William Pulles

Development of high-rate passive sulphate removal technology

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What is passive sulphate removal

- Technology must meet definition of "passive"
- Must involve linearization of the sulphur cycle
- It is **not** simply a biological sulphate reduction technology
- Will include a sulphate reduction step and a separate sulphide removal step
- A form of sulphur must be harvested and removed from the system

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Passive sulphate reduction technology features

- Remove metals by precipitation as sulphides, hydroxides, carbonates
- Neutralise acidity through production of alkalinity
- Remove sulphate by reduction to sulphide
- Remove sulphide by oxidation to elemental sulphur
- Directly compete with active biological sulphate reduction technology for < 5Ml/d
- Niche application for mine closure situations where long-term maintenance of active systems is not viable

Definition of Passive Treatment

A water treatment system that utilises naturally available energy sources such as topographical gradient, microbial metabolic energy, photosynthesis and chemical energy and requires regular but infrequent maintenance to operate successfully over its design life

Maintenance Philosophy - Sustainability

- For passive treatment to be sustainable, must design for maintenance
- For maintenance actions to be sustainable, must be run as a profitable business
- For a profitable business to be sustainable, must generate regular cashflow

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- THEREFORE, successful passive treatment must have regular maintenance

Research programme 1994 - 2010

PASSIVE

Pulles Howard & de Lange Inc.
Golder Associates Africa

ACTIVE

Rhodes University

Phase 1: Pilot studies (gold & coal)

Phase 2: Pilot studies (VCC)

Various laboratory studies and pilot studies

Phase 3: Fundamental studies (lignocellulose, sulphides, hydraulics)

Phase 4: Sulphides

Phase 5: Pilot studies (VCC)

Phase 6: Sulphides

Phase 7: Bio-neutralization studies

Phase 8: Amenability studies

Phase 9: Passive sulphides

Phase 10: Full-scale evaluation

Main Funding Agencies: WRC; Dept Science Tech.; Anglocoal; BHP Billiton
Funding value: Both passive & active (±$10 million in 2010 value)

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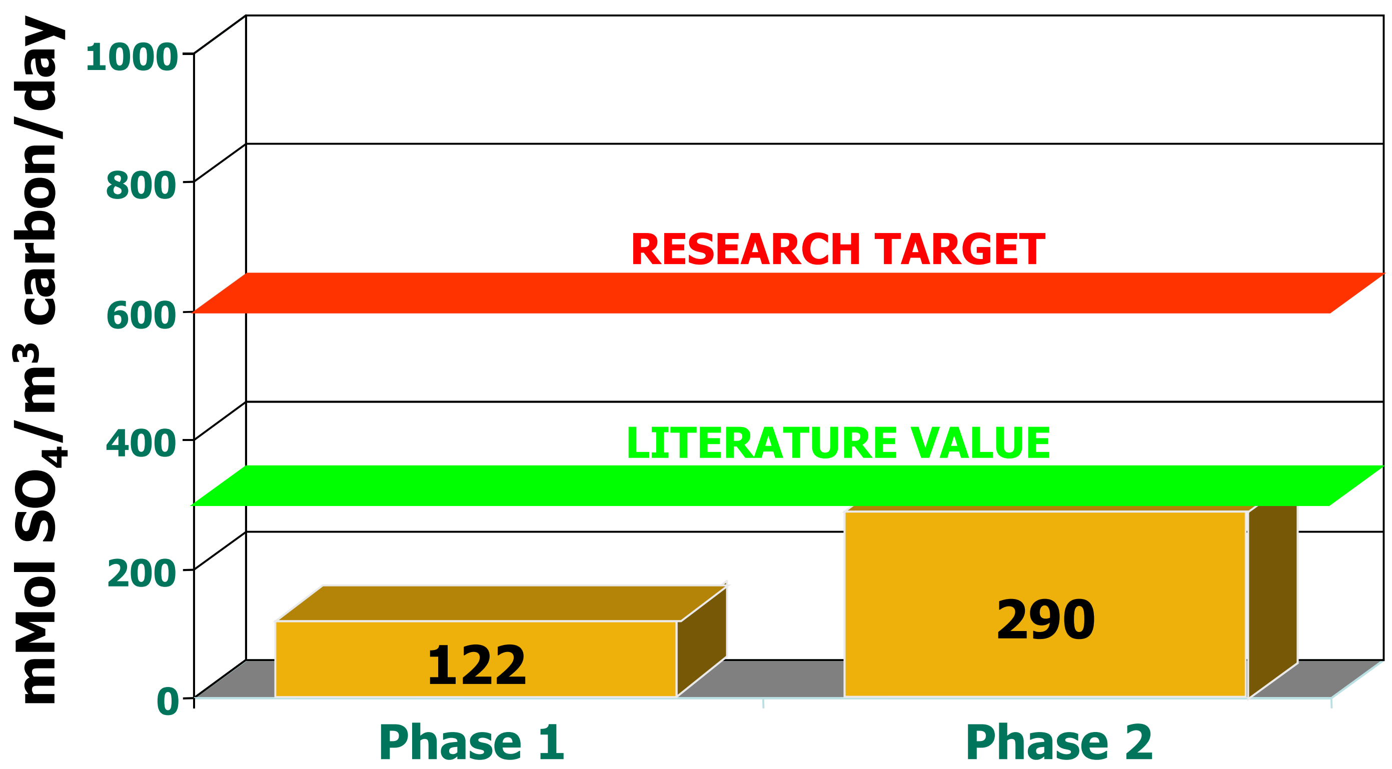
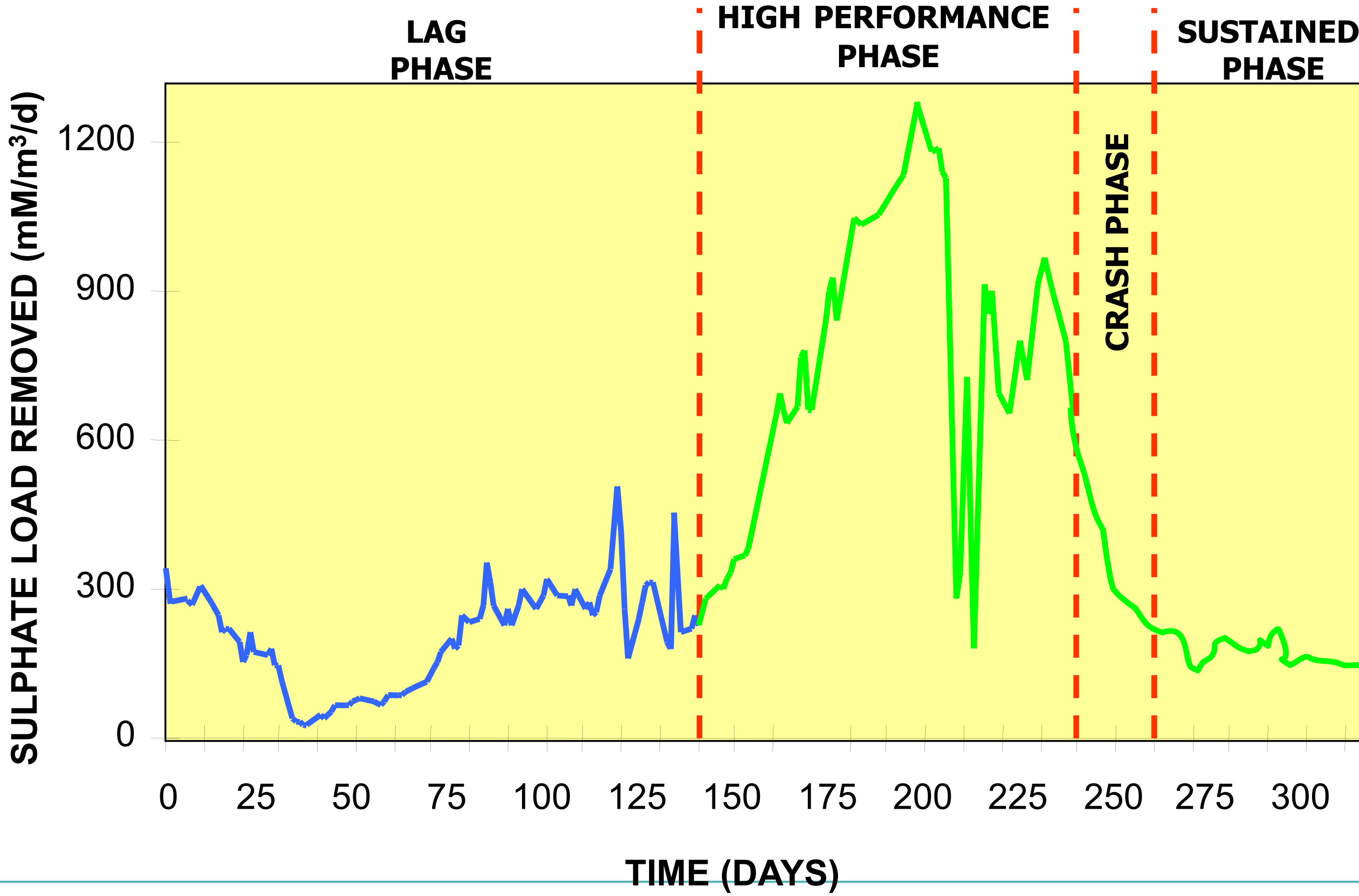
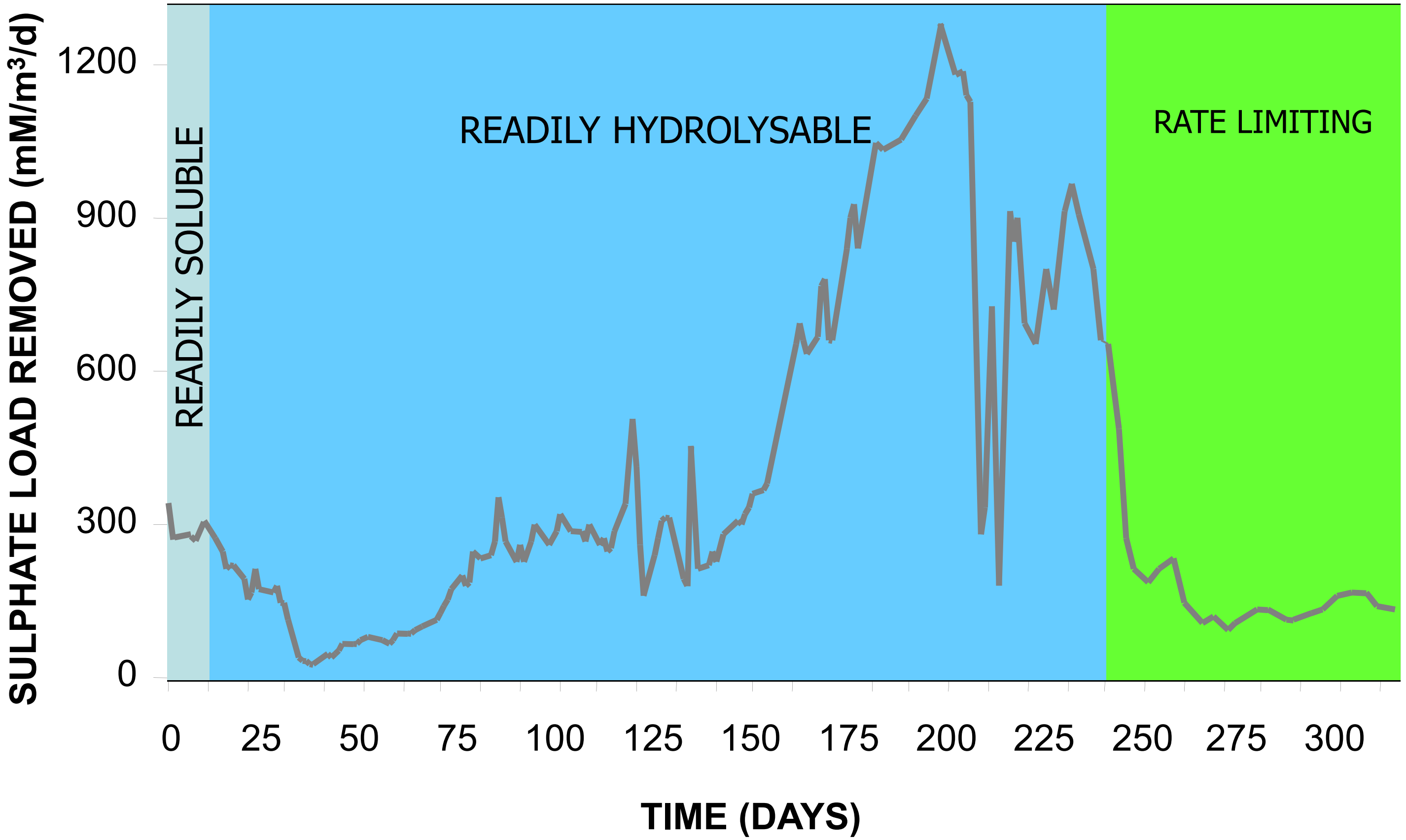
Sulphate removal rates



Typical sulphate reduction reactor performance



Typical sulphate reduction carbon cycle



Summary lessons to learn from SA research

- Published research results from columns operated for less than 12-18 months are of little practical value
- Give sulphate reducing bacteria food (electron donor) and they will reduce sulphate to maximum extent possible
- Key to sustainably increasing rate of sulphate reduction lies in enhancing rate of lignocellulose hydrolysis as this is the rate (food) limiting step
- Acceptance of the standard 300 mM SO_4/m^3 carbon/day results in unaffordable technology – require reactor volume of 35000 m^3 to remove 1000mg/l from 1000 m^3/day discharge = 30 parallel reactors of 20x20x3m size
- Maximum sulphate reduction in any single passive treatment step (in absence of significant sulphide removal metals) is 1000 mg/l due to sulphide toxicity
- Sulphate reduction must be followed by sulphide oxidation

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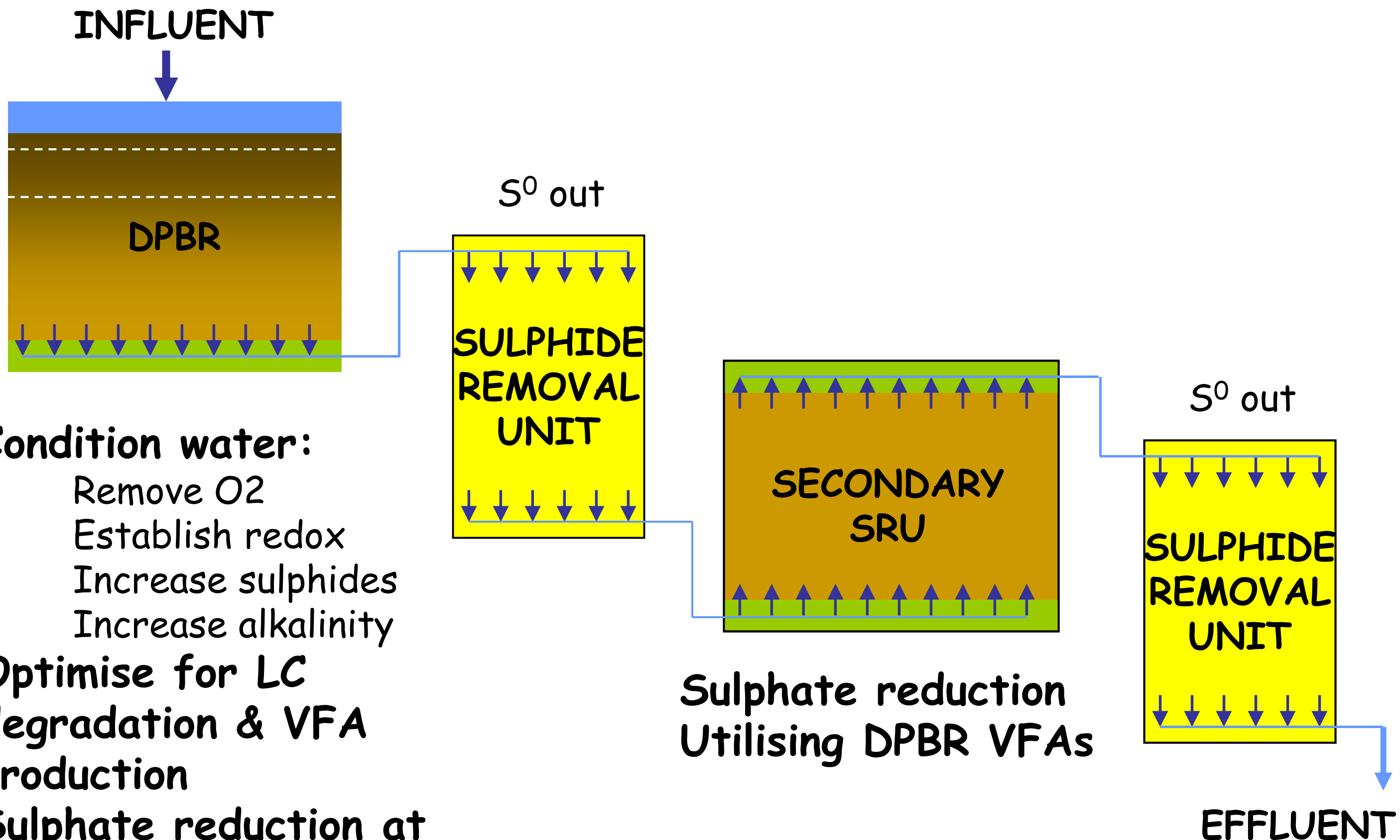
New Patented Integrated Design - IMPI



Condition water:

- Remove O2
- Establish redox
- Increase sulphides
- Increase alkalinity

Optimise for LC degradation & VFA Production

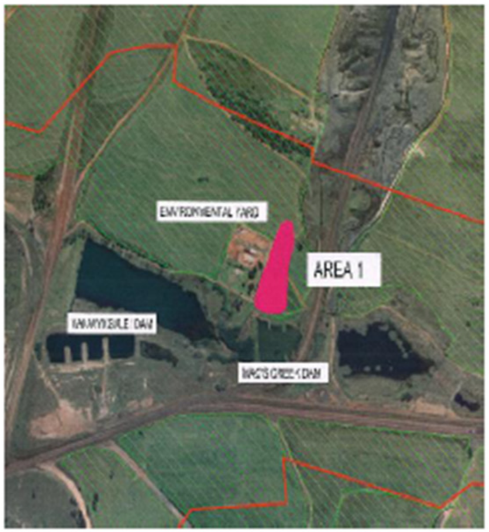
Sulphate reduction at 2500 mM $SO_4/m^3/d$

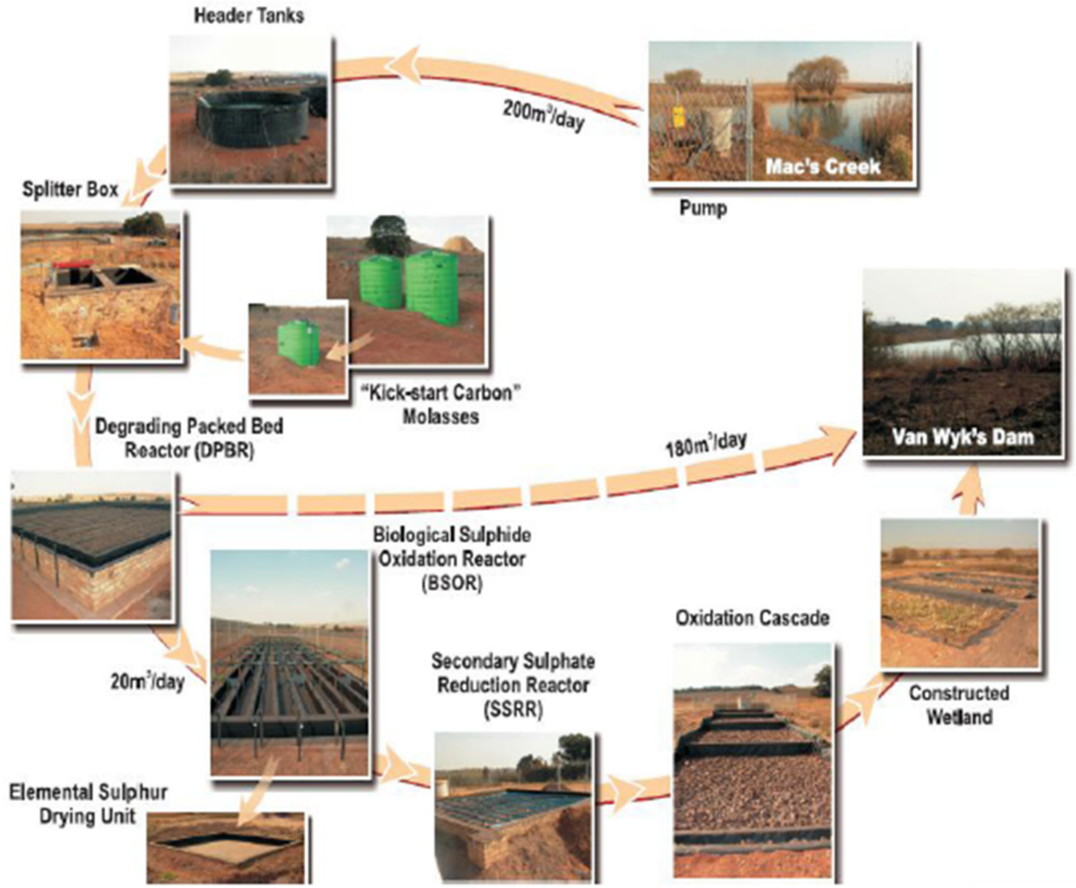
Sulphate reduction Utilising DPBR VFAs

VCC Pilot Research Facility

PHD Column Laboratory

Demonstration plant – Middelburg Mine





Degrading Packed Bed Reactor

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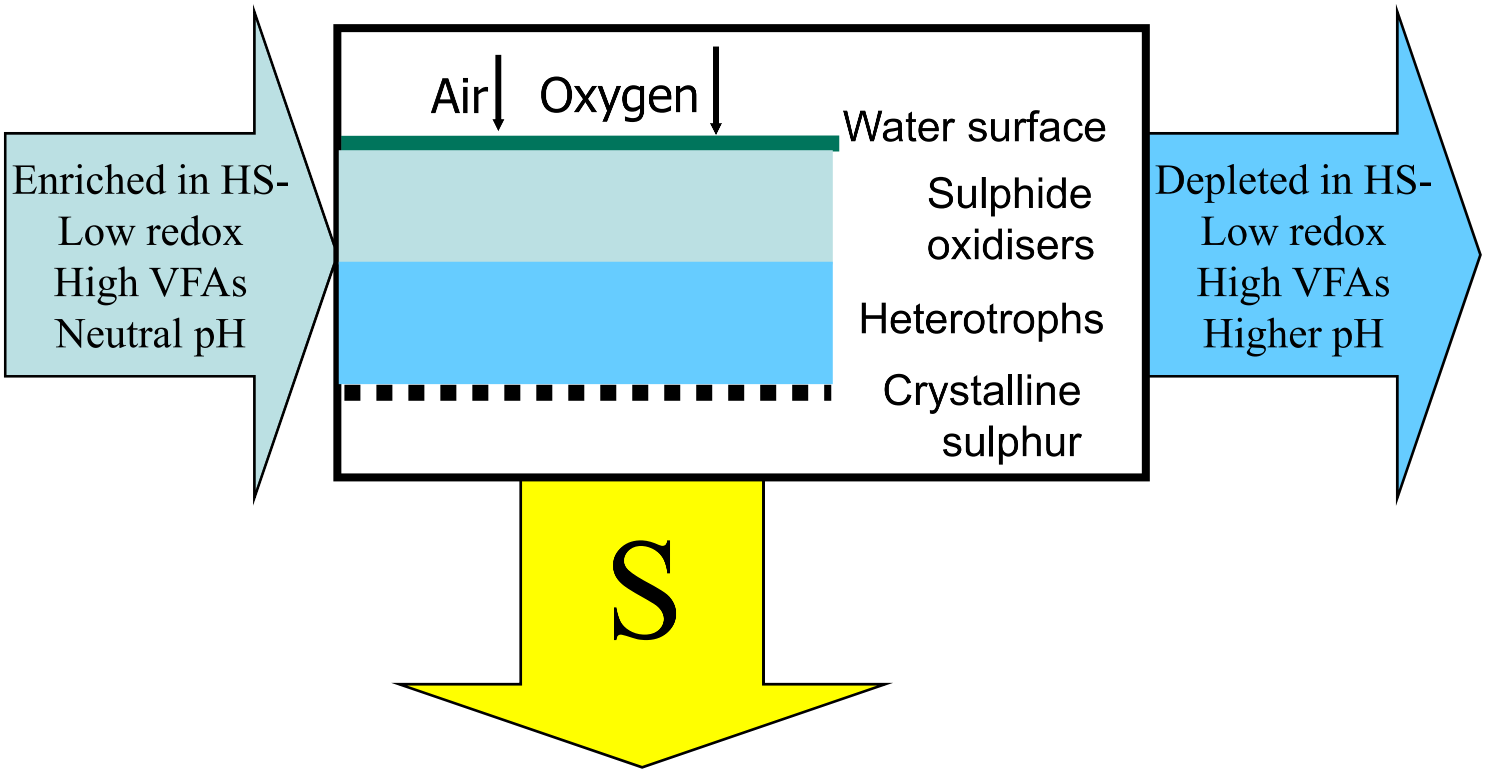
Sulphide removal process



First generation BSOR

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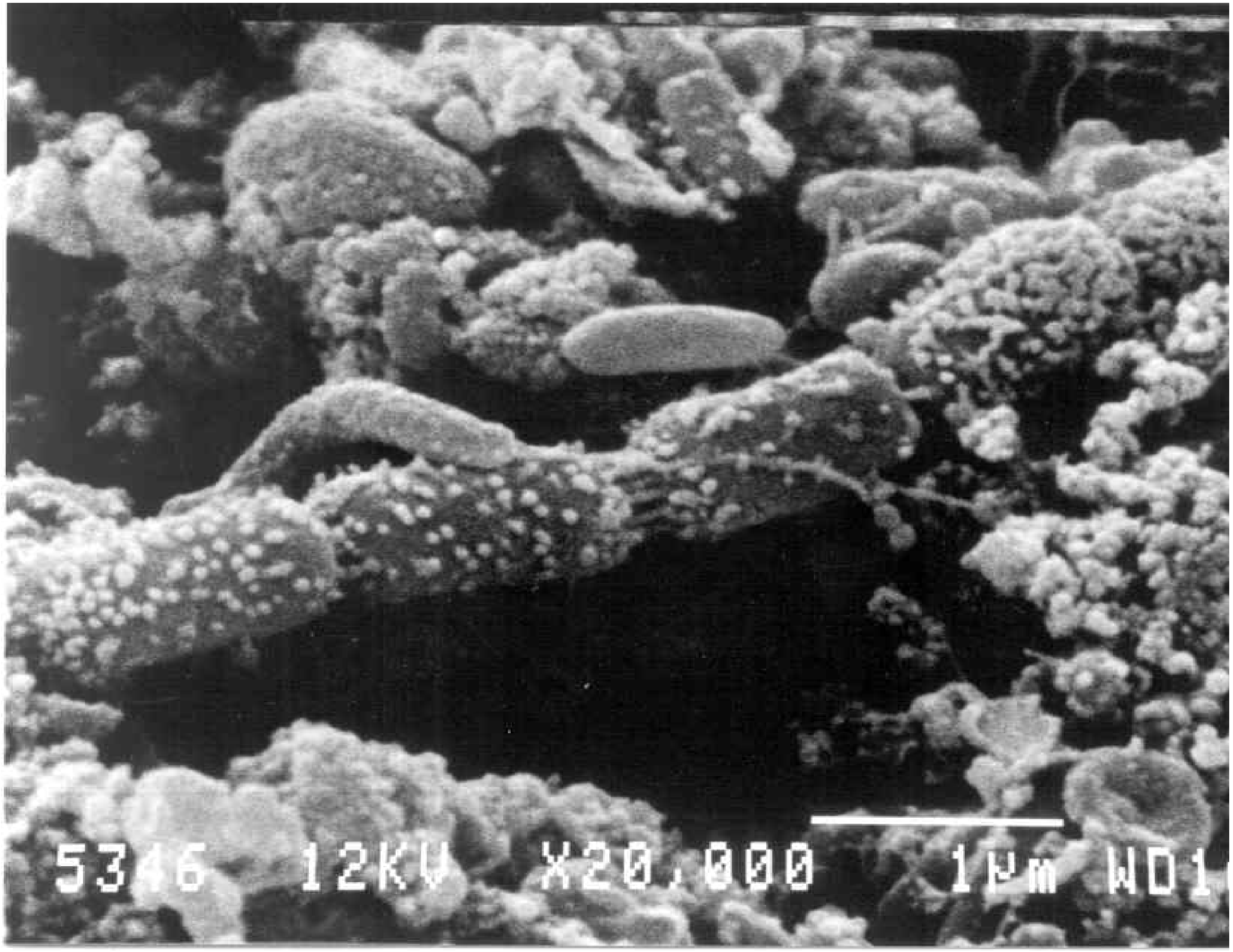
Sulphur film on reactor

Sulphur film being removed

Sulphur producing biofilm



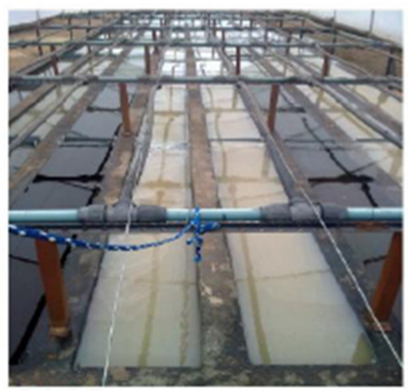
Recovered sulphur

Sulphide Removal

- Sulphide removal is a critical component of sulphate removal
- Significant advances have been made over a period of about 10 years in developing a technology that can be incorporated into a passive system
- Research currently underway at GAA with parallel lab and field scale reactors
- Currently capable of recovery of around 70% of sulphides as sulphur and polysulphide precipitate

BSOR at Middelburg Mine

Splitter box 2



BSOR

BSOR : Channel 1

Conclusions

- Detailed understanding of fundamental mechanisms has been obtained through a focused and sustained 10 year research effort, resulting in the following:
  - Sulphate reduction technology (DPBR) with sulphate reduction rates 700% higher than conventional technology
  - Passive sulphide oxidation technology already proved in extensive laboratory studies and will be finalised in field studies
  - High-rate passive alkalinity producing technology capable of adding around 1500 mg/l alkalinity
  - High rate metal removal technology as OH^- or S^-
  - Together with bio-neutralization technology can be applied to treat water with pH 2.5
  - Full scale evaluations underway