Amendment of Minesite Acid Sulfate Soils and the Use of Vetiver Grass for Re-vegetation in Dabaoshan Mine, Northern Guangdong, China

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Abstract: We report the preliminary results from our vetiver grass growth experiments, part of a minesite rehabilitation research project in Guangdong Dabaoshan Mine. The investigated acid sulfate soil was extremely acidic with pH as low as 2.76. Pot trials were conducted to investigate the effects of various soil treatments on the growth of a vetiver grass (*Vetiveria zizanioides*). These treatments involve the uses of quick- and slow-reacting acid-neutralizing agents - hydrated lime and red mud (bauxite refinery residues), biosolids, fertilizer and zeolite. The results show that treatment of the soil with "red mud" and hydrated lime enables the establishment of vetiver grass by correcting soil acidity and eliminating metal toxicity. Over-liming affected the growth of vetiver grass but some seedlings have survived the alkaline conditions. Over-application of zeolite powder might cause detrimental effects on vetiver grass, however, further examination is needed to provide proofs. The application of chemical fertilizer additional to the above mentioned soil conditioners had worse effects on the growth of the vetiver grass.

Key words: minesite rehabilitation, acid sulfate soils, "red mud", zeolite, lime, vetiver grass

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1 INTRODUCTION

The waste rocks/soils generated during mining operations for iron ore in Guangdong Dabaoshan Mine contain large amounts of sulfide minerals. After exposed to air, these sulfide minerals oxidize gradually to produce sulfuric acid and form acid sulfate soils. The pH of these soils can be below 3, which mobilizes various heavy metals to reach or exceed toxic levels. As a result, these soils do not support any plants and the scalded land is subject to severe erosion. Water draining from these soils is highly acidic and has large environmental impacts on downstream ecosystems.

Management of mine wastes by re-vegetation is an important step to minimize acid mine drainage and establish ecological conditions in the area of disposed waste rocks/soils (Maddocks *et al.*, in press). Vetiver grass is considered as one of the plants to be used for minesite revegetation in this project. Although vetiver grass is highly acid-tolerant (Truong, 1999), the extremely acidic conditions encountered in this site still represent a soil constraint for its growth. Acid neutralization is therefore required to reduce soil acidity and metal toxicity, and increase the availability of phosphorus. Organic matter is generally lacking in these soils and addition of Biosolids (sewage sludge) is considered to increase nitrogen supply and improve soil structure.

Because the soils still contain acid-generating sulfides, extra acid-neutralizing materials, particularly less leachable acid-neutralizing agents, such as "red mud" (Lin *et al.*, 2002) are needed to counteract future acidification. This will result in an initial alkaline soil condition with decreasing pH over time. Pot trials have been conducted to compare the effects of various treatments on the growth of vetiver grass. These treatments involve the uses of quick- and slow-reacting acid-neutralizing agents - hydrated lime and red mud, biosolids, fertilizer and zeolite. This paper reports the preliminary results from this ongoing project.

2 MATERIALS AND METHODS

2.1 Materials

2.1.1 Acid sulfate soil

The acid sulfate soil sample was collected from a site upstream of the waste rock/soil containment impoundment located south of the mining area. The soil consists of sediments transported from the hilltop waste rock piles during heavy rainfall events. The major chemical characteristics of the soil can be seen from Table 1.

Table 1 Major chemical characteristics of the soil used for the pot experiment

Parameter		Water -extractable	1MKCl -extractable	0.1MHCl -extractable	References
pH		2.76			
EC (dS/m)					
Organic matter (%)	0.09				Nanjing Agricultural University, 1992
Total actual acidity (mmol/kg)	506				Lin *et al.*, 2000
Titratable acidity (mmol/kg)		17.5	35.5		
Available N (mg/kg)	23.1				Nanjing Agricultural University, 1992
Available P (mg/kg)	4.17				Nanjing Agricultural University, 1992
Zn (mg/kg)		7.37	11.66	12.25	AAS
Cu (mg/kg)		31.6	41.13	59.36	AAS
Pb (mg/kg)		1.98	10.93	6.33	AAS

2.1.2 "Red mud"

The "red mud" (bauxite refinery residues) sample was collected from the Red Mud Dam of the Pingguo Aluminium Company (Guangxi, China). The "red mud" has an acid neutralizing capacity of about 5.5 moles per kilogram.

2.1.3 Biosolids

The biosolids sample used for the experiment was from Guangzhou Sewage Treatment Plant. The biosolids sample contained 0.71 mg/kg of 0.1 M HCl-extractable Cu, 0.039 mg/kg of 0.1 M HCl-extractable Pb and no detectable HCl-extractable Zn.

2.1.4 Zeolite powder

The zeolite powder sample is the product made from zeolite rocks in the Longchuan Zeolite Mine, Guangdong.

2.1.5 Chemical fertilizer

The chemical fertilizer used for this experiment was Kemira compound fertilizer containing 150 g of N, 150 g of P_2O_5 and 150 g of K_2O per kilogram.

2.1.6 Vetiver grass

The variety of vetiver grass used for the pot trials was *Vetiveria zizanioides.*

2.2 Methods

2.2.1 Soil treatment

After collection, the soil was air-dried, ground to <5 mm and completely mixed in the laboratory. Seven soil treatments were used for formulating various growth media by adding at least three of the following materials: "red mud", hydrated lime, zeolite powder, biosolids and chemical fertilizer. Details are given in Table 2.

Table 2 Composition of growth media in various treatments

Treatment	Soil (g)	"Red mud" (g)	Lime (g)	Zeolite (g)	Biosolids (g)	Fertilizer (g)
Control	2000	0	0	0	0	0
T1	2000	50	5	0	30	0
T2	2000	50	10	0	30	0
T3	2000	50	20	10	30	0
T4	2000	50	10	30	30	0
T5	2000	50	10	60	30	0
T6	2000	50	10	30	60	0
T7	2000	50	10	30	30	2

2.2.2 Pot trials

Pot trials were conducted in a greenhouse with free ventilation. All treatments and the control were in four replicates except for Treatment 7 (T7), which was in triplicate due to insufficient soil sample. The soil in each pot was incubated using sub-irrigation for 10 days before the vetiver grass seedling was transplanted (one slip in each pot). The above ground portion of each seedling was cut to a height of about 20 cm. A soil sample was collected from each pot every 10 days to measure pH and EC. Soil samples collected at 50th day were also used for determinations of water-, 1M KCl- and 0.1 MHCl-extractable heavy metals. At 55th day, some major plant growth parameters (survival rate, number of new shoots and plant height) were also examined and recorded. The experiment is expected to continue for six months. However, we only report the results obtained so far (50 days).

2.2.3 oil sample analysis

pH and EC in 1:5 (soil:water) were measured using a calibrated pH and EC meters, respectively. Heavy metal concentrations in the same extracts were determined by AAS.

3 ESULTS AND CONCLUDING DISCUSSION

Additions of lime and red mud significantly raised mean soil pH to 7.37-10.87 from 2.55 at the first day of incubation. pH tended to increase with increasing time and after 50 days of incubation, the mean soil pH for all the treatments ranges from 6.52 to 7.88 (Table 3). This was accompanied by marked drop in the concentrations of heavy metals in the treated soils. Water- and 1M KCl-extractable Zn, Cu and Pb were all below the detection limit while the concentrations of 0.1 M HCl-extractable Zn, Cu and Pb were also significantly reduced (Table 4).

The plant growth status shown in Table 5 appears to suggest that Treatments 4 and 6 (T4 and T6) have better effect on the growth of vetiver grass than other treatments. Both T4 and T6 used moderate addition rates of lime and zeolite. T1 and T2 had poor growth status and this appears to be related to a lack of added zeolite. T3 had a pH > 10 when the seedlings were transplanted and soil pH maintained at > 8.5 during the first 20 days after planting. Although this high pH did affect the growth of the plant, some of the replicates survived. Same amounts of "red mud", lime, zeolite and biosolids were added to T4 and T7. However, the additional application of chemical fertilizer in T7 did not enhance plant growth. On the contrary, it may be responsible for the reduced survival rate and number of new shoots observed in T7 at the 55th day of the experiment. It is surprising that all the replicates in T5 did not survive. The soil conditioners added to T5 was the same as T4 except that more zeolite powder was added to the soil in T5 than in T4 (60 g in T5, compared to 30 g in T4). It is not certain whether the plant death was caused by over-application of zeolite. Work is currently underway to closely examine the effects of zeolite powder on mine soil conditions for the growth of vetiver grass. Further comparison between T4 and T6 shows that adding more biosolids into the soil did not improve the growth status of vetiver grass, at least by the 55th day of the experiment.

Table 3 Changes in soil pH for various treatments during 50 days of the experiment

Treatment	1 day	10 days	20 days	30 days	40 days	50 days
Control	2.55±0.23	3.06±0.44	2.64±0.32	2.57±0.23	2.55±0.13	2.65±0.07
T1	8.59±0.23	7.87±0.26	7.67±0.18	7.41±0.20	7.10±0.13	7.32±0.37
T2	9.73±0.85	8.70±0.70	8.38±0.38	7.79±0.11	7.63±0.05	7.64±0.12
T3	10.87±0.62	10.71±0.77	9.15±0.20	8.61±0.75	8.16±0.28	7.88±0.18
T4	8.60±0.65	8.15±0.24	8.07±0.43	7.64±0.35	7.39±0.29	7.49±0.30
T5	9.14±1.32	8.57±0.53	8.26±0.28	7.88±0.03	7.65±0.14	7.68±0.14
T6	7.42±0.36	7.26±0.50	7.04±0.38	6.70±0.38	6.31±0.11	7.25±0.34
T7	7.37±0.34	6.86±0.59	6.94±0.22	6.40±0.15	5.91±0.20	6.52±0.55

Table 4 Comparison of water, 1M KCl and 0.1M HCl extractable Zn, Cu and Pb_mg/kg_between the control and various treatments

Treatment	Zn			Cu			Pb		
	H_2O	KCl	HCl	H_2O	KCl	HCl	H_2O	KCl	HCl
Control	7.37	11.66	11.55	31.60	38.17	57.01	1.98	10.93	5.67
T1	bdl	bdl	6.49	bdl	bdl	14.45	bdl	bdl	2.07
T2	bdl	bdl	bdl*	bdl	bdl	2.97	bdl	bdl	0.08
T3	bdl	bdl	bdl	bdl	bdl	0.37	bdl	bdl	0.03
T4	bdl	bdl	bdl	bdl	bdl	16.50	bdl	bdl	0.08
T5	bdl	bdl	bdl	bdl	bdl	0.65	bdl	bdl	0.08
T6	bdl	bdl	13.27	bdl	bdl	19.37	bdl	bdl	7.51
T7	bdl	bdl	10.43	bdl	bdl	11.59	bdl	bdl	6.12

*bdl: below detection limit

Table 5 Comparison of various growth criteria among different treatments

Treatment	Survival rate (%)	Number of new shoot	Plant height (cm)
Control	0	0	_
T1	25	1	37.0
T2	25	1	26.5
T3	50	2	43.75 ± 1.06
T4	100	11	76.93 ± 36.25
T5	0	0	_
T6	100	7	72.73 ± 30.17
T7	50	3	87.15 ± 6.86

The results presented here are based on data obtained at very early stage of the project. More information will be provided later in the conference to be held in October 2003.

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A Brief Introduction to the First Author

Dr. Chuxia Lin is currently holding a Professorship at the College of Resources and Environment, South China Agricultural University (Guangzhou, China) and a Visiting Professorship at the School of Environmental Science and Management, Southern Cross University (Lismore, Australia). He worked as an Environmental Scientist in Australia during the period 1989-2002 and has contributed to the establishment of Australia's international leadership in acid sulfate soil research. He is presently leading a research team to work on minesite rehabilitation in China, which involves the uses of vetiver grass for re-vegetation in abandoned mitesites.