Phytoremediation on Lead And Acid mine Drainage soils

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PRESENTATION OUTLINE

- Introduction
- Objectives
- Phytoremediation overview
- Methodology
- Results and discussion
- Conclusion
- Recommendations
- Acknowledgements

INTRODUCTION

- Underground mine shafts, runoff and discharge from open pits
- Waste dumps
- Tailings and stockpiles
- Common mineral involved – pyrite
- Low PH, High sulphate and Elevated concentrations of heavy metals

INTRODUCTION

- Edendale lead mine – abandoned
- Edendalespruit downstream of the mine (below the old plant site)
- Close to Mamelodi
- Concern is potentially lead polluted borehole water and high lead concentrations in the soil and stream
- Decommissioned before environmental legislation related to mining in SA
- Phytoremediation = recommended remediation and prevention measures at Edendale

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OBJECTIVES

- Aim : Implement phytoremediation technique
- Identify metals that can be extracted using particular plant
- Determine the extend of heavy metal pollution on Lead and AMD soils
- Determine how the two grasses species perform in terms of extracting and growing on these soils

PHYTOREMEDIATION

- Technique in which different plants are used to degrade, extract, contain or immobilize contaminants from water and soils
- Cost effective technology
- Applied in conjunction and sometimes as a substitute of expensive chemical and mechanical remediating techniques

PHYTOREMEDIATION

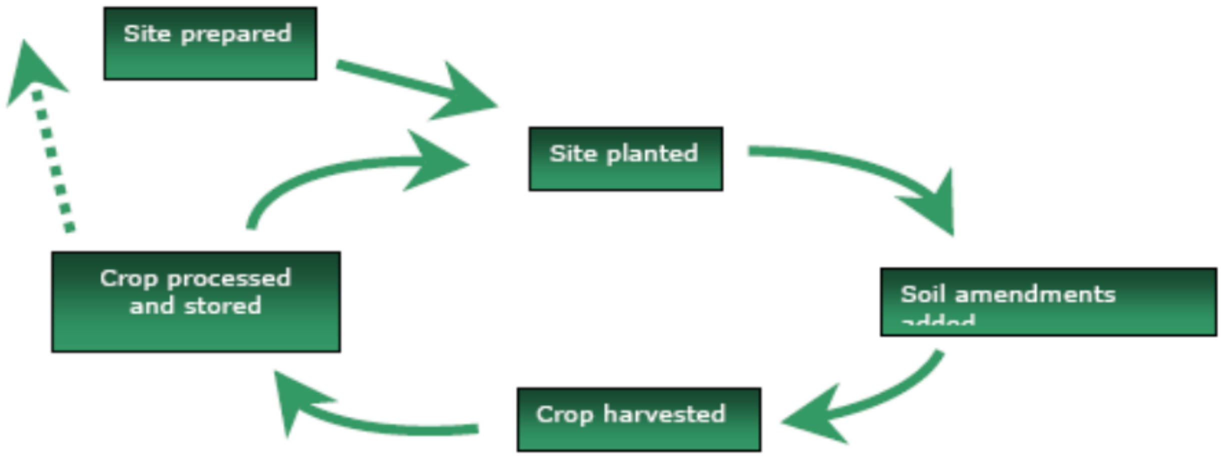
- Conventional techniques degrade soil properties, destroy biodiversity and render the soil useless for plant growth
- Phytoremediation is environmentally friendly
- Controlled by the root system of the plant, growth rate of the plant and the concentration of the contaminants
- Requires multidisciplinary inputs (Agricultural agents, botanists, hydro geologists, soil scientists, Environmental Engineers and regulators

PHYTOREMEDIATION

- Heavy metals
- Radionuclides
- Chlorinated solvents
- Petroleum hydrocarbons
- Pesticides
- Nutrients
- Landfill leachates

PHYTOREMEDIATION

- Steps



Schematic illustration of phytoremediation scheme

PHYTOREMEDIATION

- Important step in phytoremediation is to define the problem
- Includes:
  - Site investigation, identification of the media/contaminant, Regulatory requirements
  - Site preparation, vegetation establishment and site management
  - Periodically monitor the system to evaluate progress

METHODOLOGY

- Two different grass species (Vetiver and Eragrotis Curvula)
- Planted in Pb – Zn and acid mine drainage polluted soils
- Also in potty soil for control purposes
- EGU lab with dripping system connected to a tap - irrigation

METHODOLOGY

Experimental setup in the EGU lab

METHODOLOGY

- Grasses chosen based on their promising characteristics for phytoremediation
- Vetiver is tolerant to adverse condition and regrows quickly after being affected by drought
- Grows on both acidic and alkaline conditions
- Withstand and absorbs high levels of heavy metals (As, Cd, Cr, Pb, Hg and Zn)

METHODOLOGY

- Eragrotis grows on well drained acid soil
- Good for erosion control
- Two study sites chosen: Edendale mine and gold tailings dam from Nigel area
- Soil samples collected from both sites
- Characterized by XRF, XRD, paste PH and EC

METHODOLOGY

- Sample descriptions

Sample name	description
Edendale Background	Site vegetated with grass
Edendale 1	Reddish soil material with no vegetation growing on it.
Edendale 2	Site with gravel, rock boulders and some white precipitates with no vegetation
Edendale 3B	The bottom reddish soil material below Edendale 3 sample.
Edendale 3T	Top layer showing some greyish residuals of processed material
Edendale 4	Vegetated material next to the wetland.
Edendale dump 1	Mixture of soil and small rock boulders on top of a slightly vegetated dump

METHODOLOGY

- Growth rates of the grasses recorded weekly
- The dripping system was stopped during December holidays to avoid spillage in the lab
- Vetiver grass showed signs of drying up in the AMD soil

METHODOLOGY

Appearance of the grasses after December Holidays

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METHODOLOGY

- Leachate from samples collected weekly
- To determine the extent of heavy metals on soils
- Leachate analyzed for major cations

(ICP – MS) and anions (IC analysis)

RESULTS AND DISCUSSION - XRD

- Site 1: Lead contaminated site
- Mineralogical results of the Pb soils in wt%

Sample	Galena	Pyrite	Calcite	Gypsum	Anglesite	Microcline	Plagioclase	Quartz	Kaolinite/Chlorite	Chlorite	Interstratification
Edendale Background	0	2	0	0	0	trace	0	97	1	0	2
Edendale 1	0	0	0	0	0	trace	0	98	1	0	2
Edendale 2	36	2	0	0	7	2	0	47	5	0	0
Edendale 3B	0	0	0	0	0	0	0	99	1	0	0
Edendale 3T	0	0	0	10	39	0	0	25	0	26	0
Edendale Dump	0	0	1	0	0	0	1	87	9	0	2
Edendale 4	0	0	0	0	0	1	0	96	0	0	3

RESULTS AND DISCUSSION - XRD

- Site mainly dominated by quartz, galena and anglesite
- Clay fractions (Kaolinite/Chloride)
- Low interstratifications – common from physical mixtures of Illite and smectite

RESULTS AND DISCUSSION - XRD

- Site 2: AMD site

Mineralogy of the acid mine drainage contaminated soil in wt%

Sample	Quartz	Chlorite	Mica	Gypsum	Alunite
AMD	87	6	5	1	1

- Dominated by quartz, few quantities of chlorite and mica and vey little gypsum and alunite
- Muscovite and Biotite – common mica minerals

RESULTS AND DISCUSSION - XRD

- Potting soil

Mineralogical results of the potting soil in wt%

Sample	Calcite	Hematite/ Goethite	K-feldspar	Plagioclase	Quartz	Mica	Kaolinite
Potting	-	2	4	5	71	12	6

- K- feldspar, plagioclase, quartz, mica, kaolinite, Hematite and Goethite
- Quartz most dominant

RESULTS AND DISCUSSION - XRF

- XRF performed to determine the extent of heavy metal contamination
- Soil quality standards accepted by EU were used as a guideline
- Indicate the target and intervention value for soils
- Target is the maximum acceptable value without risk to humans, plants and animals
- Intervention shows values that have risks to ecological systems and requires mitigation

RESULTS AND DISCUSSION - XRF

- Guideline values

Soil quality standards

Element	**As**	**Co**	**Cr**	**Cu**	**Mo**	**Ni**	**Pb**	**Zn**
Target value (ppm)	29	20	100	36	10	35	85	140
Intervention value (ppm)	55	240	380	380	200	210	530	720

RESULTS AND DISCUSSION - XRF

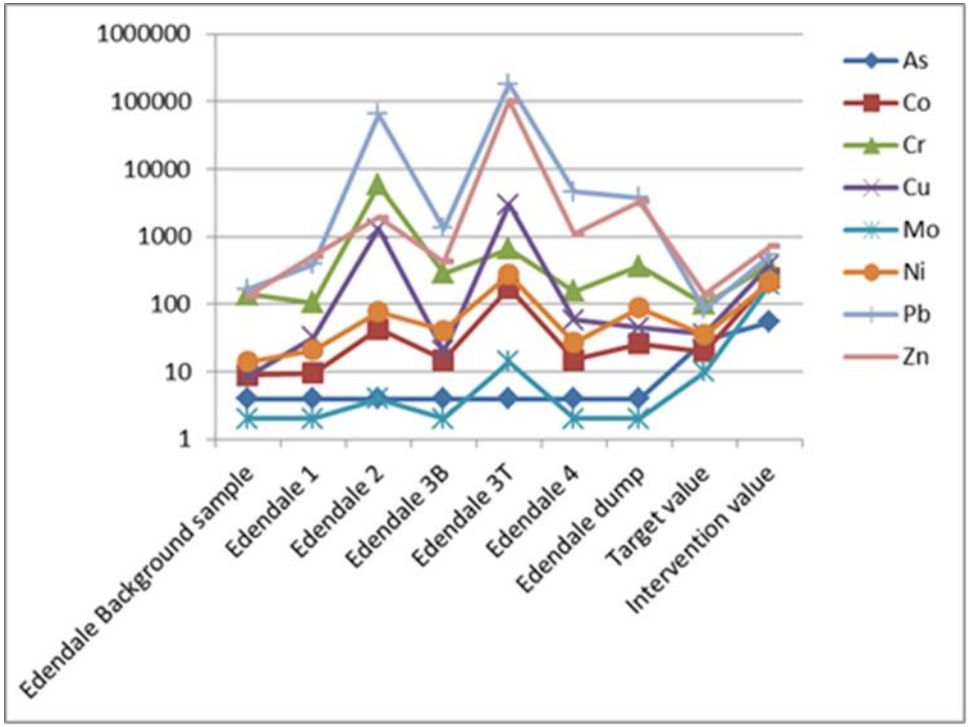
XRF results for the lead contaminated site

Sample no	XRF results (ppm)							
	As	Co	Cr	Cu	Mo	Ni	Pb	Zn
Edendale Background	<4	8.9	140	8.7	<2	14	165	133
Edendale 1	<4	9.5	106	32	<2	21	388	522
Edendale 2	<4	43	5845	1293	4	77	64281	1906
Edendale 3B	<4	15	285	20	<2	41	1335	430
Edendale 3T	<4	174	664	2986	14	277	181542	102498
Edendale 4	<4	15	155	58	<2	27	4592	1090
Edendale Dump	<4	26	367	45	<2	88	3818	3337

RESULTS AND DISCUSSION - XRF

- As < target and intervention values in all samples
- Co > target in Edendale 2, 3T and Dump 1 samples but < intervention values
- Cr > target and intervention values in Edendale 2 and 3T samples – High pollution
- Same Cr observations applies for Cu
- High pollution levels of lead, zinc and chromium

RESULTS AND DISCUSSION - XRF



XRF concentration of the lead contaminated soils

RESULTS AND DISCUSSION - XRF

- Acid mine drainage

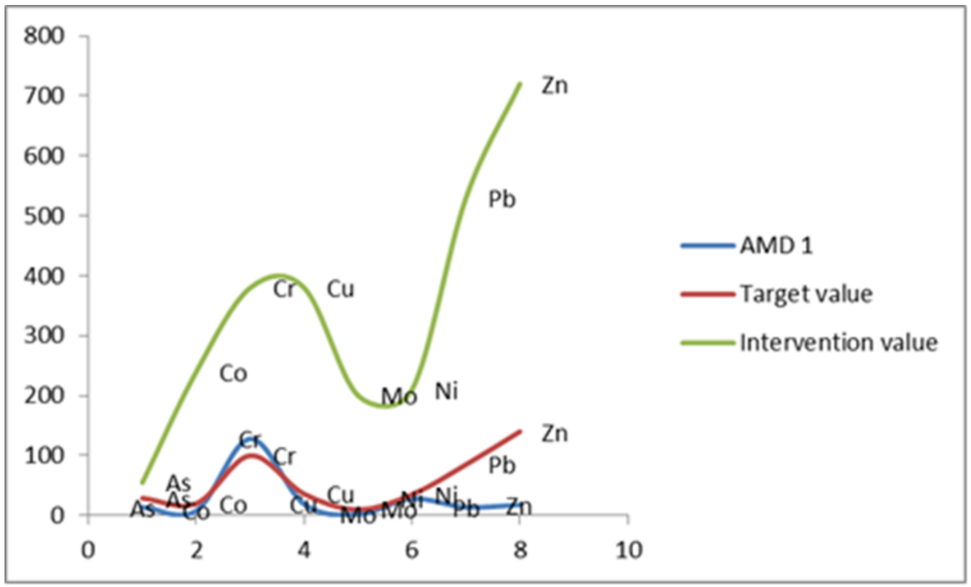
XRF analysis of the Acid mine drainage

Sample ID	XRF results (ppm)							
	As	**Co**	**Cr**	**Cu**	**Mo**	**Ni**	**Pb**	**Zn**
AMD	14	8.1	128	19	<2	28	14	18

- Arsenic, Cobalt, copper, molybdenum, nickel and Zn < target concentration
- Intervention value > Cr > target concentration
- Sample below intervention value

RESULTS AND DISCUSSION - XRF

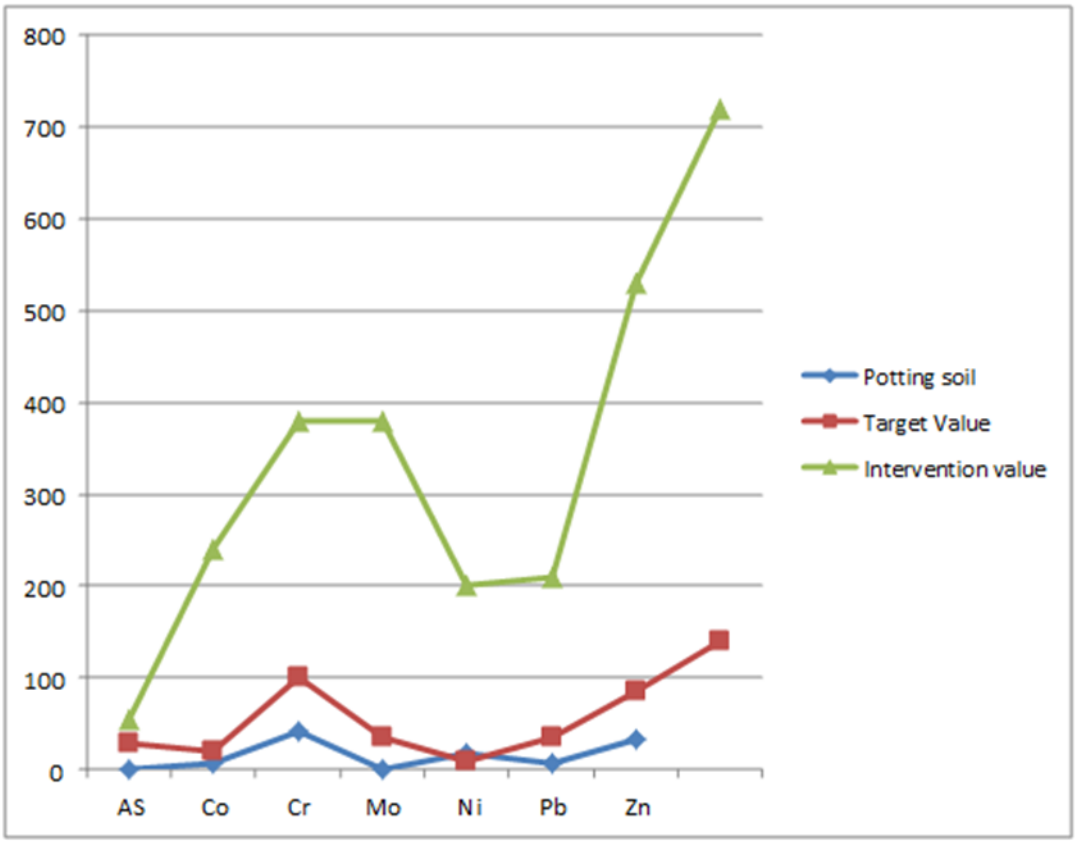
- Acid mine drainage XRF



XRF concentration of the tailings material

RESULTS AND DISCUSSION - XRF

Potting soil



XRF for the potting soil

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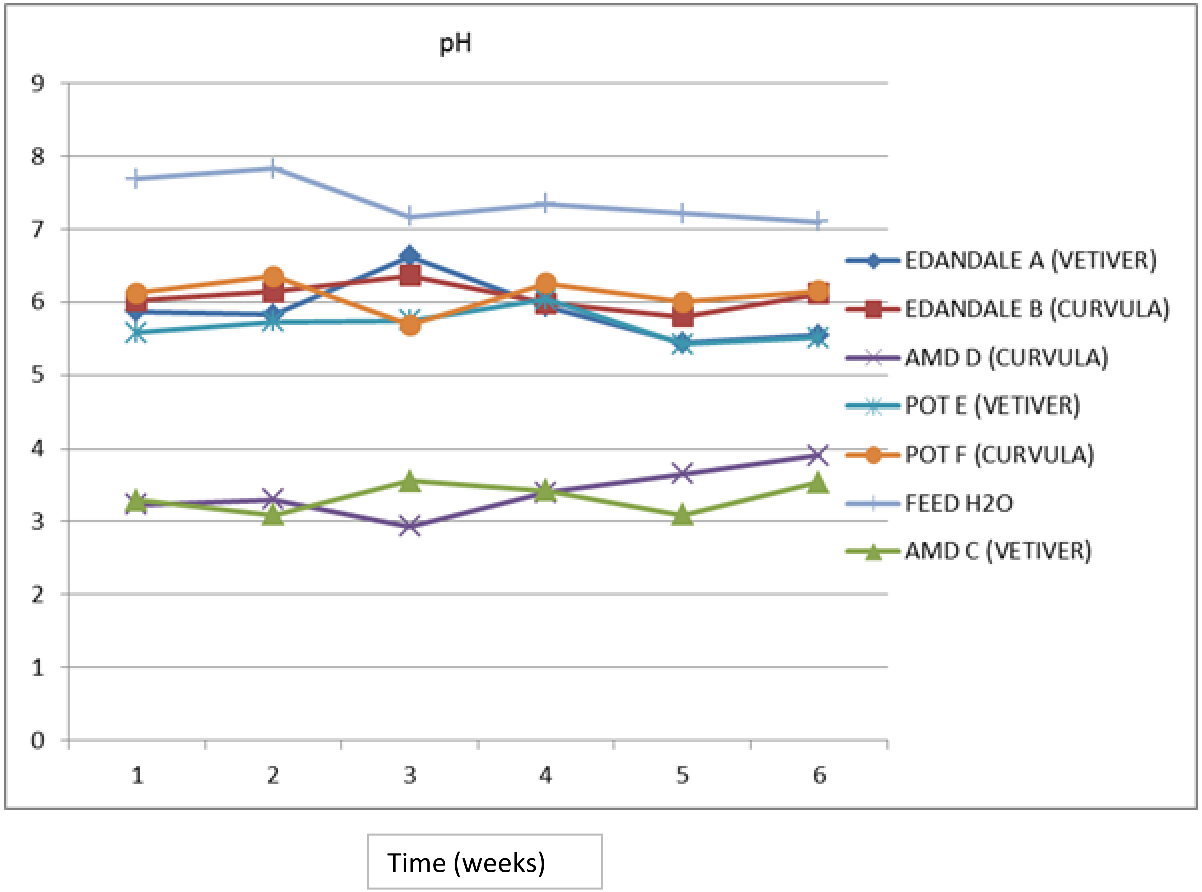
RESULTS AND DISCUSSION- PH

- Leachate PH



Leachate PH with time

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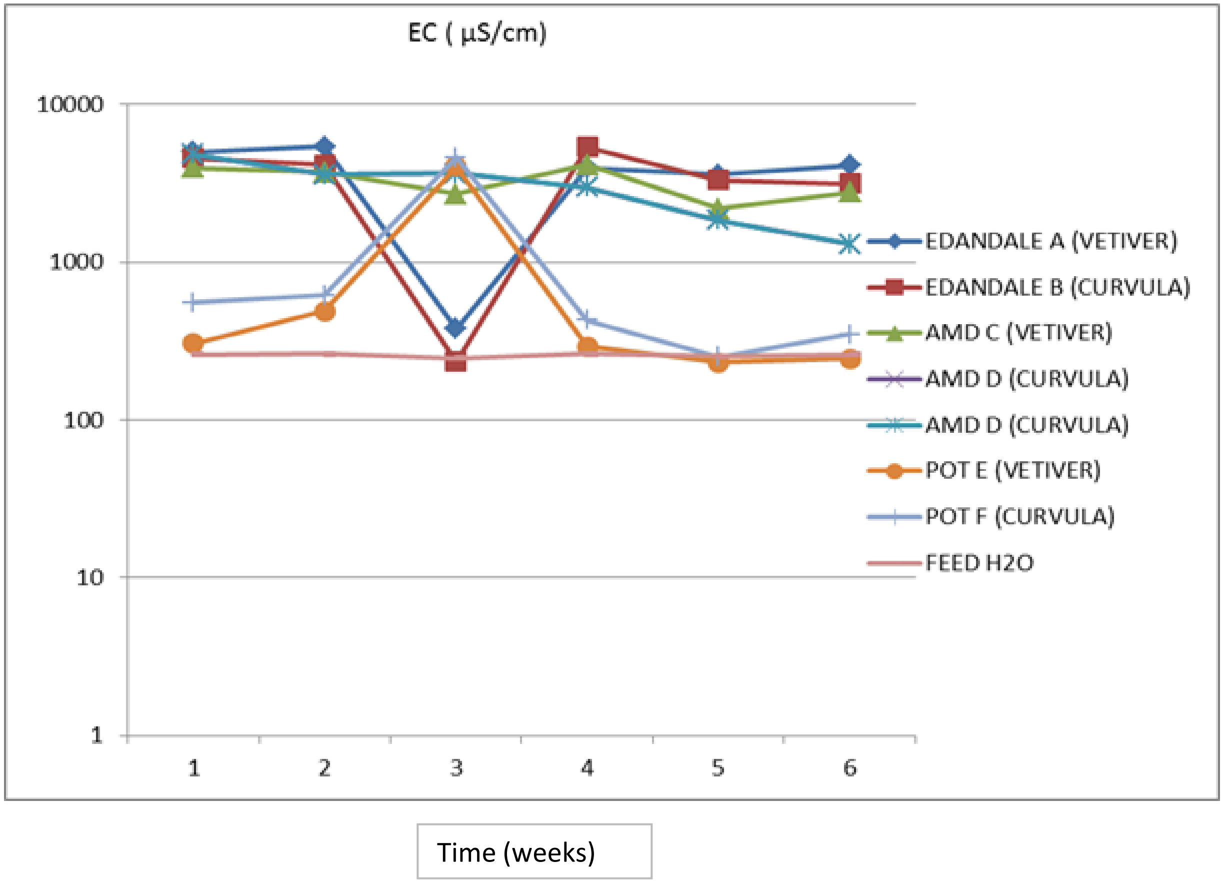
RESULTS AND DISCUSSION - EC

- Leachate EC



Leachate EC with time

RESULTS AND DISCUSSION - ICPMS

- Heavy metals occur naturally and become integrated into aquatic environment through food and water
- Mining and industrial activities result in higher concentration than those that would occur naturally
- Weekly leachate compared with SA water quality guidelines
- Aquatic ecosystems guidelines to determine the extent of heavy metal contamination

RESULTS AND DISCUSSION - ICPMS

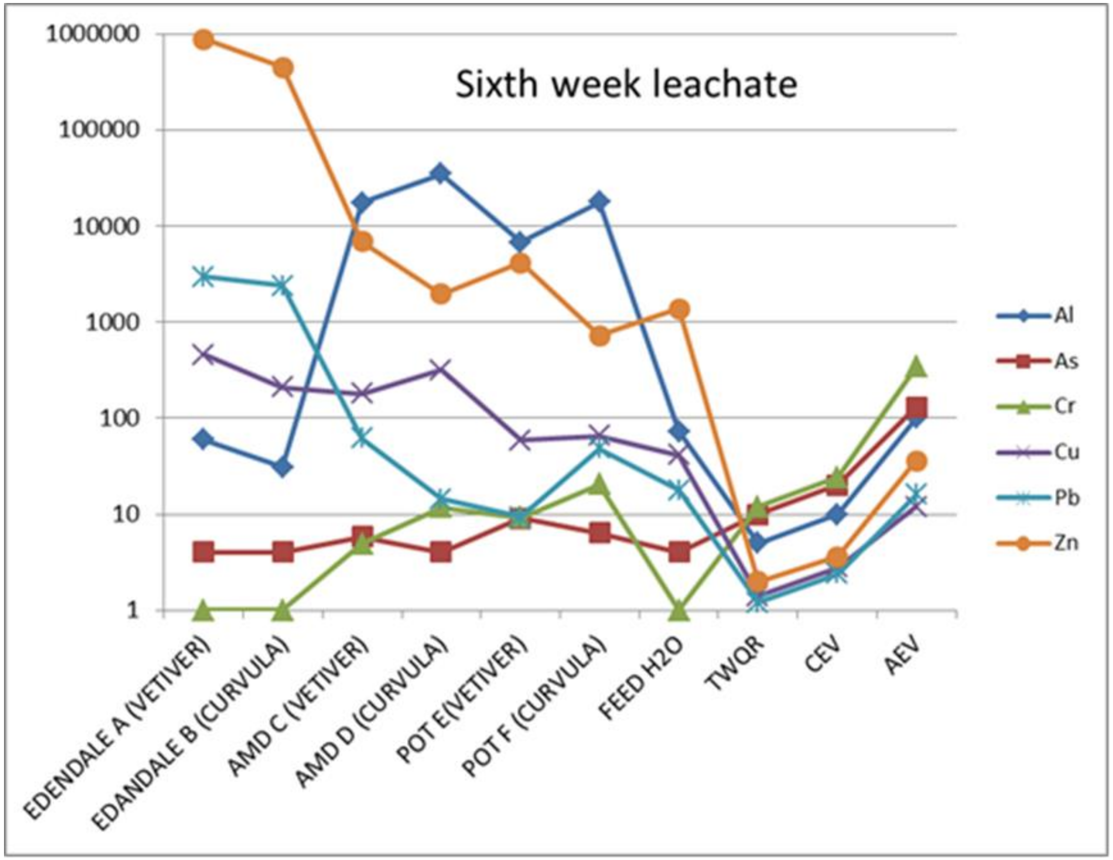
- Guidelines

Element	Target water quality range (TWQR) (µg/L)				Chronic effect value (CEV) (µg/L)				Acute effect value (AEV) (µg/L)			
Al	5				10				100			
Fe	< 10% of dissolved iron for a site											
As	10				20				130			
Co												
Cr(III)	12				24				340			
Cr (IV)	7				14				200			
Cu	st	md	hd	vh	st	md	hd	vh	soft	medium	hard	Very hard
	0.3	0.8	1.2	1.4	0.53	1.5	2.4	2.8	1.6	4.6	7.5	12
Pb	0.2	0.5	1.0	1.2	0.5	1.0	2.0	2.4	4.0	7.0	13	16
Mo												
Ni												
Zn	2				3.6				36			

RESULTS AND DISCUSSION - ICPMS

- TQWR – concentration levels with no adverse health effects
- CEV – measurable chronic effect of up to 5% expected in the aquatic community
- AEV – toxic effects of up to 5% expected
- Heavy metals plotted with time to observe their trend

RESULTS AND DISCUSSION - ICPMS



Summary of the sixth week leachate for different metals in each soil

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RESULTS AND DISCUSSION -ICPMS

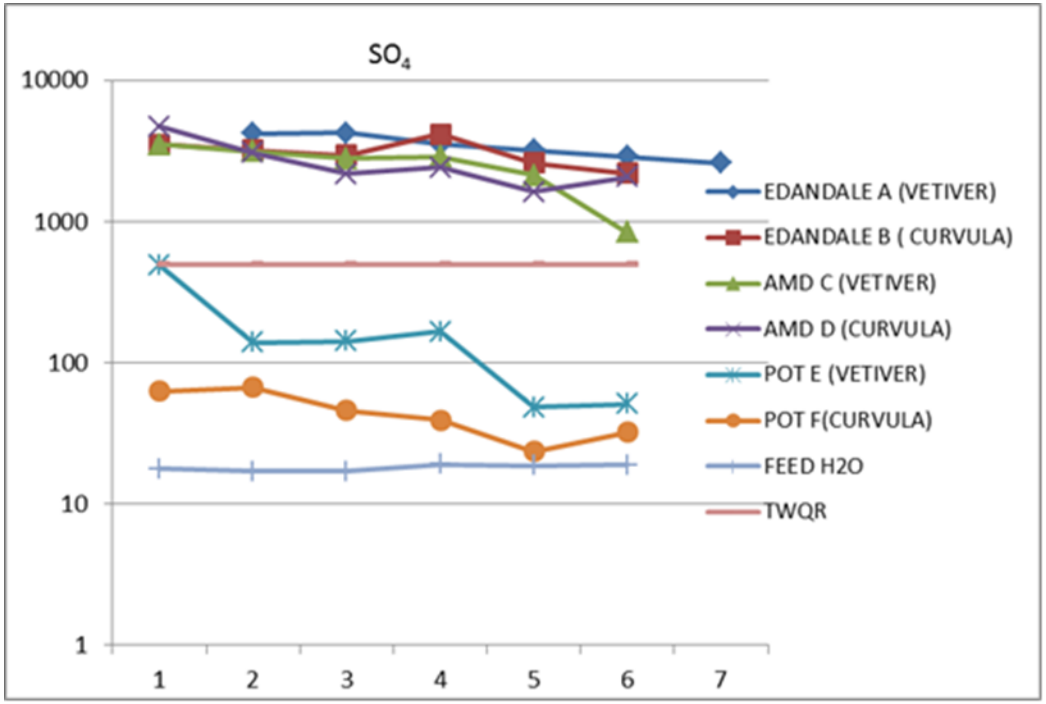
- Summary of the sixth week leachate shows high pollution of aluminium, copper, lead and zinc
- Concentrations extremely higher than the TWQR for the aquatic ecosystem
- No indication of arsenic pollution

RESULTS AND DISCUSSION - IC

- IC gives results for anions such as chloride, nitrite, fluoride, bromide, nitrate and sulphate
- High levels of sulphate, nitrate and chloride are observed in some of the samples
- Sulphate is a typical constituent found in water
- Results from dissolution of mineral sulphates and form salts with K, Ca, Pb and Na
- Ingestion of large amounts (Na and Mg) = dehydration in human beings

RESULTS AND DISCUSSION - IC

Sulphate



Time (weeks)

Leachate sulphate concentration

RESULTS AND DISCUSSION - IC

- Sulphate adopted to protect aquatic life = 500 mg/L
- WHO guideline
- More than 500 mg/L notify relevant authorities
- Edendale and AMD leachate samples exceeds 500 mg/L
- Sulphate in Edendale from dissolution of Anglesite ($PbSO_4$)
- High sulphate concentration typical for AMD

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CONCLUSION

- Anglesite in the Edendale samples indicates pollution in the area
- Alunite in the AMD site
- Amongst the Jarosite group common in acidic soils and mine water
- XRF shows high lead, zinc and copper – Edendale
- High Cr in the AMD site

CONCLUSION

- Vetiver grass developed new shoots after a week of planting
- Highest growth rate observed in the potting soil
- Growth rate in the Pb soil was higher than acid mine drainage contaminated soil
- Curvula grass showed signs of drying up in fewer portions of the shoot
- Vetiver grass could be a good phytoremediation candidate – long period in harsh conditions

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CONCLUSION

- Weak curvula grass
- Died in the potting soil which did not have any pollution problems
- Vetiver did not die in the potting soil
- Dying of vetiver in the AMD and lead soil
- Interruption with the monitoring programe during December
- Extremely high contamination level - Pb

RECOMMENDATIONS

- Pilot investigation of Vetiver grass
- Addition of fertilizers to enhance growth
- Soils with extreme pollution levels should be diluted with the background soils
- Help to reduce pollution levels
- Plants growing around the polluted environments should also be investigated
- Adapted and reconditioned themselves to the surrounding pollution

ACKNOWLEDGEMENTS

- Professor Evans Chirwa - UP
- Dr Mosidi Makgae
- Dr Henk Coetzee
- Mr Supi Tlowana
- Mpho Kotoane and laboratory staff of the CGS
- Bonginkosi and his team, Leon Lekgothwane
- Carl Nöffke – Hydromulch
- Council for Geoscience

Thank You

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