Evaluating the suitability of Paspalum as a candidate for Rehabilitation of Mine Tailings dams: A Case study of New Union Gold Mine

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Abstract Although mining has contributed considerably towards the GDP of a country it is the disposal of waste associated with mineral benefication has resulted in mine tailings that have an impact on the environment. Studies were carried out to assess the heavy metal uptake by Paspalum grass species at a mine tailings dam (New Union Gold Mine, Limpopo South Africa) and a control site. The Paspalum dilatatum on average, absorbed total metal concentrations of 290.7 mg/kg (mine tailings) and 44.7 mg/kg (control) and these were significantly different ($p< 0.0$). The heavy metal concentration uptake of P. dilatatum probably originated from the mine tailings. This was confirmed by the metal composition (range) of the soil mine tailings: Mn [72.0 – 173.0 mg/kg]; Zn [12.0 – 30.0 mg/kg]; Cu [15.0 – 37.0 mg/kg]; Pb [3.0 – 6.0 mg/kg]; Cd [< 1.0 mg/kg] and Co [1.0 – 3.0 mg/kg]. For the control soil samples the heavy metal composition was: Mn [18.0 – 22.0]; Zn [3.0 – 6.0]; Cu [6.0 – 11.0]; Pb [1.0 – 2.0]; Cd [< 1.0] and Co [< 1.0]. With the exception of Cd, there were significant differences ($p < 0.0$) between the metal composition of soils originating from the mine tailings and the control. The mine tailings were highly acidic with a pH range of 3.45 to 3.48 whilst that of the control the pH was in the range of 5.24 to 5.31 and were significantly different ($p < 0.0$). Thus P. dilatatum was capable of absorbing the metals and showed poor growth under the acidic conditions (mine tailings). The control grass samples were healthy and thriving under the moderate pH conditions. P. dilatatum may not be a suitable candidate for re-vegetation of mine tailings as a protective barrier against wind and or water erosion.

Key Words mine tailings, Paspalum dilatatum, rehabilitation, wind and water erosion

Introduction

The mining and processing of valuable mineral ores such as gold does contribute to creation of employment opportunities in the mining sector including the benefication. But major environmental challenges come after mining has stopped and the mine tailings are now a source of environmental problems throughout the world and are on the increase (Bell et al 2001; Ogola et al 2002; Naicker et al 2003; Mendez et al 2007). For example mining occurred at New Union Gold Mine, South Africa until the 1990s when the gold bearing ores were depleted (Ward and Wilson 1998). During the processing of gold, mercury and cyanide were used and the mine wastes were dumped in tailing dams (Naicker et al 2003). These tailing rich in heavy metals including mercury and cyanide pose a danger to local ecosystems and human health due to the dispersal of dust and sediments by water erosion and dust storms (Meza-Figura et al 2009).

Thus it is important to rehabilitate the mine tailings by establishing a permanent vegetative cover to contain toxic metals by accumulation in root tissue, leaves and stem (Mendez et al 2007). The main aim of the study was to assess the suitability of P. dilatatum as a candidate for the rehabilitation of mine tailings at New Union Gold Mine. The specific objectives were: to determine the heavy metal composition of mine tailings to determine the pH of the mine tailings; and to determine the heavy metal uptake by P. dilatatum.

Materials and methods

Study and sampling areas

Mine tailings and P. dilatatum grass samples (served as treated) were collected from the New Union Gold mine tailings dam (longitude 23°01'24"S, latitude 30°43'36"E) for a period of six months. The control grass and soil samples were collected at Ka-Madonsi village.

pH determination and analysis of heavy metal content of mine tailings and grass samples

The collected samples (mine tailings and grass) were sealed in plastic sachets, labeled with date of sampling and then these were processed following the procedure that was used by Mulugisi et al (2009).

Data analysis

The analytical raw data was processed as per procedure of Mulugisi et al (2009) and statistical analysis was carried with unpaired *t*-test.

Results and discussion

pH and Heavy metal distribution of tailings at New Union Gold Mine

The pH of the tailings soils at New Union Gold Mine were more acidic (Table 1). The tailing dam A had a pH range of 3.45 to 3.48 whilst the control for the pH was in the range 5.24 to 5.31. The unpaired t-test showed that the pH were significant difference ($p < 0.0$) between the mine tailing dam and the control site. These pH values are probable due to high levels of pyrite and sulphide minerals which undergo chemical process (oxidation) when they are exposed to oxygen and water which result in acid mine drainage (Naicker et al 2003; Petrik et al 2007). These findings are in agreement with typical pH values that range from 2 to 4.4 that are prevalent in acid mine drainage areas that are dominated by coal and gold mine and old underground workings (Naicker et al 2003). The following heavy metals Mn, Zn, Cu, Pb, Cd and Co and their levels were determined at the tailings dams of New Union Gold Mine (Table 1). The concentration of Mn was the highest followed by Cu and the Zn. The concentrations of Pb, Cd and Co were the lowest in all cases, below 5.0 mg/kg. The concentration of Cd remained stable with a concentration of 1.0 mg/kg. Using the unpaired t-test, showed that metal composition (mean values) were significant difference ($p < 0.0$) between the mine tailings and the control. The exception was the Cd metal which was similar in both cases.

The heavy metal uptake by grass species at New Union Gold Mine

The P. dilatatum species from the mine tailing dam accumulated approximately seven times more of the toxic heavy metals in comparison to the control site (Table 2). This is remarkable since the grass species was growing the adverse pH conditions of 3.45 to 3.48.

Table 1 *pH and Metal concentrations in mine tailings and control soils*

	Tailings dam A					Control				
	Mean	(SD)	Median	Min	Max	Mean	(SD)	Median	Min	Max
pH	3.47	0.01	3.47	3.45	3.48	5.29	0.03	5.30	5.24	5.31
Total metal concentration (mg/kg)										
Mn	111.2	18.9	110.0	72.0	173.0	20.0	1.4	20.0	18.0	22.0
Zn	18.9	6.2	16.0	12.0	30.0	4.6	1.1	5.0	3.0	6.0
Cu	26.7	6.4	27.0	15.0	37.0	9.0	2.0	10.0	6.0	11.0
Pb	4.4	1.0	4.0	3.0	6.0	1.8	0.4	2.0	1.0	2.0
Cd	1.0	1.0	1.0	1.0	1.0	1.0	0.4	1.0	1.0	1.0
Co	1.8	1.8	2.0	1.0	3.0	1.0	0.0	1.0	1.0	1.0
	Means (Standard deviation), n = 45					Means (Standard deviation), n = 15				

Table 2 *Heavy metal uptake by different grass species from mine tailings*

	Mine Tailings dam A					Control				
Metal	Mean	(SD)	Median	Min	Max	Mean	(SD)	Median	Min	Max
Mn	207.7	22.8	208.5	170.0	254.0	23.3	2.3	24.0	19.0	25.0
Zn	35.6	7.9	36.0	17.0	47.0	6.0	1.9	6.0	3.0	8.0
Cu	40.3	8.1	38.0	31.0	61.0	10.8	1.9	10.5	9.0	14.0
Pb	4.2	1.0	4.0	3.0	6.0	2.0	0.9	2.0	1.0	3.0
Cd	1.0	0.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0
Co	1.8	0.9	2.0	1.0	5.0	1.5	0.5	1.5	1.0	2.0
Total	290.7					44.7				
	Mean (standard deviation), n = 45					Mean (standard deviation), n = 15				

The highest concentration of heavy metals at the tailings dams was the concentration of Mn, the concentration of Mn was followed with the high concentration of Cu, and Zn, and was also followed by the low concentration of Pb and Co, and the lowest was the concentration of Cd which remains stable in all the samples with the concentration of 0.001 mg/g. The research findings show that P. dilatatum species are tolerant to metal toxicity and the adverse environmental conditions. Other studies have also indicated that similar P. notatum species are also tolerant of the metal toxicity and have been used in re-vegatition of mined sites (Shu et al 2000).

Phytoaccumulation of heavy metals and implications for phytoremediation and environmental transfer

The studies of Li et al (2007) and Moreno-Jiménez et al (2009) have shown that bioaccumulation coefficient is a better tool to evaluate the phytoaccumulation potential of plants and grasses. This evaluates what aspects of the plant structure are likely to bioaccumulate the metals and has important implications for phytoremediation and health implications to other mammals including humans. There were wide variations of heavy metal phytoaccumulation among the P. dilatatum grass species. From the two sampling sites, *P. dilatatum* specie, all had BAC above 0.5 and below the 2.0 BAC categories for the accumulation of Mn, Zn and Cu (Figure 1). Thus *P. dilatatum* may not be regarded as a great hyperaccumulator for Cu and Zn. This is important in the selection of grasses species in order to target toxic metals such as Mn which have severe health hazards to mammals and humans (Erikson and Aschner 2003). This aspect of phytoremediation includes the removal of metals through hyperaccumulation and stabilization of tailings soils and binding such that soil erosion is minimized.

According to Li et al (2007) hyperaccumulators must have the Biological accumulating coefficient (BAC) and Biological transfer coefficient (BTC) that is greater than 1. In another study from the same area showed that C. dactylon was a better hyperaccumulators for the removal of Co, Cd, Cu, Zn and Mn (Mulugisi et al 2009). These toxic heavy metals may be transported to mammals including humans through a variety of routes. The transportation routes are varied and maybe via contamination groundwater, contamination of surface water following a rainfall event or a dust event blowing in the direction of human settlements or mammals consuming grasses and plants that colonize the tailings dams. The grasses at New Union Gold Mine are grazed upon by domestic animals such as goats, cattle and wild animals such as rabbits and wild dogs that prey on the rabbits as indicated by visual observation of animal droppings at the tailings dams (Mothetha 2009). This may be the transportation route in which the heavy metals are transferred from the tailings to mammals and humans. Visual observation indicated that the P. dilatatum, did not grow well under the adverse environmental conditions in comparison to the control (it was a healthy plant).

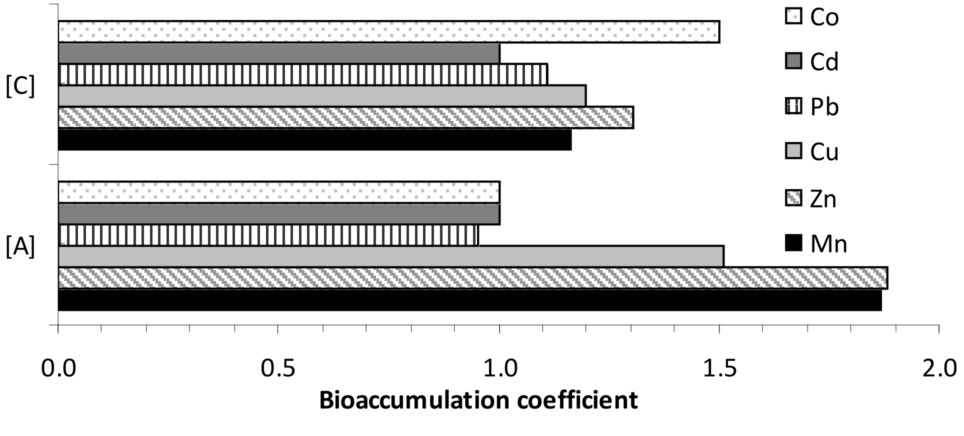

Figure 1 *The bioaccumulation coefficient (BAC = $[metal]_{leave}/[metal]_{soil\ (tailings\ or\ control)}$) for heavy metals for Paspalum dilatatum species growing at tailings dam [A] or Control [C]*

Conclusion

Though *P. dilatatum* grew poor under the adverse environmental conditions it can not be classified a great hyperaccumulator.

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References

Bell FG, Bullock SET, Halbich TFJ, Lindsay P, (2001) Environmental impacts associated with an abandoned mine in the Witbank Coalfield, South Africa. Int J.Coal Geology. 45: 195—216.

Erikson KM and Aschner M, (2003) Manganese neutrotoxicity and glutamate-GABA interaction. Neurochem. Int. 43: 475—480.

Li MS, Luo YP, Su ZY, (2007) Heavy metal concentrations in soils and plant accumulation in a restored manganese mineland in Guangxi, South China. Environmental Pollution. 147: 168—175.

Mendez MO, Glenn EP, Maier RM, (2007) Phytostabilization Potential of Quaibush for Mine Tailings: Growth, Metal Accumulation and Microbial Community Changes. J. Environ. Qual. 36: 245—253. doi:10.2134/jeq2006.0197.

Meza-Figura D, Maier RM, de la O-Villanueva M, Gómez-Alvarez, Moreno-Zazueta A, Rivera J, Campillo A, Grandlic CJ, Anaya R and Palafox-Reyes J, (2009) The impact of unconfined mine tailings in residential areas from mining town in a semi-arid environment: Nacozari, Sonora, Mexico. Chemosphere. Doi:10.1016/j.chemosphere.2009.04.068

Moreno-Jiménez E, Peñalosa JM, Manzano R, Carpena-Ruiz RO, Gamarra R, Esteban E, (2009) Heavy metals distribution in soils surrounding an abandoned mine in NW Madrid (Spain) and their transference to wild flora. Journal of Hazardous Materials. 162: 854—859.

Mothetha ML, (2009) Assessment of Environmental Impacts From A Dysfunctional New Union Gold Mine: A Case Study From Malamulele, Limpopo Province. Honours thesis (unpublished). University of Venda, Thohoyandou.

Mulugisi G, Gumbo JR, Dacosta FA and Muzerengi C, (2009) The Use of Indigenous Grass species as part of Rehabilitation of Mine Tailings: A Case study of New Union Gold Mine. Proceedings of the International Mine Water Conference, South Africa.

Naicker K, Cukrowska E, McCarthy TS, (2003) Acid mine drainage arising from gold mining activity in Johannesburg, South Africa and environs. Environmental Pollution. 122: 29—40.

Ogola JS, Mutuilah WV, Omulo MA, (2002) Impacts of gold mining on the environment and human health: A case study in the Migori Gold Belt, Kenya, Environmental Geochemistry and Health, 24: 141 -158.

Petrik L, Hendricks N, Ellendt A, Burgers C, (2007) Toxic Element Removal from Water Using Zeolite Adsorbent Made from Solid Waste Residues. WRC Report No 1546/1/07.

Shu WS, Xia HP, Zhang ZQ, Lan CY, Wong MH, (2000) Use of Vetiver and other Three Grasses for Revegetation of a Pb/Zn Mine Tailings at Lechang, Guangdong Province: A Field Experiment. http://www.vetiver.com/PRVN_IVC2_17.PDF. Date accessed: 30/05/2010

Ward JHW and Wilson MGC, (1998) Gold outside the Witwatersrand Basin. In: The mineral resources of South Africa. 6 Edition. Handbook 16. Council for Geoscience. Pretoria. 350—386.