Exploring the Potential Utilization of Vetiver in Treating Acid Mine Drainage (AMD)

Wensheng Shu
School of Life Science, Sun Yatsen (Zhongshan) University, Guangzhou 510500, China

Abstract: Acid mine drainage (AMD) released from mining industry usually has a low pH and contains high levels of heavy metals, which significantly impacts on the water quality and ecosystems of southern China. Constructed wetlands have been considered effective, low cost and a practical approach for the cleanup of different wastewaters including AMD. A microcosm test was conducted to assess the tolerance of different wetland species to AMD and purification capacity of wetlands. The plant species trialed included: *Vetiveria zizanioides* (VZ), *Phragmites australis* (PA), *Cyperus alternifolius* (CA), *Panicum repens* (PR), *Gynura crepidiodes* (GC), *Alocasia macrorrhiza* (AM) and *Chrysopogon aciculatus* (CHR). Chemical analysis indicated that AMD collected from Lechang lead/zinc mine tailings contained high concentrations of Zn, Mn, Pb, Cd, Cu and SO_4^{2-}, and was also extremely acid. The 75-day experiment indicated *Cyperus alternifolius* had the highest but *Gynura crepidiodes* had the lowest tolerance index to AMD among the six plants tested. *V. zizanioides* also had a high tolerance to the AMD. The capacity of the microcosm (wetland) in adjusting pH and removing SO_4^{2-}, Cu, Cd, Pb, Zn and Mn only lasted for 35 days, which may be due to the high acidity of AMD. Further experiments should be conducted before using wetlands in treating AMD in practice, especially the acidity of AMD should be reduced before it discharged into the wetland.
Key words: constructed wetland, *Vetiveria zizanioides*, mine wastes, wastewater
Email contact: Wensheng Shu <ls53@zsu.edu.cn>

1 INTRODUCTION

Mine tailings produced from the mining activities are major solid wastes in China and are of environmental concern due to potential hazards of surface or groundwater pollution (Shu, 1997). Pyrite bearing mine tailings disposed at neutral or slightly alkaline conditions can weather within months or a few years to produce extreme acidity, and lead to acid mine drainage (AMD) (Robbed and Robison, 1995). AMD usually contains a high level of heavy metals besides having a low pH, and significantly impacts water quality and natural ecosystems in southern China (Shu, 1997). It is also a serious environmental problem around the world (Salamons and Forstner, 1988; Dudka and Adriano, 1997). Constructed wetlands have been considered as an effective, low cost and practical approach for the cleanup of different wastewaters, such as domestic sewage, industrial wastewater and AMD (Brodie *et al.*, 1989; Fennessy and Mitsch, 1989; Moshiri, 1993).

The vegetative component is one of the major factors in the treatment process, which occurs in wetland treatment systems. In general, constructed wetlands are often planted with emerging plants to improve their efficiency in treating wastewater. However, only a few species from *Typha*, *Cyperus* and *Phragmites* genera are commonly used on constructed wetland. Vetiver grass has been proved to possess a high tolerance to heavy metals, acidity, salinity and agrochemicals (Greenfield, 1995; Truong and Baker, 1996; Truong, 1999, 2000; Cull *et al.*, 2000). It also has a great potential in purifying domestic sewage, landfill leachate and pig farm leachate (Xia *et al.*, 2000). However, its potential value capability in purifying AMD by comparing Vetiver with other six common wetland species including *Phragmites australis* and *Cyperus alternifolius,* using a microcosm test. It is expected that this project will provide valuable information relating to treatment of AMD with vetiver, which will be useful in the design of full-scale constructed wetlands.

2 MATERIALS AND METHODS

2.1 Site description

The Lechang Pb/Zn mine is about 4 km east of Lechang City with an area of about 1.5 km^2, and about 250 km from Guangzhou City. The climate is humid sub-tropical with an annual rainfall of about 1500 mm, mainly from summer thunderstorms. The mine deposit is located at the east of the mine site. The minerals mainly consist of pyrite, sphalerite, galena, magnetite and to a lesser extent calcite, muscovite, and quartz. Mining is carried out in a conventional underground way. Mine tailings produced from milling processing are discharged into a tailings pond as slurry. Approximately 25,000 t of waste rocks and 30,000 t of tailings are generated annually with a dump area about 8300 m^2 and 60,000 m^2, respectively. The average concentrations of Pb, Zn and pyrite of the tailings are 3,051, 3,655 and 87,200 mg kg^{-1} respectively. The tailings are extreme acidic due to the oxidation of pyrite. Our previous investigation indicated that AMD released from the tailings contained high levels of Pb, Zn, Fe, SO_4^{2-}, and is extremely acidic (pH varied from 1.6 to 2.8). For conducting the present experiment, a pond of 3 m _ 3 m_ 3 m was constructed at the tailings site to received the acid mine drainage.

2.2 Plant Species Tested

The tested plant species included: *Vetiveria zizanioides* (VZ), *Phragmites australis* (PA), *Cyperus alternifolius* (CA), *Panicum repens* (PR), *Gynura crepidiodes* (GC), *Alocasia macrorrhiza* (AM) and *Chrysopogon aciculatus* (CHR).

2.3 Microcosm Experiment

Six microcosms (0.8 m_0.5 m_0.6 m) were constructed with a volume of 0.24 m^3 and surface area of 0.4 m^2. Each microcosm was filled to a depth of 20 cm with a mixture of soil, limestone and pig manure. A plastic barrier was placed vertically down the center of each microcosm (between the inlet and outlet) to maximize the length of the water-flow path. The tested plants were transplanted into each of the six microcosms, and a quarter-strength Hoagland’s nutrient solution was added to each microcosm, giving a surface water depth of 6 cm. A Quarter-strength Hoagland’s solution was then pumped continuously into the inlet of each microcosm each day. The microcosms were placed in the greenhouse of Zhongshan University. After four months growth (June 21, 2001-October 30, 2001), the plants in the 6 microcosms were fully established. Three microcosms were selected at random to receive AMD collected from the tailings pond, while the 3 remaining microcosms received tap water; these control microcosms provided a baseline against which plant performance in the treatment microcosms could be compared.

The treatment lasted for 75 days, during which the inlet flow rate was monitored daily to ensure a steady flow into each microcosm. Water from the outlet of each microcosm was collected in a covered container, and its volume recorded every fifth day. Sub-samples of inlet and outlet waters were collected every fifth day for analysising pH, EC and COD immediately, and remaining samples were stored in cool room for determining Pb, Zn, Cu, Cd, Fe, Mn and SO_4^{2-} concentrations. The removal efficiency was calculated:

$$\text{Removal efficiency (\%)} = \frac{\text{Concentration of pollutant in inlet of microcosm}}{} \times 100$$

The experiment was terminated on Day-75. All surviving plants were removed from the microcosms. Each plant species was separated into shoots and roots, washed thoroughly in distilled water, dried at 60°C for 24 hours and weighed. The tolerance of each plant to AMD can be compared by calculating their tolerant index. The tolerance index of each species was calculated with the following formula:

$$\text{Tolerance index (\%)} = \frac{\text{Biomass of plant growing in AMD}}{\text{Biomass of plant growing in tap water}} \times 100$$

3 RESULTS AND DISCUSSION

3.1 The Chemical Properties of AMD

The selected chemical properties of acid mine drainage collected from Lechang lead/zinc mine tailings is listed in Table 1. In general, AMD of Lechang lead/zinc mine contained high concentrations of Zn, Mn, Pb, Cd, Cu and SO_4^{2-}, and was also extremely acid with an average pH of 2.42.

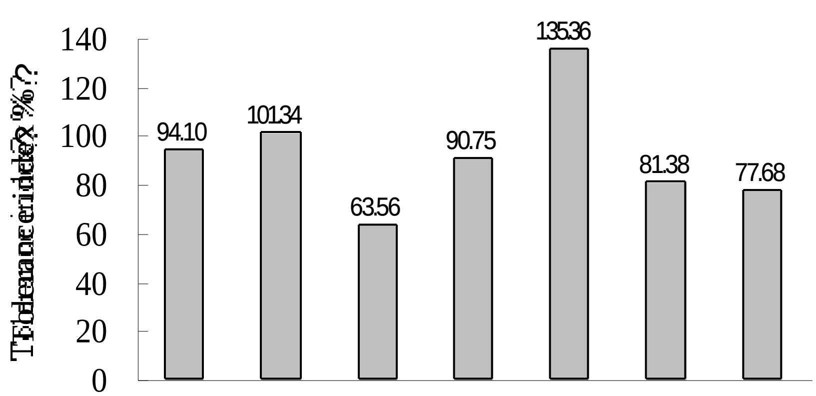
Table 1 The chemical properties of acid mine drainage collected from Lechang lead/zinc mine tailings (n=15)

	pH	SO_4^{2-}	Zn	Pb	Mn	Cd	Cu
		mg/L					
Mean±sd	2.42±0.12	1963±121	58.9±4.5	0.46±0.04	3.69±0.43	0.12±0.01	0.35±0.08
Range	2.35-2.55	1856-2001	54.1-66.2	0.35-0.55	3.11-4.00	0.11-0.13	0.29-0.47

3.2 The Tolerance Index of Each Species

The tolerance index of each species to AMD was illustrated in Fig. 1. It reveals *Cyperus alternifolius* (CA) had the highest and *Gynura crepidiodes* (GC) had the lowest tolerance index to AMD, while *Vetiveria zizanioides* (VZ) and other species had similar tolerance level to AMD. It is well recognized that *P. australis* can withstand extreme environmental conditions, including the presence of toxic heavy metal contaminants, such as Zn, Pb and Cd (Ye *et al.*, 1997a, b, c). In the last two decades, it had been widely used in constructed wetlands for treatment of industrial wastewater containing metals, and AMD of coal mines (Wieder, 1989; Brodie *et al.*, 1989). The present experiment indicated that *V. zizanioides* had the similar and even slight higher tolerance index than *P. australis.*

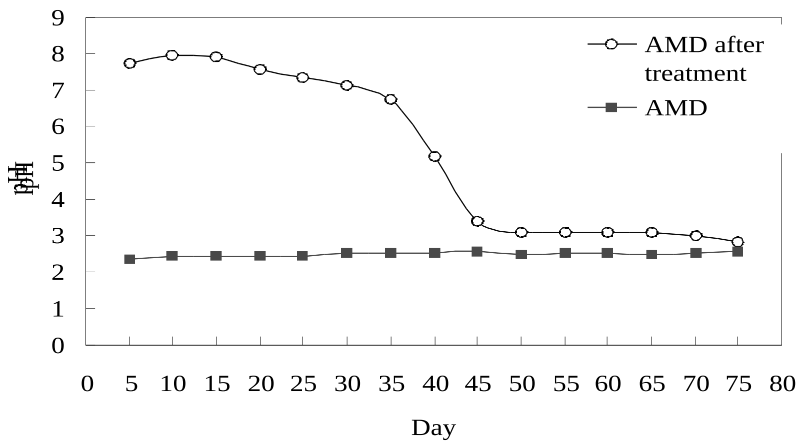
Fig. 1 The tolerance index of different species subjected to AMD for 75 days (*Vetiveria zizanioides, Phragmites australis, Cyperous alternifolius, Panicum repens, Gynura crepidiodes, Alocasia macrorrhiza* and *Chrysopogon aciculatus*)



3.3 Purification Capacity of Microcosm

The capacity of a microcosm (wetland) in adjusting pH and removing SO_4^{2-}, Cu, Cd, Pb, Zn and Mn are shown in Fig. 2, 3 and 4, respectively. It was found that the pH at the outlet of the AMD treatments after 35 days decreased significantly, which indicated that the substrate of this wetland could not neutralize more acidity from AMD, and the buffer capacity of the substrate was destroyed (Fig. 2). As a consequence, the capacity of the microcosm (wetland) in removing SO_4^{2-}, Cu, Cd, Pb, Zn and Mn was also reduced, SO_4^{2-} (Fig. 3) and heavy metals (Fig. 4) removal efficiency decreased dramatically after 35 days treatment. This indicates that the purification capacity of the microcosm only lasted for 35 days, when it was subjected to the AMD, which contained high acidity and heavy metals. It was also found that this wetland was more effective in removing Pb, Cu and Cd while less effective in removing Mn (Fig. 4).

Fig. 2 The capacity of wetland in adjusting pH of acid mine drainage (AMD) collected from Lechang Pb/Zn mine



4 CONCLUSIONS

1. The acid mine drainage (AMD) collected from Lechang lead/zinc mine tailings contained high concentrations of Zn, Mn, Pb, Cd, Cu and SO_4^{2-}, and was also extremely acid.
2. According to tolerance index of the 7 tested species subjected to AMD for 75 days, *Cyperus alternifolius* had the highest but *Gynura crepidiodes* had the lowest tolerance index to AMD. *V. zizanioides* had the similar and even slight higher tolerance index than *P. australis*, suggesting that *V. zizanioides* also had high tolerance to adverse conditions such as AMD.
3. The capacity of a microcosm (wetland) in adjusting pH and removing SO_4^{2-}, Cu, Cd, Pb, Zn and Mn only lasted for 35 days, might be due to the high acidity of AMD. Further experiments should be conducted before using wetlands in treating AMD; especially the acidity of AMD should be reduced before it discharged into wetland.

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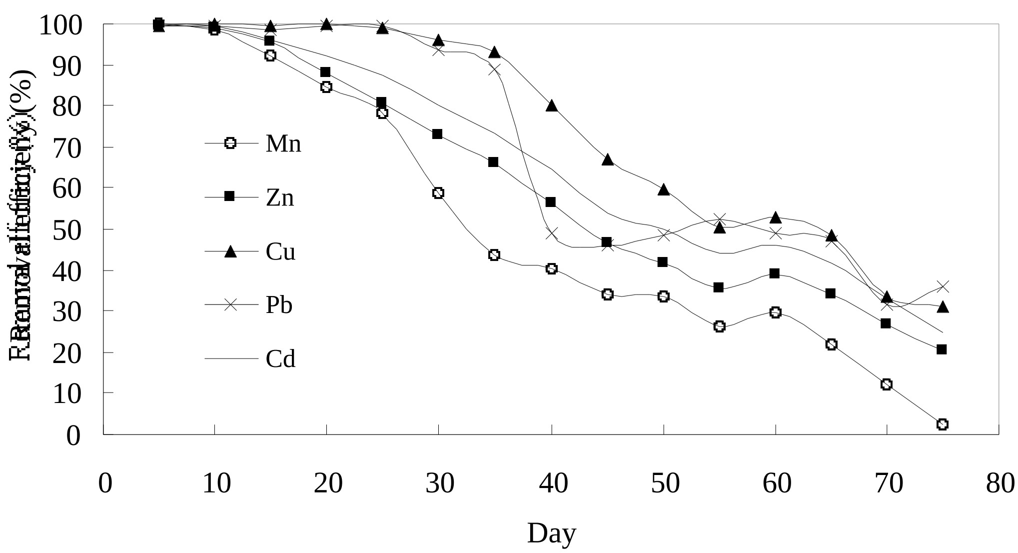
Fig. 3 The capacity of wetland in removing SO_4^{2-} of acid mine drainage (AMD) collected from Lechang Pb/Zn mine

Fig. 4 The capacity of wetland in purifying Cu, Cd, Pb, Zn and Mn in acid mine drainage (AMD) collected from Lechang Pb/Zn mine



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A Brief Introduction to the Author

Dr. Wensheng Shu (W.S. Shu) is an associate professor in ecology in School of Life Science at Sun Yatsen (Zhongshan) University, Guangzhou, China and honorary research fellow of Institute for Natural Resources and Environmental Management Hong Kong Baptist University (2001-2004). He maintains active research in restoration of mining wastelands and phytoremediation of soil and water contaminated by heavy metals. He has received the King of Thailand Vetiver Award in Research in 2000, the Second Prize in Natural Science by the Ministry of Education of China in 2000, and an Academic Award for Outstanding Young Scientist in Environmental Science in 2002 by the Association of Chinese Environmental Science.