



Recommended guidelines to remediate heavy
metals contaminated mine tailings in
Namibia:
Oamites Abandoned Mine Tailings, Namibia

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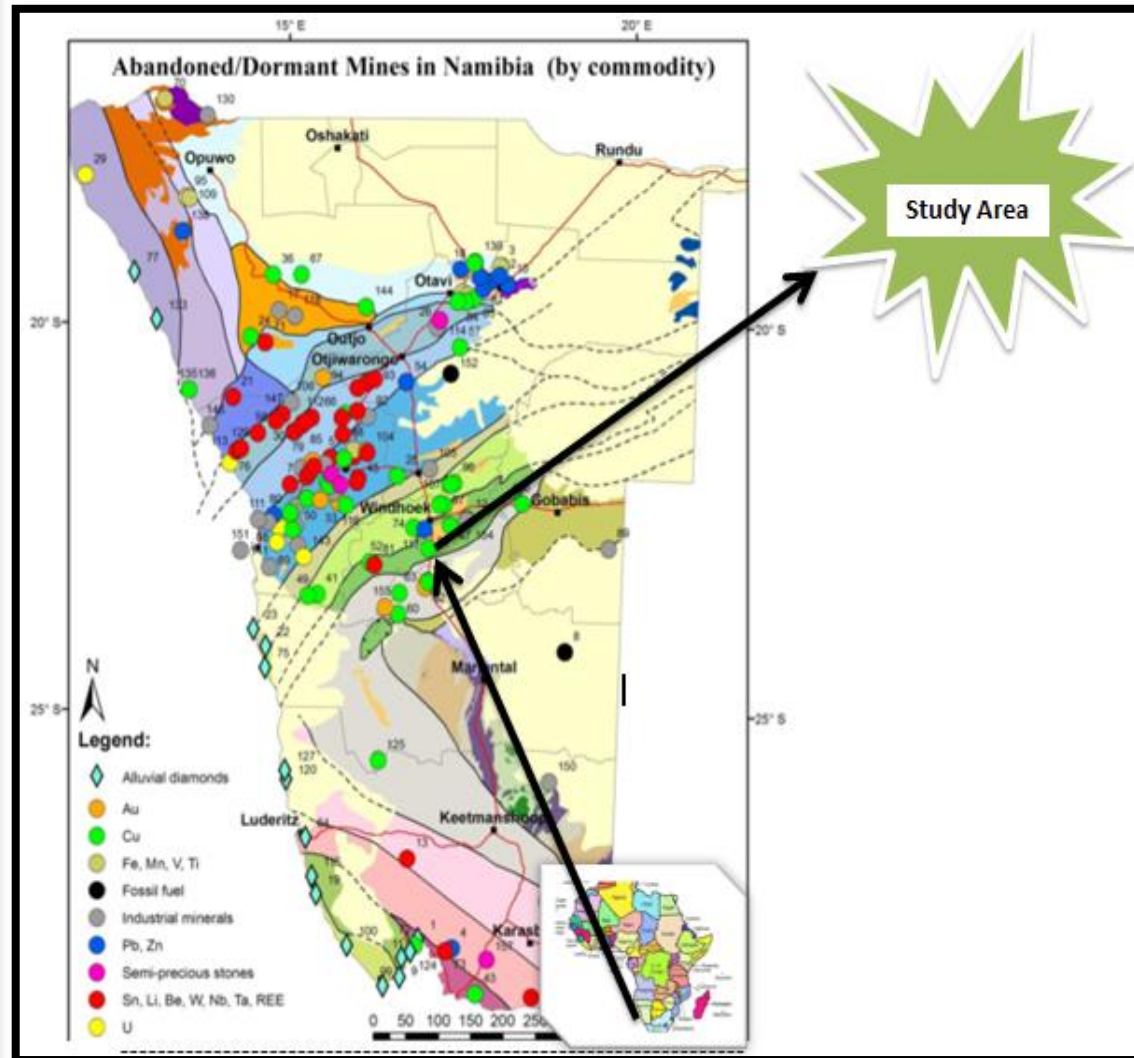


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Introduction



*Prior to the Namibian independence (Before 1990): Over 200 mines were exploited and the resultant tailings were left un-rehabilitated (DEEG).

Adverse environmental and social impacts

* The Namibian Government inherited this liability

•And is now faced with a huge challenge of cleaning up these mine tailings sites which have financial implications

* The legislation (Environmental Management Act 2007)- Does not account for Abandoned Mine Tailings



Aim

The study aims to develop the best practice guide to remediate large scale mine tailings in Namibia.



Objectives

- The study explores the phytostabilization strategy in-depth as the best approach to remediate abandoned mine tailings and to a lesser extent other remedial strategies.
- The study also took into consideration, the successful stories and lessons from other phytoremediation work, specifically, phytostabilization projects, which dealt with the restoration of contaminated mine tailings.
- The study analysed the OMT results by using x-ray fluorescence geochemical data to understand the heavy metals present on the tailings
- The study further used GIS to assess the distribution of heavy metals on OMT, specifically those that possess high phytotoxic levels.
- Finally, the study addressed its main objective which is to provide the Namibian government with suggestions and recommendations on the best remedial measures for the remediation of heavy metal contaminated mine tailings.



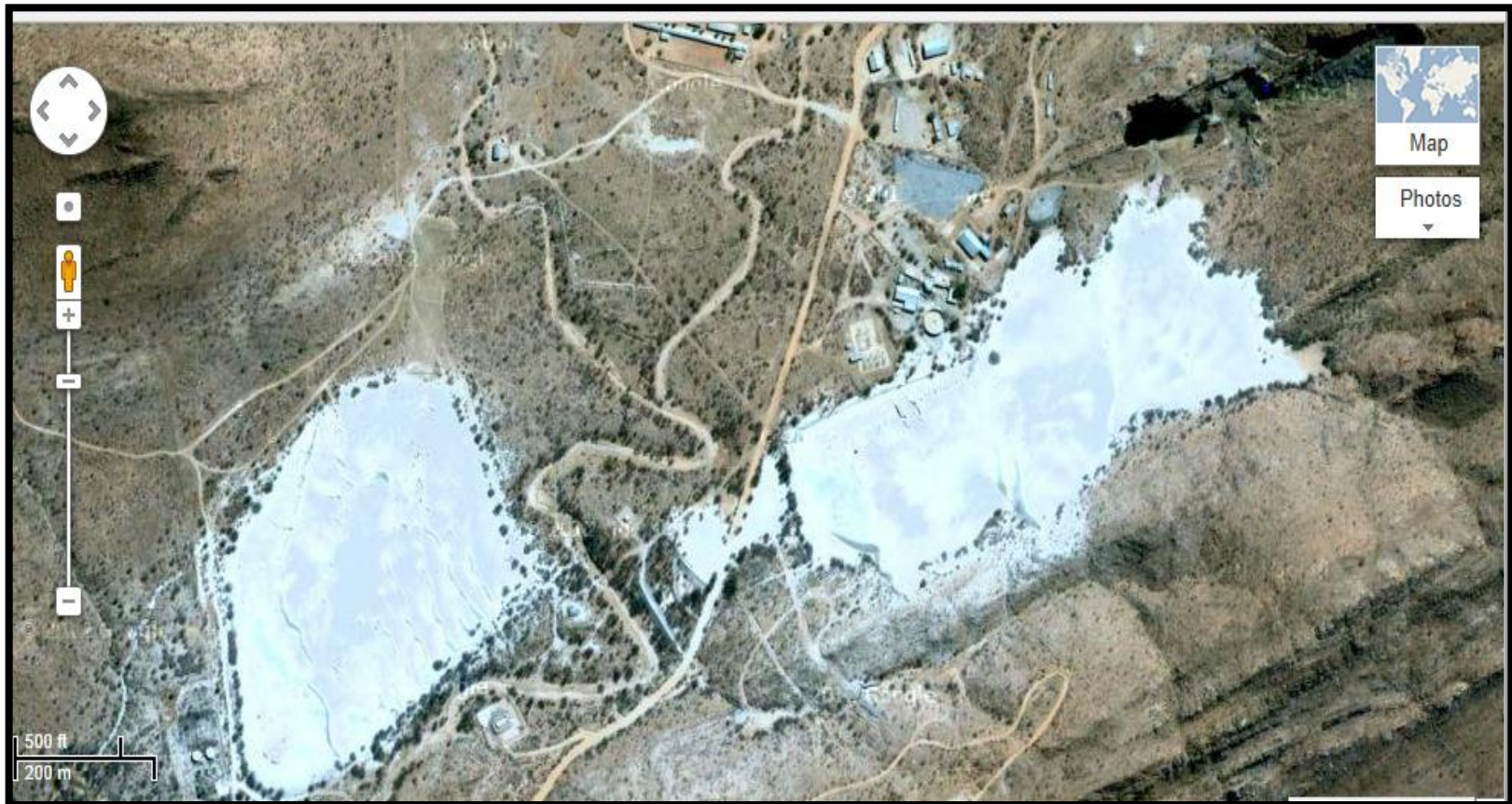
Study Area: Background Information... 1

- The underground mine closed in 1985, having produced more than 13 000 tonnes of Copper in 1983 and 10 000 tonnes in 1984.
- Primarily, the Oamites prospect comprised of copper ore minerals, such; as Bornite and Chalcopyrite, and other secondary ore minerals such as chalcocite, nedigenite, covellite and galena and a high content of pyrite, Iron Sulphide FeS_2
- The mine tailings which have been abandoned since 1985 are estimated to contain approximately 5.5 million tonnes of mine tailings of about 6m in height.



Study Area: Background Information...2

- The Oamites abandoned mine site consist of two mine tailings, namely, the western and the eastern tailings situated adjacent to each other.





Study Area: Background Information....3



Wind pollution: Health hazard possess by the OMT as there is an Army Base Camp
The mine tailings are situated in an arid to semi-arid environment of Namibia where the rainfall is relatively low. The average annual rainfall is approximately less than 300mm (NNRC, 2002)

Unstable tailings dam with deep erosion gullies: Promotes further Environmental Degradation

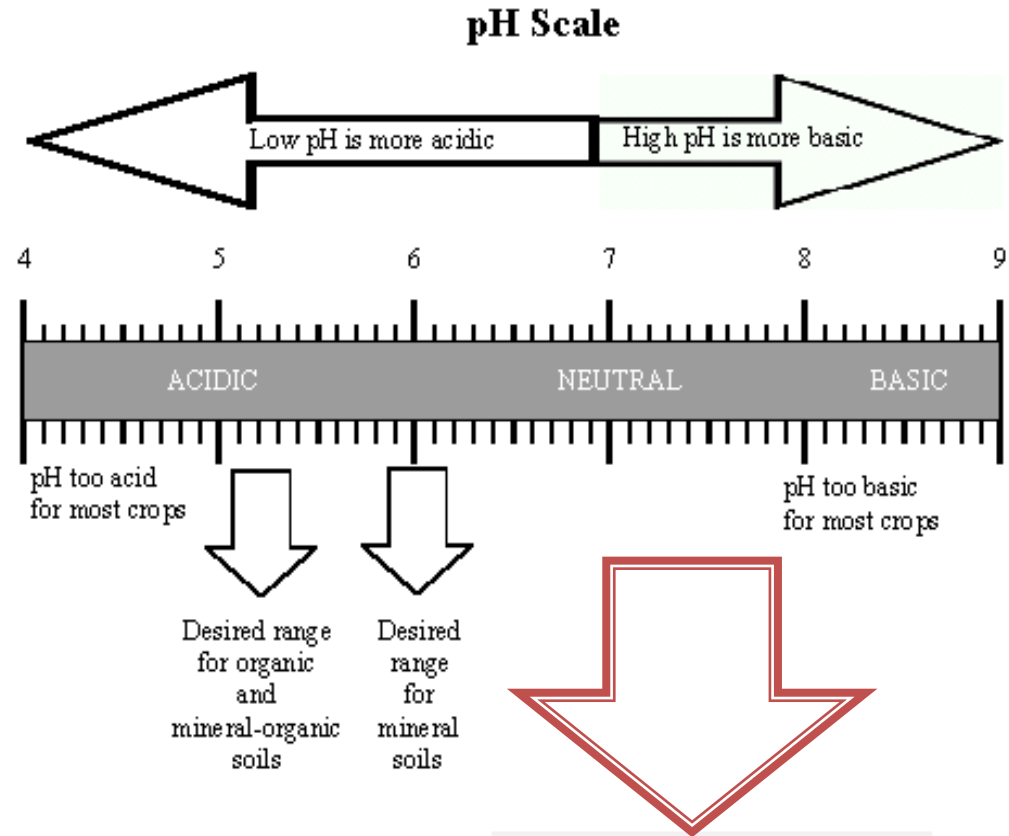




Study Area: Background Information...4

The pH of OMT??

- Water sources have pH values ranging from 7.1 to 8.1 (Amkongo, 2007)
- High Pyrite Content of OMT



Water sources in the vicinity of OMT has alkaline pH (Not Affected by the mine tailings)

(After NCAGR, 2012)



Methodology

- Research on available remedial techniques and supporting best practice measures
- Comparative analysis of CS
- Review available OMT geochemical data
- GIS Applications



Summary of Remedial Techniques

Heavy Metal Contaminants Remedial Techniques:

**Soil washing*

** Monitored Natural Attenuation*

**Chemical and Physical Stabilization of Tailings*

**Excavation and Backfilling*

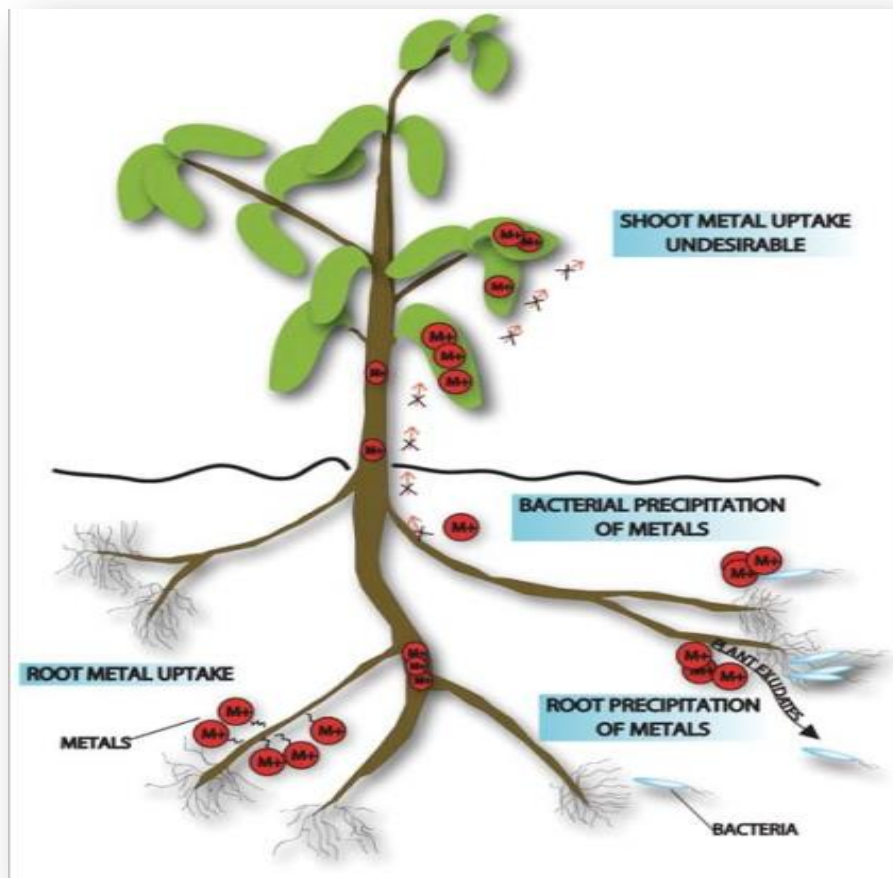
**Backfilling higher cost implications compared to Phytoremediation*

**Phytoremediation*

**Phytoextraction *Phytostabilization*



Phytostabilisation as a Remediation Strategy



*Heavy Metals Contaminants and Geochemistry

Metal excluder plant selection that is tolerant to Ni, Cr, Hg, and Cu, Salt and semi-arid climatic environments and also tolerant to extreme pH conditions

Heavy Metals stabilisation Concept

* The root structure zone in the rhizosphere soil horizon creates a conducive environment wherein the heavy metals can accumulate and stabilise, and not in the plant tissue (Mendez and Maier, 2008)

*Limitations

- * However, the phytostabilisation technology has limitation if the soil is highly toxic
- * Introduction of bacteria to help support plant growth in harsh environments



Advantages of Phytostabilisation

➤ As a result this remedial technique has various advantages:

The established cover by the phytostabilisation process helps to.

- Avoid erosion of the metaliferous mine tailings
- Accumulate heavy metal contaminants in the rhizosphere of the soil structure where the root zone occur- this helps to reduce leaching of heavy metals and therefore avoid the contaminations of underground water (Ernst, 2005).
- Prevent uptake of heavy metals into the plant system- no introduction of heavy metals into the food chain
- Establish and develop a long term self-sustaining vegetation cover- which helps to prevent the dispersion of harmful particulate matter in the atmosphere. (Solis-Dominquez et al.,2011).
- Most importantly it is a permanent and cost effective solution.



Supporting Best Practice Measure



Soil:
Amendments
for Vegetation
Establishment
Soil pH soil
compaction

Post monitoring
issues

Erosion Control
Measures

➤ In semi-arid environments: The tailings requires significant and specific considerations as the tailings are dry, compacted, and are often unstable. In this regard, best physical soil preparation needs to be done.

➤ The **physical preparation** methods includes concave shaping and level the mine tailings to increase soil water storage, increase the stability of the tailings so as to avoid seepage and runoff.



Case Study 1: Boston Mill Upper Tier Mine Tailings

- **2 Case Studies:** These case studies were used to make relevant comparative analysis and assessment with that of the Oamites mine tailings so as to delineate plausible best practise measures for remediating mine tailings in Namibia.
- The first phytostabilisation selected case study represents the Boston Mill Upper Tier mine tailings located in an arid to semi-arid climatic conditions-Alkaline mine tailings of Cochise County, Arizona
- **Success:** The selection of the right plant species which best suits an arid to semi-arid climatic conditions, as well as salt tolerant species can also contribute towards a successful establishment of a vegetation cover on the tailings without supplemental irrigation.
- **Lesson:** The following factors limited seed germination and re-vegetation success on the northern half of the mine tailings, and there occurred as a result of short, but intense rainfalls;
 - Greater sheet erosion and surface riling
 - Crusting
 - Seed washout
 - Less rainfall infiltration
 - Concave shape of the tailings



Case Study 2: Dabaoshan, China Cu Mine Tailings

- Phytostabilisation field experiment on metal-toxic pyrite copper mine tailings located in evergreen subtropical environment, **Dabaoshan, China.**

- **Successes:**
 - Reduced wind and water erosion
 - Increased stability of the mine tailings
 - Improved aesthetic appearance of the tailings
 - Enhanced nutrients accumulation in the mine tailings
 - Improved pH levels of the mine tailings

- **Lessons:** Evidence of possible re-acidification (ANC-test) of the mine tailings, thus continuous monitoring of the tailings, followed by the addition of lime and chicken manure to prevent re-acidification and to facilitate the survival and growth of the vegetation cover



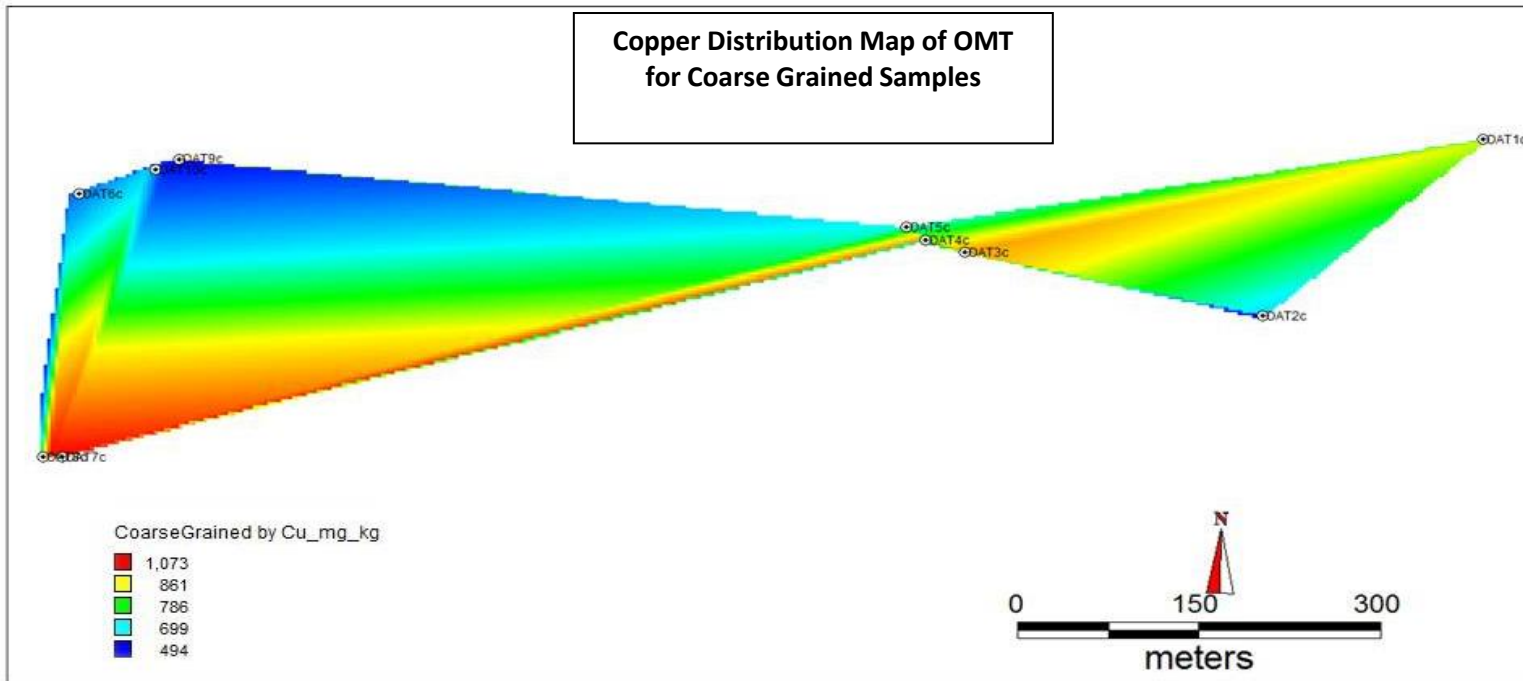
OMT: X-ray fluorescence (XRF) Geochemical Data

Heavy Metal	Coarse Soil Concentration range mg/kg	Fine Soil Concentration range mg/kg	Overall Range	Mean Concentrations mg/kg	Regulatory limit Soil mg/kg
Pb	42-170	57-124	42-170	106	600EIL-AUS
Ni	53-121	56-674	53-674	363.5	60EIL-AUS
U	49-89	55-108	49-108	78.5	N/A
Cr	45-71	51-96	45-96	70.5	50EIL-AUS
Mn	160-440		160-440	102	500EIL-AUS
Hg (Inorganic)		13-56	13-56	34.5	1 EIL-AUS
Se	11-17	11-22	11-22	16.5	120-ALL-UK
Zn	85-170	106-205	85-205	145	200EIL-AUS
Ti	994-3314	58-3639	58-3639	1848.5	N/A
Cu	494-1075	33-750	33-1075	554	100EI-AUS
Mo	13-21	9.3-21	9.3-21	15.15	40EIL-AUS

- The heavy metal geochemical results for the Oamites tailings were benchmarked against the Ecological Investigation Levels (EILs) of Australia
- EILs determine whether the concentrations of metals in the soil of the area under investigation possess a potential risk to the environment. The EILs values are based on phytotoxicity and threshold levels for uptake by plants.
- **Cu, Hg, Cr and Ni** values exceeded the regulatory limit.....



GIS Applications



- The Copper distribution map of the OMT exhibit elevated concentrations of copper throughout both the western and the eastern tailings.
- These copper concentrations exceed EILs value of 100mg/kg. The southern portion of the western tailing shows the highest copper concentration values, whereas its northern equivalent shows the lowest concentration, which though exceeds the EILs.
- The eastern tailings predominantly show medium concentrations in comparison to the western tailings. Therefore, copper tolerant plants are highly recommended for both tailings.



Discussion

- It is essential to acknowledge that the remediation practices and recommendations to be proposed does not contain thorough inspection tests/research data conducted on the OMT (pH, Geochemical data limitations). However, the available data was optimally utilised. In future thorough geochemical analysis, pH, soil compaction tests.
- The ultimate goal for this discussion was to draw possible remediation measures from both the case studies and to integrate it with the literature reviewed, and also to relate to the available OMT geochemical data.
- As a result, one could put FW and recommend possible remediation measures.



Recommendations and Conclusions

- **Remedial Technique:** Excavation and landfilling, physical and chemical stabilization, soil washing, are temporal measures, with high cost implications, and have environmental impacts. The most preferred and acknowledged remedial technique is the phytoremediation technology, specifically, phytostabilization. Phytostabilization is the most appropriate option to deal with vastly extending mine tailings impact like in the case of the OMT.
- Phytostabilization remedial method of growing metal excluder plants on the tailings has been identified as the best remedial method to remediate heavy metal contaminated mine tailings. Despite the challenges and limitations encountered during this remedial measure, the method has more added advantages attached to it.



Recommendations and Conclusions *continue*

- **Physical Soil Preparation Measures** are vital to support the Phytostabilisation Strategy (Concave Shaping of Tailings)
- **Plant Selection Criteria:** Ni, Cr, Cu and Hg tolerant, also the plants should be able to withstand the harsh environment – Semi arid, salty and extreme pH environment. Further research should be done on the best possible native trees occurring in the vicinity where the tailings are (Case 1)

Anacardiaceae	<i>Schinus molle L.</i>
Asteraceae	<i>Isocoma veneta (Kunth) Greene</i> , Cd, Cu, Mn, Pb, Zn
Euphorbiaceae	<i>Euphorbia sp.</i> Cd, Cu, Mn, Pb, Zn
Fabaceae	<i>Dalea bicolor humb. And Bonpl.</i> Ex Willd, Cd, Cu, Mn, Pb, Zn
Asteraceae	<i>Bidens humilis</i> H.B.K Cd, Cu, Mn, Pb, Zn
	<i>Atriplex Canescens</i> (Pursh) Nutt, As, Hg, Mn, Pb
Asteraceae family	<i>Helichrysum Candolleanum</i> H. Buek, Ni, Cu
Aconthaceae family	<i>Blepharis diversispina</i> (Nees) C.B.Clarke Ni, Cu
	<i>Hoslundia Opposita</i> , excluder plant for Cr



Recommendations and Conclusion *continue*

- The application of bacterial fungi such as the *Azospirillum Brasilense* SP6 and the *Arbuscular Mycorrhizal* fungal to the acidic and metaliferous tailings the soil microbial community stimulate and supports plant growth and seed germinations in toxic, acidic and arid to semi-arid climatic conditions.
- Similarly, the application of bacteria such as *Pseudomonas Putida* and *Bacillus Megaterium* can also be recommended to stimulate indigenous plant growth under dry climatic conditions.
- Lime should be added to the tailings, because lime has a high ion exchange capability, and thus, can help to reduce the toxicity levels of the mine tailings.
- In addition to this, **soil amendments** should be added to the soil to improve the organic content of the mine tailings.
- Composted sewage sludge- nitrate problem
- After planting in case study 2, the plot was covered with straw mulch which helped to reduce higher evaporations, this mechanism can also be applied to the OMT due to the fact that the tailings occurs in a water deficit terrain to avoid evaporation and retain moisture for plant growth.



Recommendations and Conclusions *continue*

- After planting, initial irrigation is needed to help stabilize the newly planted species into the soil.
- **Post-monitoring measures**
 - ❑ Finally the application of GIS to monitor vegetation development and change, as well as heavy metal distribution over time and other methods such as DTPA-extractable (Bioavailability of heavy metals) to test the bioavailability of heavy metals in the plants. The ANC (Acid neutralising capability) test to determine whether the microbial community has been established well (biodiversity establishment such as earthworms, and butterflies), and the organic matter is vitalizing effectively.
 - ❑ Also, other measurements and assessments such as the height of trees, mortality and vitality rate of trees, plus the assessment of biodiversity over time are recommended to determine the effectiveness of the established vegetation.
- International Guideline Values- The results showed that Cu, Cr, Ni, and Hg concentration exceeds the EILs of Australia, and might therefore possess a phytotoxic risk to the surrounding environment.



Thank You!