VETIVER GRASS TECHNOLOGY FOR REHABILITATION OF MINING WASTES AND TAILINGS

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TREATMENT OF CONTAMINATED SITES

Containment

In Situ

- Immobilisation by Amendment
  - Fe Oxyhydroxides
  - Fe SO₄
  - Mn Oxides

- Physical barrier or partition

Ex situ

Solidification

- Vitrification

Stabilisation

Vetiver System

Clean Up

Micro encapsulation
TREATMENT OF CONTAMINATED SITES

- Containment
  - Clean Up
    - In situ
      - Soil flushing
      - Electro Kinetics
      - Phyto remediation
        - Vetiver System
      - Bio remediation
        - Absorption Extraction
    - Ex situ
      - Screening
      - Sedimentation
      - Microbial Leaching
        - Soil Washing
Application of VST in Mining Area

- VST could be used as an integrated technique for environmental management of mining activities.
- Firstly, solid mining wastes such as tailings and waste rocks could be stabilized by vetiver to control or reduce air and water erosion, then reduce the release of heavy metals to surroundings.
- Secondly, wastewater including acid mine drainage (AMD) could be purified by phytofiltration.
- Thirdly, the surrounding lands contaminated by heavy metals could be further cleaned up by phytoextraction.
- A progressive worldwide increase in metalliferous mining in recent years opens up a vast range of prospects for IVT application.
Special Characteristics of Vetiver Grass

The following characteristics make vetiver grass highly effective for mining wastes and tailings:

• A deep, penetrating and extensive root system that binds the soil, and reinforces the soil structure which requires extraordinary force to dislodge.

• Erect and stiff stems forming a dense hedge which is very effective in retarding water flow and reducing the erosive power of high velocity overland flows.

• Vetiver is tolerant to highly adverse conditions such as saline, sodic and acidic soil conditions.

• Vetiver is highly tolerant to elevated levels of heavy metals in mine tailings

• Vetiver is tolerant to fire, frost, drought, water logging and inundation
Stiff and erect stems:
Erect stems up to 1.8m tall and over 2m with flower head

Forming a thick hedge when planted in row which can spread and slow down runoff water
Special Morphological Features

Even at this young age the stiff stem is strong enough to trap large size gravel.

Strong current flattened the native grass but not vetiver on this waterway.
DEEP, EXTENSIVE AND PENETRATING ROOT SYSTEM

China: One year old with 3.3m deep root system

Vietnam: Agriculture & Forestry University, Saigon
Special Morphological Features

Wall

Strong root reinforcement holding up this wall of soil against water erosion

Solid wall reinforced by vetiver roots
Special Physiological Features

Submergence and drought tolerance

Tests conducted in China found that when completely submerged, vetiver survived for 54 days.

Vetiver remained green but all native grasses were brown off under semi arid conditions in western Queensland.
Tolerance to high soil and water salinity

Saline threshold level is at EC_e = 8 dsm\(^{-1}\), 50% growth reduction at 17.5 dsm\(^{-1}\). Salt level of sea water is about 45-50 dsm\(^{-1}\) and vetiver can survive at 47.5 dsm\(^{-1}\) under dry land salinity conditions.

Half sea water
Physiological Features

One year after planting, vetiver growing among mangrove seedlings
Salt tolerance level of Vetiver grass as compared with some crop and pasture species grown in Australia.

<table>
<thead>
<tr>
<th>Plant Species</th>
<th>Soil EC$_{se}$ (dSm$^{-1}$)</th>
<th>Saline Threshold</th>
<th>50% Yield Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bermuda Grass (Cynodondactylon)</td>
<td>6.9</td>
<td></td>
<td>14.7</td>
</tr>
<tr>
<td>Rhodes Grass (C.V. Pioneer) (Chloris guyana)</td>
<td>7.0</td>
<td></td>
<td>22.5</td>
</tr>
<tr>
<td>Tall Wheat Grass (Thynopyron elongatum)</td>
<td>7.5</td>
<td></td>
<td>19.4</td>
</tr>
<tr>
<td>Cotton (Gossypium hirsutum)</td>
<td>7.7</td>
<td></td>
<td>17.3</td>
</tr>
<tr>
<td>Barley (Hordeum vulgare)</td>
<td>8.0</td>
<td></td>
<td>18.0</td>
</tr>
<tr>
<td>Vetiver (Vetiveria jizanioides)</td>
<td>8.0</td>
<td></td>
<td>18.0</td>
</tr>
</tbody>
</table>
Tolerance to high soil acidity

Vetiver thrives at soil pH=3.8 and Al saturation percentage of 68% and 87% under field conditions.
Special Physiological Features

Highly erodible acid sulfate soil (pH 3.0) in coastal Australia

One year after planting
### Threshold levels of heavy metals to vetiver growth as compared with other species

<table>
<thead>
<tr>
<th>Heavy Metals</th>
<th>Threshold levels in soil (mgKg⁻¹)</th>
<th>Threshold levels in plant (mgKg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vetiver</td>
<td>Other plants</td>
</tr>
<tr>
<td>Arsenic</td>
<td>100-250</td>
<td>2.0</td>
</tr>
<tr>
<td>Cadmium</td>
<td>20-60</td>
<td>1.5</td>
</tr>
<tr>
<td>Copper</td>
<td>50-10</td>
<td>Not available</td>
</tr>
<tr>
<td>Chromium</td>
<td>200-600</td>
<td>Not available</td>
</tr>
<tr>
<td>Lead</td>
<td>&gt;1 500</td>
<td>Not available</td>
</tr>
<tr>
<td>Mercury</td>
<td>&gt;6</td>
<td>Not available</td>
</tr>
<tr>
<td>Nickel</td>
<td>100</td>
<td>7-10</td>
</tr>
<tr>
<td>Selenium</td>
<td>&gt;74</td>
<td>2-14</td>
</tr>
<tr>
<td>Zinc</td>
<td>&gt;750</td>
<td>Not available</td>
</tr>
<tr>
<td></td>
<td>Vetiver</td>
<td>Other plants</td>
</tr>
<tr>
<td>Arsenic</td>
<td>21-72</td>
<td>1-10</td>
</tr>
<tr>
<td>Cadmium</td>
<td>45-48</td>
<td>5-20</td>
</tr>
<tr>
<td>Copper</td>
<td>13-15</td>
<td>15</td>
</tr>
<tr>
<td>Chromium</td>
<td>5-18</td>
<td>0.02-0.20</td>
</tr>
<tr>
<td>Lead</td>
<td>&gt;78</td>
<td>Not available</td>
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<tr>
<td>Mercury</td>
<td>&gt;0.12</td>
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</tr>
<tr>
<td>Nickel</td>
<td>347</td>
<td>10-30</td>
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<tr>
<td>Selenium</td>
<td>&gt;11</td>
<td>Not available</td>
</tr>
<tr>
<td>Zinc</td>
<td>880</td>
<td>Not available</td>
</tr>
</tbody>
</table>
CASE STUDY 1: Fresh coal mine overburden

Highly erodible alkaline and sodic overburden of open cut coal mine in central Queensland

Vetiver planted on contour line to conserve soil moisture and stabilising loose surface materials
Eighteen months after planting

Nine years after planting, note the return of native trees
CASE STUDY 2: Old coal mine overburden

This coal mine waste rock dump remained barren after 50 years

Vetiver planting to stop gully erosion and trapping sediment

One year after planting
CASE STUDY 3: Coal mine tailings

The tailings was saline, highly sodic, high levels of soluble S, Mg.Ca, Cu, Zn and Fe but extremely low in N and P.

Five salt tolerant species were used: vetiver, marine couch (*Sporobolus virginicus*), common reed grass (*Phragmites australis*), cumbungi (*Typha domingensis*), and *Sarcocornia* spp.

Complete mortality was recorded after 210 days for all species except vetiver and marine couch. Vetiver’s survival was significantly increased by mulching but fertiliser application by itself had no effect.
CASE STUDY 4: Bauxite Redmud tailings

Old Redmud

Three week after planting with only N and P fertilizers
Another byproduct of Alumina processing is residue sand, which is almost as caustic as red mud.

Bermuda grass grows on higher ground which is less caustic.
Old Residue Sands: Alcan Alumina processing at Gove, Australia

New planting on highly caustic old residue sand

Vetiver grew well on residue sand except in some extremely caustic area

Vetiver PC: Morell J
CASE STUDY 5: Bentonite mine waste dump

This Bentonite mine tailings dump is barren with an extremely erodible surface which has low water infiltration and high runoff rates.

Fourteen months after planting, note the growth of other species.
# Chemical analyses of the Bentonite tailings

<table>
<thead>
<tr>
<th>Analyses</th>
<th>Overburden</th>
<th>Bentonite tailings</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>5.4</td>
<td>5.4</td>
</tr>
<tr>
<td>EC (mS/cm)</td>
<td>0.18</td>
<td>0.14</td>
</tr>
<tr>
<td>Cl (mg/kg)</td>
<td>135.0</td>
<td>47.4</td>
</tr>
<tr>
<td>NO3-N (mg/kg)</td>
<td>1.9</td>
<td>0.7</td>
</tr>
<tr>
<td>P (mg/kg)</td>
<td>2.0</td>
<td>5.0</td>
</tr>
<tr>
<td>SO4-S (mg/kg)</td>
<td>66.0</td>
<td>101.0</td>
</tr>
<tr>
<td>Ca (meq/100g)</td>
<td>0.19</td>
<td>0.93</td>
</tr>
<tr>
<td>Mg (meq/100g)</td>
<td>4.75</td>
<td>6.44</td>
</tr>
<tr>
<td>Na (meq/100g)</td>
<td>2.7</td>
<td>7.19</td>
</tr>
<tr>
<td>K (meq/100g)</td>
<td>0.16</td>
<td>0.43</td>
</tr>
<tr>
<td>Organic Matter (%)</td>
<td>0.45</td>
<td>0.35</td>
</tr>
<tr>
<td>ECEC (meq/100g)</td>
<td>8</td>
<td>15</td>
</tr>
<tr>
<td>Exchangeable Sodium %</td>
<td>35</td>
<td>48</td>
</tr>
</tbody>
</table>
Case Study 6: Old gold tailings dump

Kidston mine old gold tailings: An extremely acidic (pH 2.7, sulfate 8 500mg/kg) gold mine tailings in north Queensland.

Good establishment and growth with lime and fertiliser application on this site.
CASE STUDY 7: Fresh gold tailings dump

Strong wind causes dust storm, which is highly contaminated with heavy metals such as Arsenic, Copper etc.

Kidston mine large fresh tailings pond, typical of a big gold mine.
Conventional measure is to plant a surface cover crop and to build fences to control wind erosion promoting crop establishment.

Despite its very solid construction, these rigid and expensive fences are also vulnerable to high wind velocity.
The flexible Vetiver hedges provided a low cost and permanent wind barrier unaffected by strong winds, providing excellent protection for crop establishment (2 years after planting)
Ten years after planting, no fertilizers and occasional grazing

Ten years after planting, no fertilizers and heavy grazing
CASE STUDY 8: Pb – Zn tailings rehabilitation in China
Research: Vetiver had the highest tolerance and accumulated the lowest concentrations of heavy metals in shoot.
Application: The land around the smelting factory was severely contaminated by heavy metals. Many efforts were failed but Vetiver was well established after 5-months.
CASE STUDY 9: Coal mines in South Kalimantan, Indonesia

VST was successfully used for:
* Rehabilitation of mine tailings slopes
* Stabilizations banks of channels of waste water disposal ditches.

PC: D Booth
CASE STUDY 10: Gold mines in North Sulawesi, Indonesia

VST application at PT Meares Soputan Mining, Toka Tindung gold mine site
CASE STUDY 11: Iron ore mine in West Bengal, India
CASE STUDY 12: Gold mine tailings dam in South Africa

3 months after planting

Vetiver
Same tailings dam wall, 3 year later
The Rio Tinto- Simandou, Guinea

Anglo America Ashanti Gold Mine in Guinea, West Africa.
Vetiver grass slips planted in contour furrows and hydromulched at Anglo Ashanti Gold, Ghana
Ambatovy Project, Moramanga to Tamatave, Madagascar

- Length of rows: 220 km
- Area rehabilitated: 550ha
- Rehabilitation period: 3 years
- Vetiver plants & fascines sourced from local communities
Rehabilitation of Chromium Waste Dump - extremely difficult work conditions with limited access- Planting of “potted” Vetiver grass and hydroseeding
Vetiver planted in rows 1 meter apart at intervals of 250mm. Areas between rows of Vetiver scarified and hydroseeded with native grass species.

Vetiver turned brown due to winter frost, will regrow in spring.
CASE STUDY 13: Open cut Bauxite Mining at Los Pijiguaos, Venezuela (pH 4-5; Rainfall 2 400-2 900mm/y)
SUMMARY

The Advantages of Using the Vetiver System for Mine Rehabilitation

1. Containment: Erosion and sediment control of waste rock dump and infrastructure

2. Clean Up: Control/reducing the contaminated materials from spreading to the environment by phytoremediation

3. VST is natural: no secondary by-products are produced and can be grazed by livestock.
Queensland is one of the largest mining states of Australia, its Department of Mineral and Energy recommended VST for mine and quarry rehabilitation in the state.