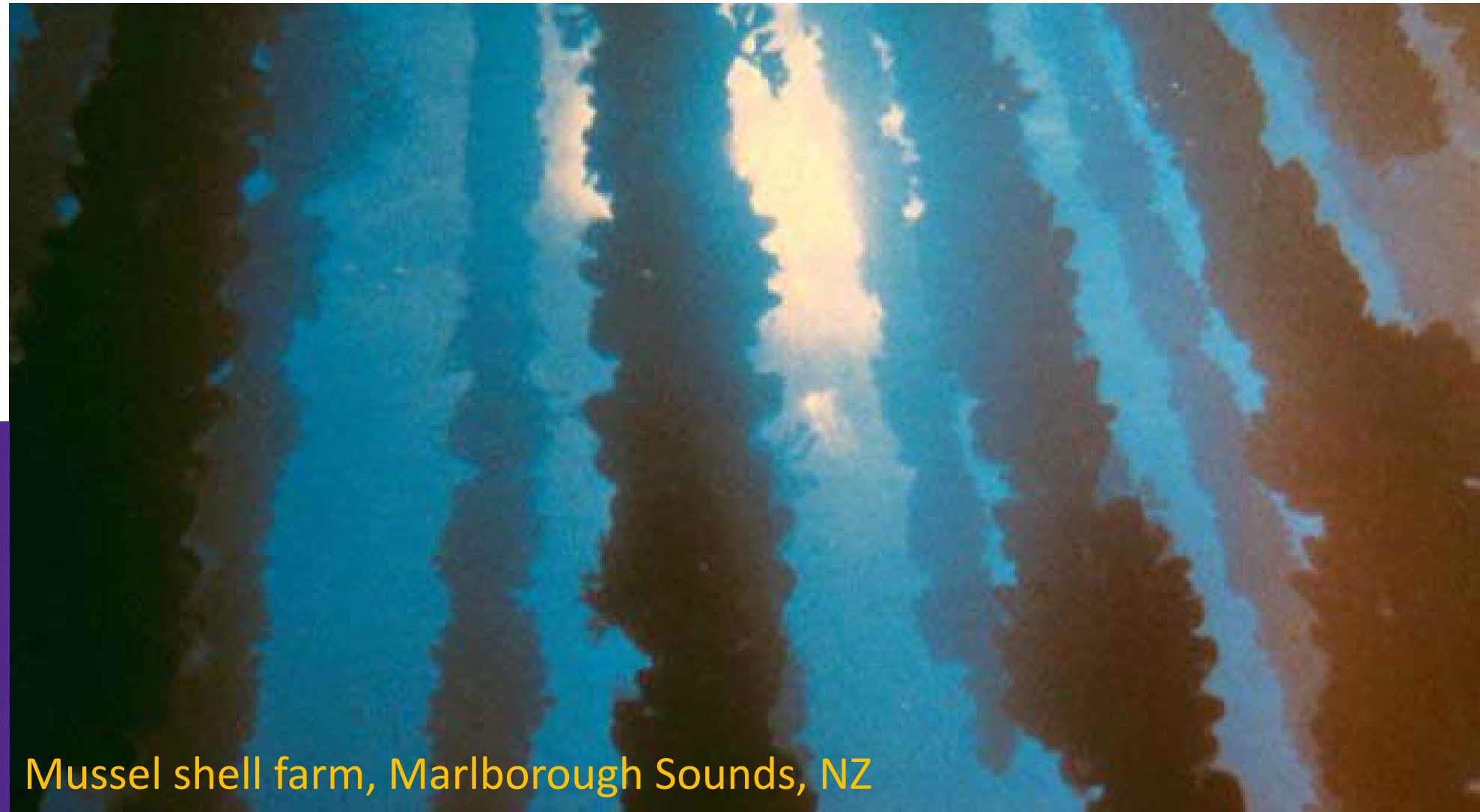
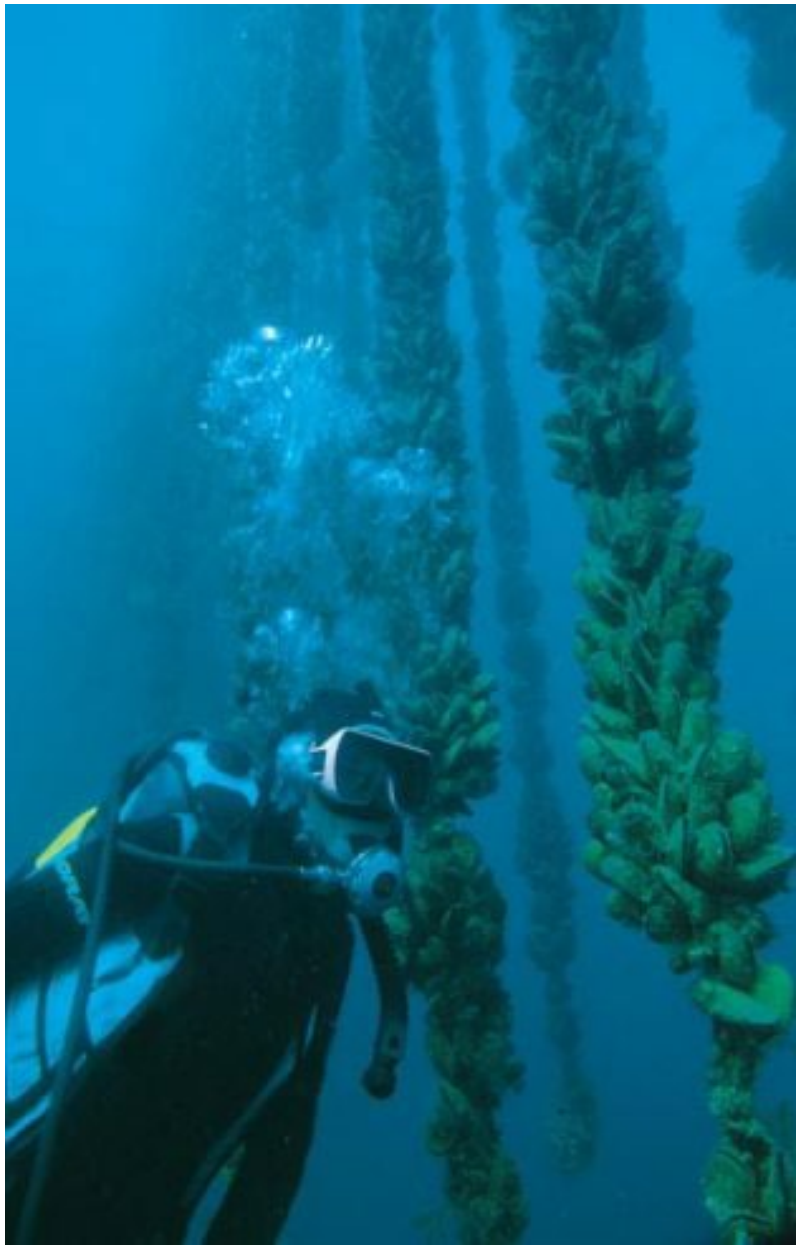


Mussel shell farm, Marlborough Sounds, NZ

Outline

- The New Zealand Greenshell Mussel
- Mussel Shell reactors for AMD treatment
- Full-scale installation at Echo Mine
- Results and Discussion

The Greenshell Mussel
(Perna canaliculus)



#1 seafood export

~ $600 M/year

The shells stay in New Zealand

- ~70,000 tonnes shell waste annually
- Approx 10% waste mussel meat

Waste mussel shell mountain near Havelock (note seagulls)

Mussel Shell Reactors

- Early experiments
  - As a replacement of limestone in bioreactors
  - Later trialed as a shell-only reactor
    - More effective than limestone
    - Minimal armouring
- Several full-scale reactors constructed
  - Fe, Al hydroxides accumulate at top
  - SRB activity with TE sulfides forming at depth

Craig McCauley (PhD 2007)

Ben Uster (PhD 2015)

Paul Weber, Manchester Street, Stockton (2010)

Stockton

Escarpment

Rockies

Coalgate

Hydroxides accumulate on surface
Results in low permeability
Requires periodic removal

The up-flow mussel shell reactor

- AMD encounters highly reduced environment
- Sulfate reduction throughout reactor
- Formation Fe hydroxides prevented
- Removal of TE as sulfides
- Bicarbonate alkalinity produced through sulfate reduction, extending lifespan of shells

Echo Coal Mine
Site of largest full-scale up-flow reactor (to date)

- Reactor design based on:
  - Results of field trials (ICARD 2015)
  - Results of Bellvue full-scale reactor (IMWA 2021)

Inlet AMD

Average Flow (L/s)	14
pH	3.4
Fe (mg/L)	20.4
Al (mg/L)	4.4
Zn (mg/L)	1.0
Ni (mg/L)	0.38
Sulfate (mg/L)	1,269

Organics

- **3,000 m^3 of fresh mussel shells**
- **Harvested/processed in Havelock (260 km)**

Installation

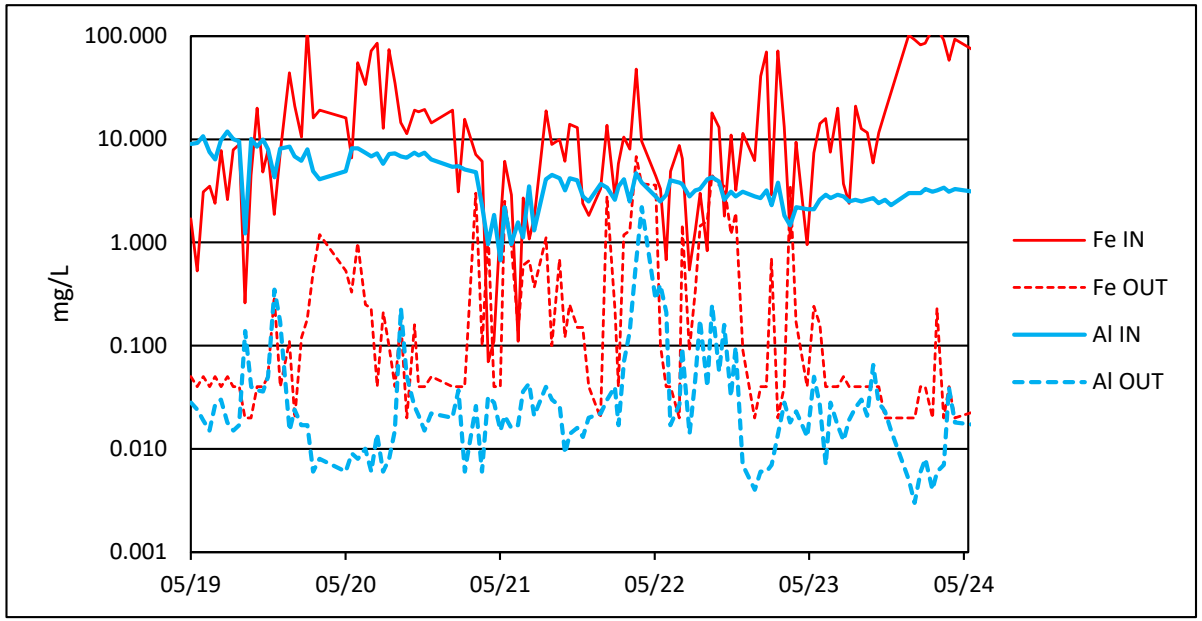
- Original AMD channel used
- 130m long, 8m wide, 3m deep

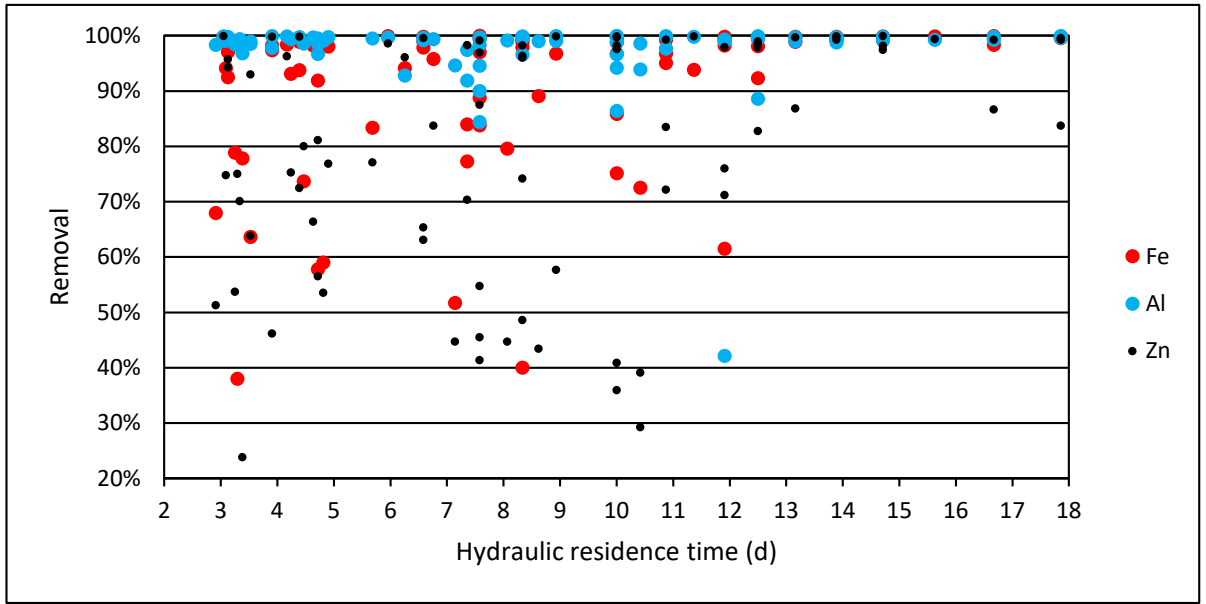
- Geofabric along the bottom
- Two perforated inlet pipelines along the length (100mm dia)
- AMD enters from header pond


HITACHI


HITACHI

- 0.7m free water over shells to maintain reducing conditions
- Outlet through culvert on downstream end
- Mix with untreated AMD and discharge to stream
- Sampled fortnightly

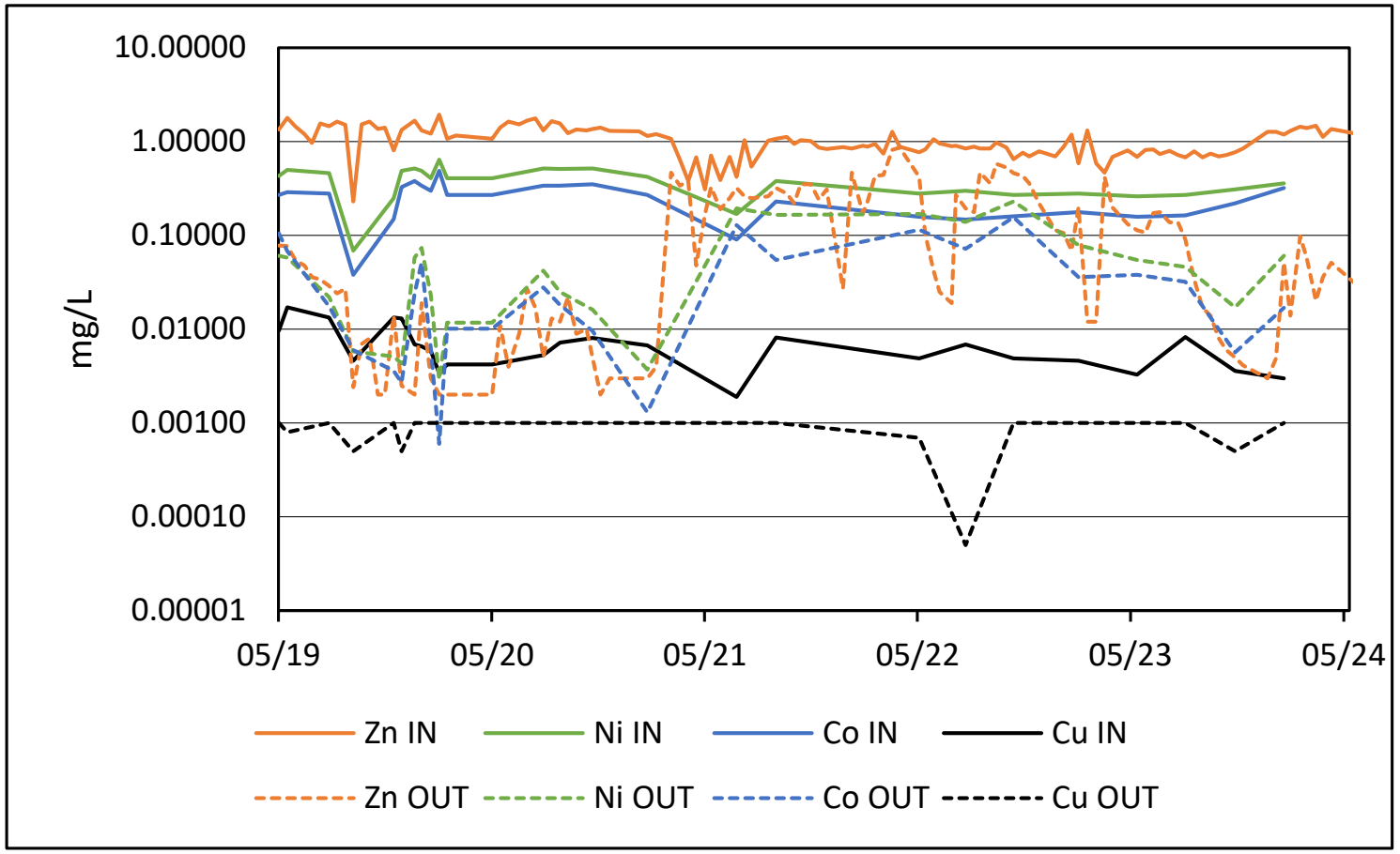




Results – metal removal

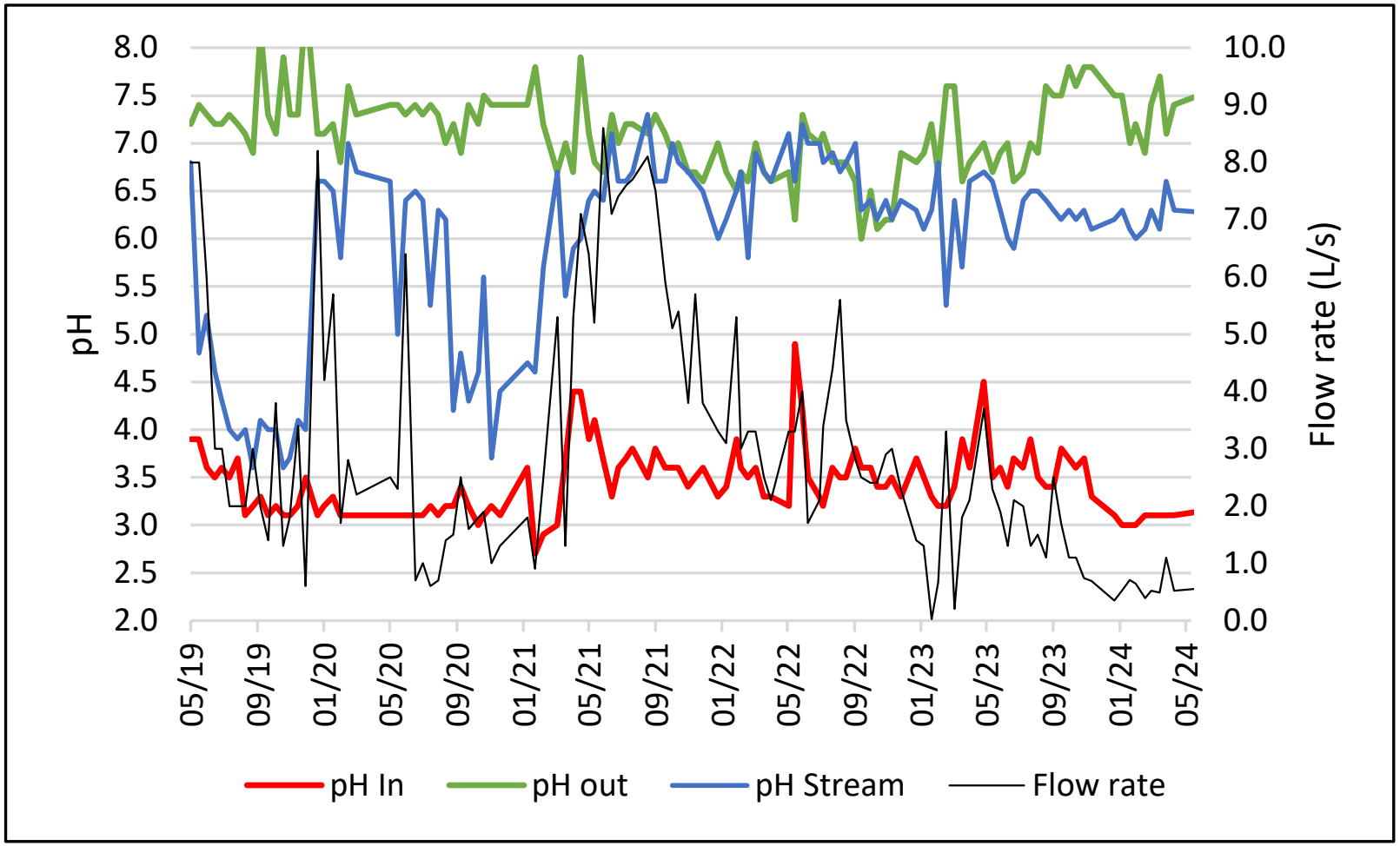
- Flow rate 3.0 L/s (average)
  - max 8.6 L/s
- HRT median 10 days
- Average metal removal:
  - Fe 86%
  - Al 98%
- Average sulfate removal 523 mg/L (46%)
- Correlated with HRT

Results – trace elements



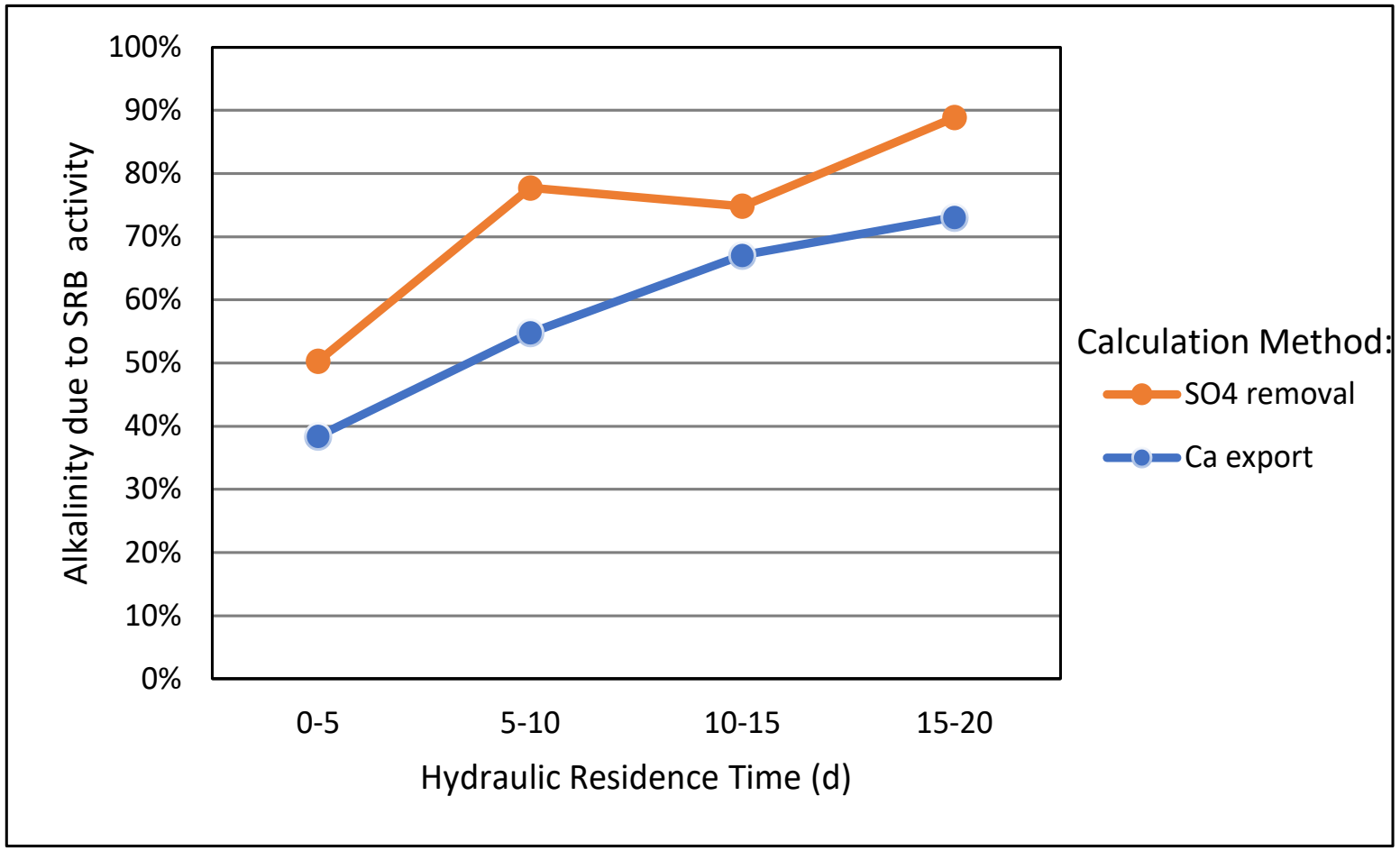
- Most trace elements removed
- Average metal removal:
  - La 98%
  - Cs 96%
  - Tl 96%
  - Pb 93%
  - Cd 84%
  - Cu 83%
  - Zn 82%
  - Ni 82%
  - Rb 82%
  - Co 81%
  - U 74%

Results – pH



- pH raised to neutral
- pH increased in receiving stream
- Initial difficulties with low flow rate resolved by periodically blasting air through piping

Alkalinity: shell dissolution vs. SRB activity



Alkalinity produced = 240 mg/L (avg)
(change in acidity and alkalinity)

Source calculated using (in mol/L):

- Ca export ($CaCO_3$ dissolution)
- Sulfate removal (SRB activity)

- 45 – 80% from SRB activity
- Longer residence times favour SRB source

Maintenance and operational/future considerations

- Perforated pipes block with time (bacteria? sulfides? hydroxides?)
  - Resolved with periodic blast of compressed air
  - Flush valve periodically opened: hydroxides expelled for brief time, then sulfides evident
- H_2S odour can be a hazard
  - H_2S meter used, levels currently not hazardous
- Lifespan of system unknown
  - Generation of alkalinity from SRB extends lifespan of shells
  - If SRB activity declines, estimated lifespan from shell dissolution in the order of decades (due to size of reactor)

April 2022

June 2024

Conclusions

- The Greenshell Mussel industry: 70,000 tonnes of shell waste per year.
  - Shells provide alkalinity in mussel shell reactors treating AMD
  - The waste contains 10% mussel meat, which provides organic material for SRB

- Mussel shell reactors
  - Down-flow configurations: Fe hydroxides accumulate on the surface reducing permeability
  - Up-flow configurations: entirely reducing, forming sulfides throughout the reactor

- The largest full-scale up-flow reactor was constructed at the Echo Coal Mine.
  - At an HRT of approximately 10 days, the reactor removes 82-98% of Fe, Al, Zn, Ni and restores pH
  - A host of trace elements are also removed (74-98%)

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