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Technical Article

Metal Removal Potential by Three Aquatic Plants in an Acid Mine Drainage Wetland

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Abstract. This study was conducted to gauge the metal bioaccumulation potential of hydrophytic vegetation in a wetland constructed in McCreary County, Kentucky, USA, to treat a coal mine effluent averaging 787 mg/L Fe, 12.6 mg/L Al, 10.9 mg/L Mn, and 2,244 mg/L acidity. Three dominant plant species, cattail (*Typha latifolia*), bulrush (*Scirpus validus*), and tickseed sunflower (*Bidens aristosa*), were sampled and analyzed for Al, Fe, and Mn, so that relationships could be drawn about their capability to bioaccumulate metals from the wastewater. Results showed that Al and Fe were retained mainly in the roots of the plants, while Mn was more mobile throughout the plant. Iron bioaccumulation was similar for all three plant species at high metal concentration gradients, but somewhat reduced in *T. latifolia* at low concentration gradients. *Scirpus validus* appeared to be the most Al-tolerant species, considering its greater Al bioaccumulation potential at high metal concentration gradients. In spite of the high metal load and acidity of the water, there were no visible toxicity effects, but *B. aristosa* and to a lesser extent *S. validus* seemed to prefer low-metal concentration environments. All plants bioaccumulated some Al, Fe, and Mn, but their concentrations were fairly miniscule compared to overall metal retention by the wetland substrate. This suggests that the main plant contribution is through substrate stabilization, microbial attachment, and rhizosphere oxidation rather than phytoremediation. Therefore, plant selection criteria for high metal load wetlands should mainly be based on metal tolerance and rhizosphere surface area rather than metal bioaccumulation potential.

Key words: constructed wetland; metal removal; bioaccumulation; hydrophytic vegetation

Introduction

Phytoremediation is a process by which plants remove, contain, or render harmless environmental contaminants (Cunningham et al. 1997). This practice is increasingly used to remediate sites contaminated with heavy metals or toxic organic compounds. There are two main processes of heavy metal accumulation by plants in constructed wetlands: phytoextraction and rhizofiltration (Salt et al. 1995). Phytoextraction involves hyperaccumulating plants, which uptake metals from the wetland substrate and concentrate them into the roots and stems of plants so that they may be harvested. Rhizofiltration is the process by which plants absorb, precipitate, and concentrate toxic metals from polluted effluents in their roots (Cunningham et al. 1997).

While establishing a substrate environment suitable for oxidation, hydrolysis, precipitation, complexation, and reductive/dissolution reactions for effective metal removal is a clear objective (Brodie 1990; Hedin and Nairn 1990; Kleinmann et al. 1991), the contribution of aquatic plants through filtration, adsorption, cation-exchange, microbial, and other rhizosphere-induced biochemical processes can only vaguely be appraised (Skousen et al. 1994).

Metal bioaccumulation by plants as a removal mechanism has been sporadically investigated in constructed wetlands treating acid mine drainage (AMD). In the reported cases, direct uptake of Fe, Al, and Mn into the plant tissues appeared to account for only a small proportion of the total removal by the wetland system (Sencindiver and Bhumbla 1988; Mitsch and Wise 1998; Ye et al. 2001). However, information is limited to a few plant species or to a few relatively low acidity and metal load wetland systems. Elevated metal concentrations in root relative to shoot tissue suggest that aquatic plants can adopt external or internal exclusion mechanisms to inhibit translocation of metals to the above-ground biomass. Aquatic plants, such as *Typha latifolia* (cattail), *Scirpus validus* (bulrush), *Oryza sativa,* and *Phragmites australis*, have the ability to transport O_2 from their aerial tissue and release it into their rhizosphere, and form plaques on their root epidermis that may limit the mobility of metals to above-ground plant tissue (Snowden and Wheeler 1995; Batty et al. 2000; Hansel et al. 2001). In high metal concentration coal-mine wastewaters, root plaques appear to consist mainly of Fe-oxide and hydroxide precipitates with minor admixtures of other metals. However, Al and Mn plaques on roots of aquatic plants have also been reported in the literature (Batty et al. 2000). Although the presence and composition of these plaques is well documented, their function as physical barriers or metal tolerance adaptations at high metal concentration and acidity gradients is not well understood (Batty et al. 2000; Hansel et al. 2001).

The primary objectives of this study were to determine the effectiveness of three different plant species growing within a high acidity and metal load wetland in accumulating metals, and to establish bioaccumulation patterns and the effectiveness of different plant parts for retaining metals. The experiment focused on Al, Fe and Mn, since these were the metals with the highest concentrations in the AMD being treated.

Materials and Methods

The experiment was conducted in the Jones Branch constructed wetland, which is located in McCreary County, Kentucky, USA and is designed to treat water in the Jones Branch of White Oak Creek, a tributary to the Big South Fork River. This wetland treatment system was extensively renovated in 1995 by adding two anoxic limestone drains (ALDs) after an initial settling pond in the pretreatment stage, and converting the original surface flow wetland to a subsurface flow system with a new substrate consisting of 30 cm limestone gravel overlain by 50 cm of hay/manure compost (Barton and Karathanasis 1999). The current treatment system consists of a precipitation lagoon, where AMD from two coal mines is collected and then transported via two ALDs to the first wetland field containing three precipitation basins and three wetland cells. The AMD is then transported by a flume to a second wetland field, consisting of two precipitation basins and two wetland cells. From the final wetland cell, the effluent is discharged into Jones Branch (Figure 1). The wetland cells were planted with *T. latifolia* and *S. validus* in 1995 in a 1-m grid, using local transplants. Tickseed sunflower (*Bidens aristosa*) was a volunteer plant with spotty establishment within the wetland, originating from seeds within the compost used as a substrate during the renovation of the wetland.

Water and plant samples were collected within each vegetated wetland cell, approximately 3 m from the inlet and outlet points (Figure 1) in early September of 1999, at a near-average AMD flow rate. At each sampling location, two 250 ml grab water samples were collected, acidified ($pH < 2$) with 0.1 N nitric acid to prevent metal precipitation, and stored at 4° C until metal analysis. Water pH was measured in the field using a Cole-Parmer portable pH meter. At each sampling point, two plants from the three dominant species, representing the average growth and biomass state of each wetland cell, were also sampled (Figure 1). The whole plants were divided into two sub-samples, consisting of roots/rhizomes and stems/leaves, air-dried and finely ground using a plant tissue grinding apparatus. Afterwards, 0.25 g of plant material was digested with 8 mL of nitric-perchloric acid (HNO_3-$HClO_4$) and the resulting slurry was placed on a steam-plate overnight to speed the digestion process (Westerman et al. 1990). The next day the samples were dried on a gas-plate to remove any residual liquid. In the case where complete plant matter oxidation did not occur, 30% hydrogen peroxide (H_2O_2) was added to complete the oxidation. The resulting residue was treated with 25

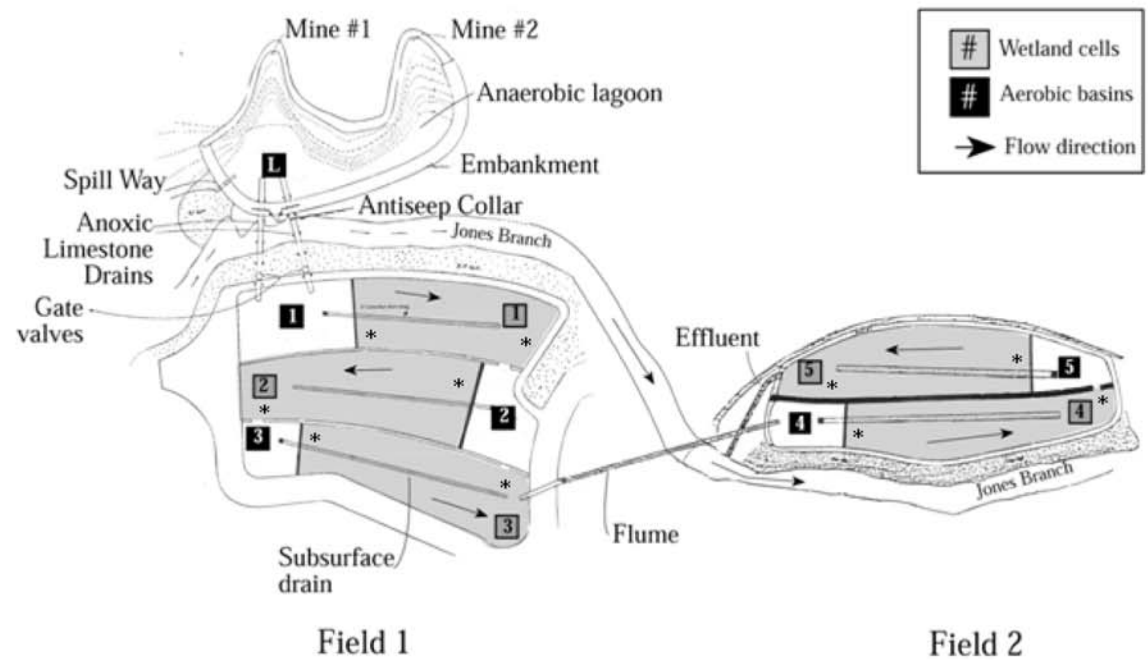

Figure 1. Site plan and sampling points(*) for the Jones Branch constructed wetland

mL of 1 N hydrochloric acid (HCl) for atomic absorption (AA) analysis. Duplicate plant residue and water samples were analyzed via AA for Al, Fe, and Mn. The remaining plant matter was dried at 100° C and desiccated overnight to express metal content on an oven-dried weight basis.

Biomass was estimated for each species by counting the number of plants within three 1-m² plots in each cell. One representative plant from each species within each plot was harvested to determine total biomass by species, cell, and wetland.

In order to evaluate the effect of different metal concentrations on metal bioaccumulation, two soluble metal concentration gradients (high and low) were established for Fe and Al. Only one, an average gradient, was used for Mn because the concentrations of Mn did not differ drastically within the wetland. Estimated mean values of plant metal content in the roots and stems/leaves were compared to average water metal concentrations for each gradient. In addition, using influent and effluent metal values and flow rates for the entire wetland, the total metal retention was estimated and compared to the bioaccumulated metals contributed by the dominant plant species based on the estimated total biomass for each species.

Results and Discussion

Water Chemistry

Average water quality data for a two-year monitoring period (1995-1996) for the AMD entering the first settling pond of the treatment system are shown in Table 1 (Barton and Karathanasis 1999). Although the Al (12.6 mg/L) and Mn (10.9 mg/L) levels of this AMD are within the range of the values reported in the literature, total Fe concentrations are very high. However, a considerable reduction in Fe concentration and acidity takes place in the pretreatment stage in the settling pond and the ALDs so that the wetland itself is not often subjected to such high metal and acidity loads (except for high flow periods). During our study period (1999), soluble Al wetland influent levels averaged 11.5 mg/L and decreased to non-detectable amounts in effluent waters (Figure 2a). The elevated Al concentrations in the outlet of the first wetland cell (F1C1) are probably the result of organic complexation, which is known to increase Al solubility at low pH environments. In subsequent wetland cells, organic complexation effects on Al solubility were minimized by elevated pH values. Influent Fe levels of 158 mg/L decreased to less that 0.1 mg/L in the last wetland cell (Figure 2b). The large fluctuation in Fe concentrations in the

Table 1. Average water quality and flow data for the AMD entering the first pretreatment stage (settling pond) of the Jones Branch wetland system

Parameters	Average±SD
pH	3.38±0.45
Acidity, mg/L	2244±337
Total Fe, mg/L	787±121
Total Al, mg/L	12.6±4.1
Total Mn, mg/L	10.9±2.1
Flow rate, L/min	37.1±14.4

first wetland cells is attributed to the alternating oxidizing-reducing environments imposed by the wetland treatment design. For Al, the most drastic reduction in soluble metal concentrations occurred after the first cell (F1C1), while for Fe, it occurred after the second cell (F1C2). In contrast, Mn levels decreased only slightly from 13 mg/L in the influent water to 4.3 mg/L in the effluent (Figure 2c), supporting previous declarations of insufficient Mn removal in wastewaters with soluble Fe concentrations >2mg/L (Barton and Karathanasis 1999). The pH of the AMD within the wetland increased gradually from 3.2 in F1C1 to 6.4 in F2C2 as a result of limestone gravel dissolution within the substrate, contributing to lower metal solubility and concentrations at later stages of treatment (Figure 2d). This downstream water quality, however, did not appear to have any noticeable effects on vegetation growth, as plant biomass did not change significantly from cell to cell. Similar responses to downstream water quality improvement by *T. latifolia* have also been reported by Mitsch and Wise (1998).

Two soluble metal concentration gradients were established for Fe and Al to determine plant bioaccumulation responses to varying metal levels in the wetland. A high gradient (15.3 mg/L Al and 110.1 mg/L Fe), representing high levels (mean values) of Al in F1C1 and high levels of Fe in F1C1 and F1C2, and a low gradient (0.5 mg/L Al and 8.5 mg/L Fe), encompassing average Al and Fe concentrations in subsequent wetland cells. Since the treatment of Mn was not of the same magnitude as that of Al and Fe, an average soluble Mn concentration (6.9 mg/L) over all the wetland cells was used to determine the plant bioaccumulation potential for this element.

Aluminum Uptake

T. latifolia showed a greater affinity for Al uptake at low soluble metal concentration gradients, particularly the roots (~2.5 mg Al/g plant biomass), suggesting a possible exclusion mechanism operating at high soluble metal concentrations (Figure 3a). Some Al-tolerant plants have the ability to trigger protective mechanisms (formation of AC-binding

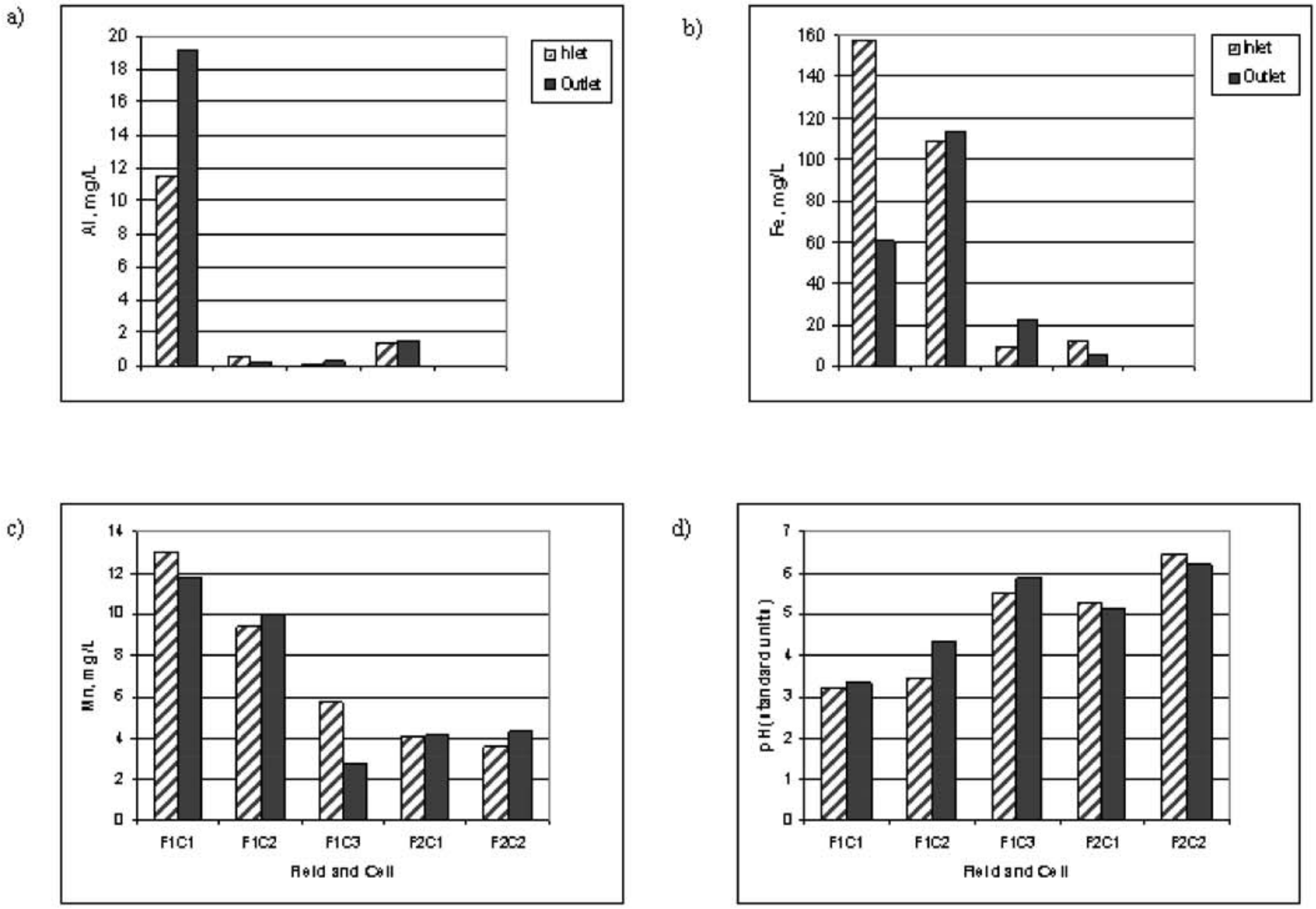

Figure 2. Mean concentrations of (a) Al, (b) Fe, (c) Mn and (d) the pH of wetland water

proteins), which slow down or prevent metal uptake when water or substrate levels exceed a certain threshold (Crowder 1991). Another explanation may be associated with the formation of plaques on the root epidermis, consisting of Al and Fe precipitates, which may act as barriers for further Al translocation into the plant tissue (Batty et al. 2000; Hansel et al. 2001). The bioaccumulated Al concentrations observed in this study are nearly 4 times higher than those reported by Mitsch and Wise (1998) for underwater *T. latifolia* stems in an AMD wetland in Ohio. In contrast, *S. validus* bioaccumulated greater amounts of Al (~3.5 mg/g plant biomass) at higher soluble Al concentration gradients (Figure 3b). The accumulated concentrations approached the highest level of 3.8 mg g^{-1} reported by Crowder (1991) for a list of aquatic macrophytes, but were considerably higher than those reported for *T. latifolia* roots (1.0 mg g^{-1}) and stems (0.025 mg g^{-1}) by Rai et al. (1995). *Bidens aristosa* did not show the uptake potential exhibited by *T. latifolia* and *S. validus* for Al (~0.5 mg/g plant biomass), being indifferent to low or high metal concentration gradients.

Metal solubility generally increases at low pH, and this is particularly true for Al, Fe, and Mn (Salt et al. 1995), so it would seem that Al uptake would be greater in wetland cells with low pH (Albers and Camardese 1993). However, the results of this study indicate that Al bioaccumulation decreased as the acidity and soluble Al concentration gradients increased in wetland cells with low pH (Figure 2). This may indicate the trigger of an inhibitory mechanism for Al uptake as the underground plant parts, such as roots and rhizomes, were increasingly exposed to higher Al concentration gradients in the substrate (Baker 1981). It could also mean that the highest range of Al concentrations observed in the wetland may have been marginally toxic to the plants, even though they did not cause a significant biomass reduction. Aluminum toxicity has been demonstrated with some aquatic species at water concentrations as low as 0.03 μg L^{-1} (duckweed) and tissue concentrations >0.3 mg g^{-1} (rice). This toxicity is materialized through reduced root growth, increased mucilage production and partial root necrosis (Crowder 1991).

For all plant species sampled, much higher concentrations of Al were present in the roots than in stems/leaves, indicating limited mobility within the plant. A similar trend for Al and other metals

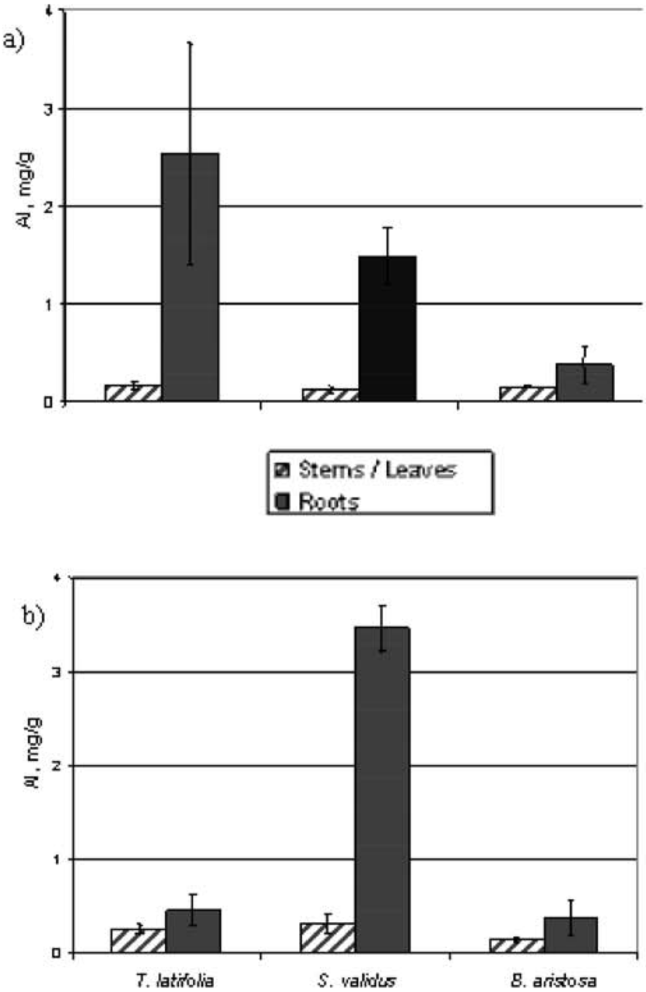

Figure 3. Mean concentrations of Al (mg/g) in *T. latifolia*, *S. validus*, and *B. aristosa* plants sampled at (a) low and (b) high soluble metal concentration gradient points within the wetland.

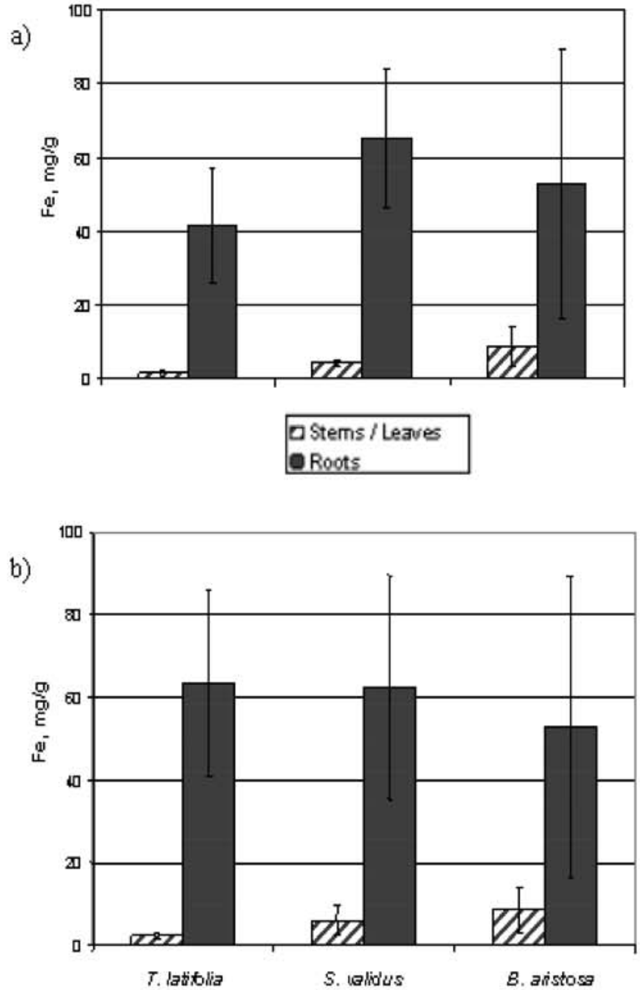

Figure 4. Mean concentrations of Fe (mg/g) in *T. latifolia*, *S. validus*, and *B. aristosa* plants sampled at (a) low and (b) high soluble metal concentration gradient points within the wetland

concentrating in the roots rather than the aboveground parts of emergent hydrophytic plants was reported by other investigators, making harvesting rather impractical for metal removal (Dunbabin and Bowmer 1992; Gupta et al. 1994). The increased concentrations of Al in the roots may be associated with the Fe-plaque; it is believed to be an accessory constituent, not necessarily adsorbed to it but forming independent Al-phosphate precipitates (Batty et al. 2000; 2002).

Iron Uptake

Iron uptake by all three plant species was the highest among the metals studied. This came as no surprise considering that Fe had by far the highest metal concentrations in the wetland (Figure 4). The Fe concentrations in plant roots found in this study are some of the highest reported in the literature, comparable only to those reported by Ye et al. (2001) in the roots of *T. latifolia* and *S. validus* growing in a 10-year old wetland treating coal ash leachate in Alabama. Iron concentrations in roots of *T. latifolia* plants harvested from AMD wetlands in West Virginia and Ohio, were 5-20 times lower, respectively (Sencindiver and Bhumbla 1988; Mitsch and Wise 1998). It is very likely that a major part of this Fe is a constituent of the plaque that is known to form on the root epidermis of aquatic plants (St. Cyr and Campbell 1996; Batty et al. 2000; Hansel et al. 2001) rather than the result of bioaccumulation. Despite extensive washing and the visual absence of orange coatings on the plant roots sampled, a considerable portion of Fe in the plaque may have been included in the biomass concentration. On the other hand, the increased bioaccumulation levels found in this study may be the result of the high Fe load this wetland is subjected to at high water flow periods during the year. Mitsch and Wise (1998) suggested that significant luxury uptake of Fe by *T. latifolia* may occur when the plants are exposed to high metal concentration gradient waters.

Vesk et al. (1999) reported that Fe levels decrease centripetally across the root, being higher in cell walls and lower within cells. Iron, like Al, was concentrated within the roots of the three plants. However unlike Al, *T. latifolia* plants bioaccumulated somewhat greater amounts of Fe at higher soluble metal levels (>60 mg Fe/g plant biomass) than at low soluble metal levels (~40 mg Fe/g plant biomass) (Figure 4), but this difference may not be significant considering the considerable variability between samples. A positive correlation between soluble Fe concentration and uptake by *T. latifolia* and sequestration, mainly in the roots/rhizomes, was also documented by Wadas et al. (1995) in coal-mine wetlands of Pennsylvania. In contrast, Fe uptake by other aquatic species, including rushes, was consistent across a range of soluble metal concentration gradients. Similar trends were exhibited by *S. validus* and *B. aristosa* in this wetland, showing no effect in metal uptake to high or low soluble metal concentrations (50-60 mg Fe/g plant biomass). The high Fe plant tissue concentrations associated with *B. aristosa* and its indifference to high or low Fe concentration gradients are surprising, considering that it is not an aquatic plant and therefore lacks Fe-plaque forming potential. Apparently a different mechanism allows this plant to tolerate high Fe concentrations and remain competitive with aquatic species within the wetland.

Iron concentrations in stems and leaves were 7-50 times lower than in the roots, indicating low Fe mobility within the plant tissue. Snowden and Wheeler (1995) suggested that root oxidative Fe-precipitation might keep Fe uptake to the shoot below a threshold value. The average range in this study was 1.0 to 7.0 mg/L, increasing in the sequence *T. latifolia* < *S. validus* < *B. aristosa*. These values are on the high end of the levels reported by Sencindiver and Bhumbla (1988) and Ye et al. (2001) for leaves and shoots of *T. latifolia* and *S. validus*. However, Ye et al. (2001) also found a 4-fold higher Fe bioaccumulation in *S. validus* shoots compared to *T. latifolia*, which is comparable to the trend found in our study. The increased Fe levels in the leaves of *B. aristosa*, even under low Fe concentration conditions, suggest greater Fe mobility within the plant tissue, and therefore, greater overall bioaccumulation potential (Figure 4a) perhaps associated with the absence of the Fe-plaque barrier in its roots. Some floating wetland plants, such as duckweed (*Lemna minor*) and water velvet (*Azolla pinnata*), have been shown to bioconcentrate Fe up to 78 times their concentration in wastewaters (Zayed et al. 1998), but through a different mechanism involving leafy parts. Some potential for bioaccumulation of Fe was demonstrated by the species sampled in this study, but not to the extent of *L. minor* and *A .pinnata*.

Manganese Uptake

Total Mn bioaccumulation by the three species was slightly lower than Al and drastically lower than Fe, consistent with metal concentration gradients in the water (Figure 5). Since the soluble Mn concentration was fairly constant throughout the wetland, there was no evident concentration gradient response by the plants. However, Mn did show some accumulation preference for the stems/leaves of *T. latifolia* and *S. validus*, suggesting greater mobility within the plant tissue (Figure 5). Similar results have been reported by Mitchell and Karathanasis (1995) and Qian et al. (1999) in simulated wetlands. *Bidens aristosa* showed the greatest overall affinity for Mn uptake, with slightly higher concentrations in the roots (~0.8 mg Mn/g plant biomass) than in stems and leaves (~0.6 mg Mn/g plant biomass). The average Mn concentrations in stems and leaves observed in this study were within the range reported by Mitsch and Wise (1998), but 2-5 times lower than those reported by Sencindiver and Bhumbla (1988), and Ye et al. (2001). This is probably a reflection of the lower Mn concentrations present in this wetland and the low pH, which may have a strong inhibitory effect on Mn uptake (Batty et al. 2000). Manganese levels in roots of *T. latifolia* plants were similar to those reported by Ye et al. (2001), but 3-4 times lower than those of Sencindiver and Bhumbla (1988). However, the roots of *S. validus* plants in this study contained as much as four times higher concentrations of Mn than reported by Ye et al. (2001).

The high mobility of Mn combined with the ability of aquatic plants to bioaccumulate Mn suggest a sorption mechanism as the dominant pathway for Mn uptake and designate them as sensitive indicators of Mn contamination (Lytle et al. 1995). The formation of Mn root plaques, which is possible at high

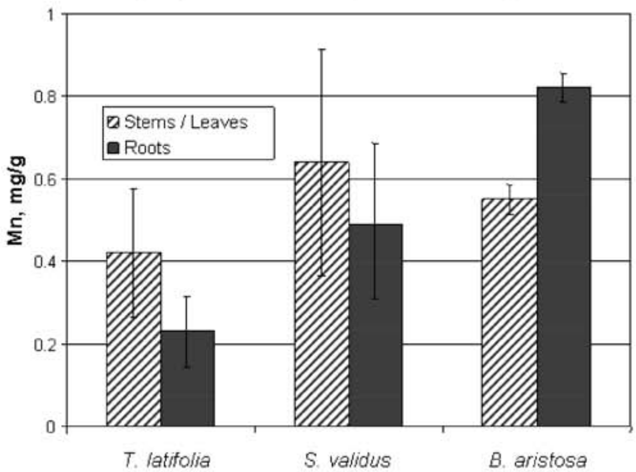

Figure 5. Mean concentrations of Mn (mg/g) in *T. latifolia*, *S. validus*, and *B. aristosa* plants sampled within the wetland

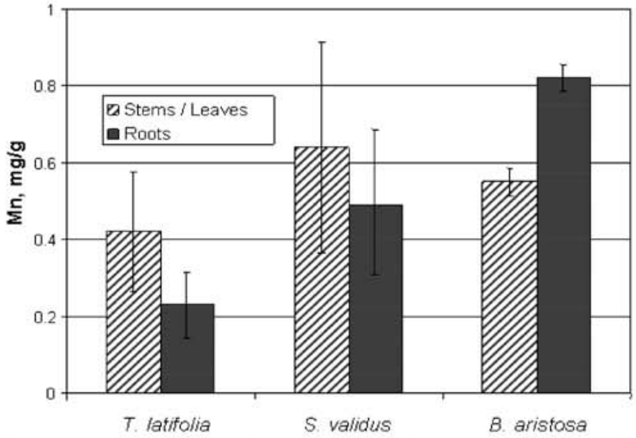

Figure 6. Contribution of each plant species through bioaccumulation to metal retention (kg metal/year), assuming a monoculture in the entire wetland

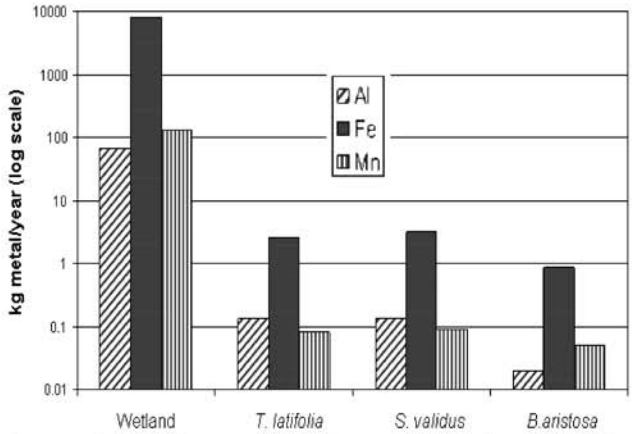

Figure 7. Metal quantities (kg metal/year) retained by the entire wetland compared to those bioaccumulated by plants

concentration gradients, was apparently inhibited by the low levels of soluble Mn in the wastewater and the extremely low pH conditions. The increased bioavailability of Mn shown by all species used in this study also indicate that Mn is not sorbed onto the root plaque formed by Al and Fe precipitates, which acts as a physical barrier for other metals. This is especially true in low pH environments (< 4.0), where the high activity of H^+ ions at the root surface overcomes any potential effect of the Fe-plaque (Batty et al., 2000). Chaney et al. (1997) reported that some aquatic plants tolerate fairly high Mn levels by being able to transport and distribute Mn throughout the plant tissue rather than concentrating it in the roots like Al and Fe.

Metal Retention within the Wetland

Calculations from influent and effluent water samples with predetermined flow rates described by Barton and Karathanasis (1999) showed that the wetland retained a major portion of the influent metals, reducing Al levels from 72 kg/yr to 3 kg/yr, Fe levels from 8090 kg/yr to 11 kg/yr, and Mn levels from 132 kg/yr to 2 kg/yr (Figure 6).

However, calculations assessing the metal bioaccumulation by each plant species, assuming a total wetland surface area of approximately 1022 m^2, an average plant density of $3.1/m^2$, and monoculture throughout the wetland suggested that the plant contribution was very small (Figure 7). Based on estimated biomasses of ~445 g/m^2 for *T. latifolia*, ~263 g/m^2 for *S. validus*, and ~187 g/m^2 for *B. aristosa*, the retention of Al and Mn by these species was less than 0.2 kg yr^{-1}, which translates to about 0.3% for Al and 0.2% for Mn . Iron retention ranged from 2.5 kg $yr^{-1}$for *T. latifolia*, 3.2 kg yr^{-1} for *S. validus*, and 0.9 kg yr^{-1} for *B. aristosa*, amounting to 0.04% to 0.01%, respectively (Figure 7). The Al and Mn removal values in this study are consistent with the range reported by other investigators. However, the Fe bioaccumulation levels, while comparable to those of Mitsch and Wise (1998), are 5-20 times lower than those reported by Sencindiver and Bhumbla (1988). The total amount of metals bioaccumulated by plants compared to the overall metal load removed by the wetland was 0.06%, suggesting that phytoremediation is not an effective treatment option. One of the main reasons that phytoremediation is ineffective in this wetland, and in AMD-treating systems in general, is the high metal concentration gradients involved. Under these high metal load conditions, other physicochemical processes, such as precipitation and adsorption are much more efficient in retaining metals within the substrate. Therefore, plant screening and selection for their metal accumulation potential and regular harvesting should not be of paramount importance in these systems. Rather, the vegetation concerns should concentrate mainly on toxicity tolerance and maintenance issues. Metal and acidity toxicity effects on biomass production were not evident in this wetland, but while *T. latifolia* dominated the entire wetland, *B. aristosa* and *S. validus* seemed to prefer low metal concentration gradient areas.

Conclusions

Our results indicate that considerable uptake of Fe, Al, and Mn by common hydrophytic plants can occur in AMD wetlands. Metal bioaccumulation varied as a function of plant species, plant parts, and soluble metal concentration gradients in the AMD. For the most part, Al and Fe were concentrated in the roots of the sampled plant species, most likely as constituents of root plaques. *Scirpus validus*, particularly the roots, had a higher affinity for Al at high soluble metal concentration gradients than the other plants, but at lower concentration gradients, *T. latifolia* had a higher affinity for Al. In the case of Fe, all three species had similar affinities in both the stems/leaves and the roots, regardless of concentration gradient. *Bidens aristosa* showed a higher affinity for Mn than the other two species, even though dissolved Mn concentrations were fairly constant in the water. Manganese was fairly evenly distributed in the stems/leaves and roots of the plants, suggesting greater mobility within the plant tissue.

Despite considerable uptake of Fe, Al, and Mn, the contribution of rhizofiltration and phytoextraction processes by the plants to the overall metal removal in the wetland was minimal. High metal concentrations in the AMD caused precipitation and sorption to be the main metal attenuation mechanisms. Therefore, phytoremediation is not as effective a treatment option for high metal load wetlands as it may be for wetlands with low metal concentration gradients. However, even though the plants do not play a major role in bioaccumulating metals, their contribution to overall AMD treatment through phytostabilization and phytostimulation processes should not be underestimated.

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International Mine Water Association – General Assembly

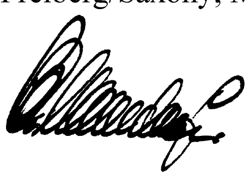
On October 22nd 2003 IMWA's General Assembly will be held in Johannesburg/South Africa. All IMWA members are encouraged to take part. If a member has any contribution he or she wishes to make and cannot attend the meeting, then please send your comments to President Peet NEL or the Secretary General Christian WOLKERSDORFER so that it can be read out at the General Assembly. Comments must arrive by September 22nd 2003.

A copy of the IMWA Statutes and By-Laws will be posted at the General Notice Board. You can obtain your personal copy of the IMWA Statutes and By-Laws or the Ustroń/Poland General Assembly minutes by sending an e-mail to GeneralAssembly@imwa.info

Agenda

1. Obituaries
2. Present
3. Apologies
4. Previous Minutes (Ustroń/Poland 2000)
5. President's report (Peet Nel)
6. Secretary's report (Christian Wolkersdorfer)
7. Treasurer's report (Adrian Brown)
8. Editor-in-Chief's report (Bob Kleinmann)
9. Election of Officers for 2003—2005
10. IMWA statutes and by-laws
11. Any other Competent Business

Freiberg/Saxony, March 16th 2003



Christian Wolkersdorfer
Secretary General