Mine Impacted Water: A resource for the circular economy in South African Mining communities

Dheepak Maharajh; Tamsyn Grewar; John Neal and Michelle van Rooyen

Water-Energy-Food Nexus: towards efficient national planning on 23-24 October at Amanzingwe Lodge & Conference Centre, Broederstroom, Hartbeespoort
**INTRODUCTION**

- **SA water scarce**
  - ~460mm vs ~850 global avg
  - Considered water stressed
  - Mining sector water use ~ 3 to 5%
  - Agriculture - ~ 50 to 70%
  - Bad water use behaviour
  - Use 60% more per person

- **Mine impacted Water**
  - Negative environmental impact
  - Ground water contamination
MINING SECTOR NOT HELPING!!!

To the Moon and Back

Mining Pollutes 17-27 billion gallons of water per year, and will do so in perpetuity.

- 2 trillion 8-inch bottles of water (32 trillion fluid ounces)
- 27 billion gallons of water
- 54 trips to the moon and back (stacking the bottles)

Effects

- Untreated acid mine drainage seriously hurts habitat and water quality. Thus killing most aquatic life and makes the environment unsuitable for organisms to thrive. It is also a problem because it can damage water quality that its citizens use such as drinking water. This problem occurs the most in PA. In 1995 PA failed EPA water quality tests because of 2425 miles of contaminated streams.
HUMAN FACTORS

Water scarcity

- Poor Water use behaviour
- Mining sector pollution
- Inefficient waste water treatment
- Agriculture – 70% clean water

70% clean water
To reduce the utilization of key resources such as energy and water,

To reduce the environmental impacts of the operations and of waste production,
SOCIO-ECONOMIC IMPACT
IMPACT OF WEAKENING MINING SECTOR

- Estimates 30 years mine lifespan remains
- What happens after mining?
- Drastic impact on poverty
NEED FOR MECHANISATION

• Could increase to 100 year lifespan
• Job cuts
• Spread of poverty
• Catch 22
• To reduce the utilization of key resources such as energy and water,
• To reduce the environmental impacts of the operations and of waste production,
• Ensure sustainable mine closure
• Create new employment to make way for mechanisation.
HOW CAN WE HELP?
HOW CAN WE ADDRESS THESE CHALLENGES?

- MIW
- SAVMIN
- Irrigation
- Food Crops
- Aquaculture
- AMD Neutralization
- Passive BSR
- Metal recovery
- >300ppm S
- BIOMIN
- Concentrated Solar Power
- Heat Storage
- Algal Culture
- Oil Extraction
- Animal Feed
- Biomass
- Gas turbine
- Electricity
- Food Waste
- Sewage
- Grey Water
- Rain Water
- Anaerobic Digester
- Biodiesel Production
- Glycerol
- Nutrient rich waste
- Digestate
- CO2
- Carbon Mineralization
- Transport Fuels
- Food
- Community Housing, Offices, Mine Buildings
- Transport Fuels
MINTEK’s AVAILABLE TECHNOLOGY OFFERINGS
AMD TREATMENT: BIOLOGICAL SULPHATE REDUCTION (BSR)

- Operated in down-flow mode
- Daily measurements of pH levels, redox potentials, electrical conductivity and sulphate concentrations
- At steady-state condition, samples removed for detailed chemical analysis

- Substrate (initially, at least):
  - 20 % cow manure
  - 20 % hay
  - 20 % wood shavings
  - 40 % wood chips
### BSR RESULTS SUMMARY

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<tr>
<th>Element/compound</th>
<th>Feed (mg/L)</th>
<th>Column 1 (mg/L)</th>
<th>Column 2 (mg/L)</th>
<th>Column 3 (mg/L)</th>
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- Detailed chemical analyses performed on day 486
- 140 mg/L SO₄²⁻ in Column 1
- 90 mg/L SO₄²⁻ in Column 3
- Sulphate removal >97 %
- 200 mg/L S²⁻; 2.5 mg/L Mn
- S²⁻ and Mn can be removed in oxidative polishing process
- NH₄⁺, HCO₃⁻, PO₄³⁻
- **Fitness for use** of final product is under evaluation – crop irrigation, algae culture
HOW CAN WE ADDRESS THESE CHALLENGES?

1. MIW
   - AMD Neutralization
   - Passive BSR
   - Metal recovery

2. SAVMIN
   - >300ppm S

3. Concentrated Solar Power
   - Heat Storage
   - BIOMIN

4. BIOMIN
   - Digestate
   - Oil Extraction
   - Animal Feed
   - Biodiesel Production

5. Algal Culture
   - Aquaculture
   - Nutrient rich waste

6. Food Crops
   - Energy Crops
   - Carbon Mineralization
   - Transport Fuels

7. Food Waste
   - Sewage
   - Grey Water
   - Rain Water

8. Waste

9. Electricity
   - Gas turbine
   - CO2

10. Anaerobic Digester
    - Food Waste
    - Animal Husbandry

11. Energy Crops
    - Oil Extraction
    - Glycerol

12. Community Housing, Offices, Mine Buildings
    - Food Waste
    - Sewage
    - Grey Water
    - Rain Water

13. Transport Fuels
    - CO2

14. CO2
    - Carbon Mineralization
• Patented in 1998
• Evolved over the last 20 years
• Latest improvements with Veolia
• >92% SO$_4^{2-}$ removal
• Metals removal
• Cost ~ R10 – R21/m$^3$ – potable quality water

**SAVMIN™ DEMONSTRATION – SULPHATE REMOVAL**

![Graph showing sulphate concentration over time](image-url)

- SANS 241 drinking water standard SO$_4^{2-}$ limit

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**MINTEK**
A global leader in mineral and metallurgical innovation
• At Stilfontein gold mine, Navigation Colliery and Grootvleli gold mine
HOW CAN WE ADDRESS THESE CHALLENGES?

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- Food Crops
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- AMD Neutralization
- Passive BSR
- Metal recovery

- Energy Crops
- Concentrated Solar Power
- Heat Storage
- BIOMIN

- Oil Extraction
- Animal Feed
- Biomass

- Digestate
- Glycerol
- Nutrient rich waste

- Food Waste
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- Grey Water
- Rain Water

- Anaerobic Digestor
- Biodiesel Production

- Algal Culture
- Aquaculture

- Animal Husbandry

- Food
- Electricity
- Community Housing, Offices, Mine Buildings

- Transport Fuels

- CO2

- >300ppm S

- Nutrient rich waste

- Biomass

- Carbon Mineralization

- Transport Fuels

- Heat Storage

- BIOMIN

- Digestate

- Gas turbine

- Food

- Electric power

- Community Housing, Offices, Mine Buildings

- Food Waste

- Waste
Algae

- Secondary water treatment – clean MIW
  - Mops up residual $\text{SO}_4$, $\text{PO}_4$, $\text{NO}_3$, metals etc
- Biomass
  - High in protein – animal feed
  - High carotenoids – high value
- Lipids
  - Contains 20 to 70% lipids
  - Converted to Biodiesel
- Biodiesel - ~ 70m litres/yr/mine
Algal culture
HOW CAN WE ADDRESS THESE CHALLENGES?
AGRICULTURE

• MIW – agricultural irrigation
• Produce crops for food, biofuel or even mining use e.g. flotation and thickening agents
• Food crops - communities
• Biofuels crops – mining vehicles
• Mine related products eg. Guar bean
• Community job creation
HOW CAN WE ADDRESS THESE CHALLENGES?
- Direct AMD use – not possible
- After algal culture cleaner water
- Algae protein – feed source
- Fish – mess up water
AQUACULTURE

- Ideal fertilizer or algal feed
- Recycle back to algae and agriculture in flow sheet
- Product sold for profit
- Waste to anaerobic digestion
Animal husbandry

- Livestock farming
- Algae protein for feed
- Livestock sold for profit
- Manure feed for Anaerobic digester
HOW CAN WE ADDRESS THESE CHALLENGES?

- MIW (Mineralization and Immobilization of Waste)
- SAVMIN (Sodium Aluminate-based Waste Neutralization)
- Irrigation
- Food Crops
- Aquaculture
- AMD (Acid Mine Drainage) Neutralization
- Passive BSR (Biological Scavenging and Remediation)
- Metal recovery
- Energy Crops
- Animal Husbandry
- Anaerobic Digestion
- Food Waste
- Sewage
- Grey Water
- Rain Water
- Waste
- BIOMIN (Bio-mineralization)
- Digestate
- Concentrated Solar Power
- Heat Storage
- Oil Extraction
- Algal Culture
- Biomass
- Animal Feed
- Aquaculture
- Glycerol
- Gas turbine
- Electricity
- Carbon Mineralization
- Transport Fuels
- Food Waste
- Community Housing, Offices, Mine Buildings
- Electricity
- Water (Grey Water, Rain Water)
- Transport Fuels
- CO2
- Nutrient rich waste
- >300ppm S
ANAEROBIC DIGESTION

- Animal waste
- Food waste
- Domestic waste
- Produce Biogas
  - Used for cooking
  - Electricity – community and mines
HOW CAN WE ADDRESS THESE CHALLENGES?

- MIW
- SAVMIN
- Irrigation
- Food Crops
- Aquaculture
- AMD Neutralization
- Passive BSR
- Metal recovery
- >300ppm S
- Concentrated Solar Power
- Heat Storage
- BIOMIN
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- Biogas
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CONCENTRATED SOLAR POWER

- Power generation – supply communities
- Smelter operations
- Desalination of MIW
HOW CAN WE ADDRESS THESE CHALLENGES?

SWM
Invasive Aquaculture
Aquaculture
Neutralization Passive BSR Algal Culture
Metal recovery

> 300ppm S

Concentrated Solar Power
Heat Storage

BIOMIN

Digestate

Irrigation

Food Crops

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Waste

Community Housing, Offices, Mine Buildings
CO₂ CAPTURE STORAGE

- SA generates ~420 Mt CO₂ per annum (1% of global emissions)
- Current CO₂ levels ~400ppm
- Expected to breach 800ppm by end of the century

South Africa’s position as a Global CO₂ emitter (Naidoo, 2013)
CO₂ CAPTURE STORAGE

- Carbon capture and storage (CCS) - physical capture and storage of CO₂ from fossil fuel combustion in such ways that it does not enter the atmosphere

- Carbon mineralisation (CM) - reaction of CO₂ with alkaline earth metals (or other wastes containing Ca and Mg) to form stable, inert and environmentally benign carbonate minerals, sustainably trapping CO₂ in solid form

- Work is currently being under-taken at Mintek to investigate the potential of using mining-related waste for this purpose
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- Electricity

- Community Housing, Offices, Mine Buildings

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- Grey Water
- Rain Water

- Transport Fuels

- Transport Fuels

- Biomass

- Animal Husbandry

- Carbon Mineralization

- Transport Fuels

- Oil Extraction

- Energy Crops

- Concentrated Solar Power

- BIOMIN

- Heat Storage

- Irrigation

- Food Crops
THE CIRCULAR ECONOMY
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- Cradle to cradle approach
- Waste or by-product never discarded
- Re-use principal
- Multiple products
- Creating community value
  - Jobs
  - Food security
  - Energy security
- Mines can move labour
  - Increase mechanisation
  - Extend mine life cycle
JOB CREATION POTENTIAL
500 to 2000 direct jobs per mine
~ 2000 to 8000 indirect jobs