MINE TAILINGS AND THEIR POTENTIAL IMPACTS: A CASE STUDY OF SOUTH AFRICAN GOLD TAILINGS DAMS

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OUTLINE

1. Introduction
2. Acid Mine Drainage Formation
3. Impacts of Acid Mine Drainage in the Wits Basin
4. Tailings Dams Management
5. Case Studies: a) Wits Basin; b) Klein Letaba;
1. Introduction: Tailings Dam

• An impoundment facility that holds mine waste from milling processes

• Nature of tailings material depends on:
  – Mineralogical characteristics of the ore
  – Physical and chemical procedures used to separate valuable mineral
Tailings Dam

- Olympic dam, South Australia (Cu and U with Au and Ag).
GOLD MINE TAILINGS DAM CONTAINS

PANNED RESIDUE (ARTISANAL)

FINE MATERIALS (PROCESSING PLANT)

URANIUM RESIDUE (PROCESSING)

CYANIDE RESIDUE (GOLD PROCESSING)
TAILINGS DAM FAILURE

- Sometimes overtopping of a tailings dam may occur due to an embankment failure during heavy rains.
2. Acid Mine Generation

- AMD is a legacy of past and present mining practices
- Mine wastes and effluents from processing plants pollute soils and surface/groundwater
- Other Sources: Low grade ore, run-off mill stock piles, waste rock dumps
- Annual liabilities can range from millions to billions of dollars
SOURCES OF AMD

- Waste Rock Dumps
- Tailings Materials
- Run-off Mill Stock Piles
- Low Grade Ore
AMD Formation

• Exposure of mine wastes to H₂O and O₂:
  - \( 2\text{FeS}_2 + 7\text{O}_2 + 2\text{H}_2\text{O} = 2\text{Fe}^{2+} + 4\text{SO}_4^{2-} + 4\text{H}^+ \) ..........(1)

• \( 4\text{Fe}^{2+} + 10\text{H}_2\text{O} + \text{O}_2 = 4\text{Fe(OH)}_3 + \text{H}^+ \) ........................ (2)

• \( 2\text{Fe}^{2+} + \text{O}_2 + 2\text{H}^+ = 2\text{Fe}^{3+} \) .............................................(3)

• \( \text{FeS}_2 + 14\text{Fe}^{3+} + 8\text{H}_2\text{O} = 15\text{Fe}^{2+} + 2\text{SO}_4^{2-} + 16\text{H}^+ \) ....(4)

• Note: Sulphide minerals reaction catalysed by H₂SO₄ and Fe-oxidising bacteria, Acidithiobacillus ferroxidants

• Fe²⁺ is oxidised to Fe³⁺ further production of acid
• AMD has pH: 4-2 and toxic metal-rich leachate
EXAMPLES OF ACID MINE DRAINAGE

AMD FROM AN ADIT OF A COPPER MINE IN AUSTRALIA
EXAMPLES OF AMD

Acidic water due to AMD

Impact of AMD ON Environment

Aluminum hydroxide (white - near top) and iron hydroxide (orange) precipitating
Contaminate water with heavy metals

Lower water pH

Riverbed coating and blocking sunlight

Destroying aquatic habitats and disturbing their life cycle

Contaminate soil: Food chain

AMD IMPATCS
MINING IMPACTS ON HUMAN HEALTH

**Pb:** Heart disease, abnormalities in children, testicular atrophy, anaemia and interstitial nephritis, carcinogenic

**Cu:** Wilson and William syndromes attack the liver

**Cd:** Kidney stones, Osteomalacia: a form of rickets

**Zn:** Anaemia, nausea, skin irritation, stomach cramps

**As:** Polyneuritis, bronchitis, cancer gastroenteritis, rhinitis, conjunctivitis

**Co:** Pneumonia, asthma, heart disease, impaired vision, thyroid gland damage
3. IMPACTS OF AMD IN THE WITWATERSRAND BASIN

- Gold mining dates back to 1886
- There are thousands of abandoned tailings dams
AMD in the West Rand
(Inter-Ministerial Report, 2010)

Acid Mine Drainage in the West Rand
ACID MINE DRAINAGE IN THE TOWN OF O’KIEP (Inter-Ministerial Report, 2010)

Decant of Copper-rich AMD in the Town of O’Kiep, Northern Cape
4. TAILINGS DAM MANAGEMENT

• Tailings dam management is based on principles that integrate mineral exploitation and environmental management and protection.

• It focuses on all phases of mineral resource development from pre-exploration planning thro’ exploration, extraction and mine closure and monitoring.
TAILINGS DAMS MANAGEMENT: STRATEGIES

• Evaluation of AMD Potential
• Design of Tailings Facility
• Formation of dump batters
• Compaction on dump batter for more reactive material
• Capsulation of Highly Sulphidic Material
Detailed discussions with the project geologist. To define ore and waste rock units based on lithology, mineralogy, fractures. Inspect drill core.

Select samples using drillhole database.

Acid base accounting.

Evaluate AMD results. Were samples represented?

Is there a potential for AMD?

Preliminary design and AMD controls.

Select samples for kinetic tests to define rate of AMD generation.

Kinetic tests

Detailed and control design.

Finalised mine plan

Approval and operation.

Monitoring and verification.

Redefine types based on AMD. Collect more samples.
Tailings dam design/site selection

• Requires:
  – Sound knowledge of geotechnical, hydrological and geochemical conditions of the site
  – Physical and chemical characterisation of tailings material, effluent and construction materials
  – Base drainage system to reduce the hydraulic head and improve deposit
Tailings Facilities

- Sites with low permeability are common foundations: clay soil
- Placement of clay liners as foundation: Clay blanket
- Geo-synthetic membrane
- Liners with seepage collection systems
Liners with seepage collection systems (AUSTRALIA EPA)
FORMATION OF DUMP BUTTERS
EPA-AUSTR
Capsulation of Highly Sulphidic Material
(EP-AUSTRA)
MINE WATER MANAGEMENT HIERARCHY (DWAF, 2008)

1. Pollution Prevention
2. Minimisation of Impacts: Water Reuse, Reclamation and Treatment
3. Discharge or Disposal of Waste and/or Waste Water: Site-Specific Based Approach
Water pumped to treatment plant at Grootvlei Mine (Inter-Ministerial Report, 2010)
THE KROMDRAAI ACID MINE DRAINAGE TREATMENT PLANT

Oxygen readings for the investigated six sites in the Basin
5. CURRENT RESEARCH WORK ON GOLD MINE WASTE MANAGEMENT

• 5.1 The Witwatersrand Basin
• 5.2 Klein Letaba Tailings dam
• 5.3 Gold reprocessing from tailings dams
CASE STUDY 1: SELECTED SITES WITHIN THE WITS BASIN (Nengovela et al., 2006)
# SELECTED SITES
(Nengovhela et al., 2006)

<table>
<thead>
<tr>
<th>Site</th>
<th>Area (ha)</th>
<th>Height (m)</th>
<th>Tonnage ((10^6))</th>
<th>Vol. ((m^3))</th>
<th>Decom. Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>#</td>
<td>10.5-22.5</td>
<td>11</td>
<td>#</td>
<td>1950?</td>
</tr>
<tr>
<td>B</td>
<td>10</td>
<td>19</td>
<td>#</td>
<td>1028000</td>
<td>1973</td>
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<tr>
<td>C</td>
<td>38</td>
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<td>1976</td>
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<tr>
<td>D</td>
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<td>32</td>
<td>#</td>
<td>7576000</td>
<td>1975</td>
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<tr>
<td>E</td>
<td>#</td>
<td>34</td>
<td>#</td>
<td>#</td>
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<td>#</td>
<td>#</td>
<td>#</td>
<td>31422569</td>
<td>1997</td>
</tr>
<tr>
<td>G</td>
<td>#</td>
<td>#</td>
<td>#</td>
<td>#</td>
<td>1999</td>
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</table>
### TAILINGS DAM PROFILE: CMR 4L19

<table>
<thead>
<tr>
<th>H (cm)</th>
<th>%</th>
<th>Bottom of the dam</th>
<th>OZ - Mature oxidized</th>
<th>TZ - Transition zone</th>
<th>UZ - Unoxidized</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
<td>41</td>
<td><img src="#" alt="Graph Color" /></td>
<td><img src="#" alt="Graph Color" /></td>
<td><img src="#" alt="Graph Color" /></td>
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<tr>
<td>600</td>
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<td><img src="#" alt="Graph Color" /></td>
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<tr>
<td>800</td>
<td>43</td>
<td><img src="#" alt="Graph Color" /></td>
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<tr>
<td>1000</td>
<td>43</td>
<td><img src="#" alt="Graph Color" /></td>
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<tr>
<td>1200</td>
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</tr>
</tbody>
</table>

- OZ: Mature oxidized
- TZ: Transition zone
- UZ: Unoxidized

- Graph Color: ![Graph Color](#)
Oxygen Readings for the Six Sites: 1-10 m
CASE STUDY 2: DISPERSION OF HEAVY METALS AT KLEIN LETABA GOLD TAILINGS DAM, LIMPOPO PROVINCE
WIND EROSION OF TAILINGS DAM AND ANIMALS GRAZING NEARBY
PROCESSING OF TAILINGS MATERIAL
Sampling at Klein Letaba tailings dam and its environs
AUGERING OF KLEIN LETABA TAILINGS DAM ALONG THE SITED PROFILES
RESULTS AND DISCUSSION

Concentration of heavy metals in the tailings dam

- Cu (ppm)
- Co (ppm)
- Zn (ppm)
- Pb (ppm)
- As (ppm)
- Cd (ppm)
- Ni (ppm)
- Mn (ppm)
DISTRIBUTION OF HEAVY METALS WITHIN THE KLEIN LETABA TAILINGS DAM
DISTRIBUTION OF GOLD WITHIN THE KLEIN LETABA TAILINGS DAM ALONG PROFILE 2
RESULTS AND DISCUSSION

Concentration of heavy metals in sediments

- Ni (ppm)
- Cu (ppm)
- Co (ppm)
- Zn (ppm)
- Mn (ppm)
- As (ppm)
- Cd (ppm)
- Pb (ppm)
Concentration of Heavy Metals in Water

Max. 5.9

- Ni (mg/l)
- Cu (mg/l)
- Co (mg/l)
- Zn (mg/l)
- Mn (mg/l)
- As (mg/l)
- Cd (mg/l)
- Pb (mg/l)
- Fe (mg/l)
CONCLUSION

• Gold was found to have a mean concentration of 468 ppb and the highest concentration was 740 ppb.

• The total amount of gold within the tailings dam was found to be 699 kg which at the current gold price in the world market would be US$ 29,639,575.
Recommendations

• Mine waste management requires proactive approach that includes:
  – pre-exploration planning thro’ exploration, extraction and mine closure and monitoring.
  – Turning mine waste into a resource: reprocessing of gold and other ore metals from tailings dams; converting tailings into construction material.
THANK YOU?