Title: Geochemical processes governing the performance of a constructed wetland treating acid mine drainage, Central Scotland			November 2004
Author(s):	Woulds, C. and B.T. Ngwenya	**Information Source:**	Applied Geochemistry, Vol 19, p. 1773-1783
Technology Type:	Wetlands	**Mine/Facility Type:**	Iron Mine
Study Scope:	Monitoring study	**Mine Name:**	Benhar Bing Mine
Source:	Acid mine drainage	**Location:**	Scotland, Europe
Contaminant(s):	Sulfate, Iron, Aluminum, Magnesium, Manganese	**Receiving Media:**	Surface Water, Soils/Sediments
Keywords:	Sulfate reduction, constructed wetlands, iron, acid mine drainage		

Abstract: Constructed wetland systems often represent a low cost means for the remediation of dissolved metal and SO_4-rich acid mine drainage. The surface water, sediment, and porewater geochemistry of one such wetland were investigated to determine the active geochemical processes that govern wetland performance; this particular wetland was constructed to remediate acid mine drainage from the Benhar Bing Mine in Central Scotland, 45 km east of Glasgow. The influent drainage has a pH of 2.6, 200-250 mg/L of dissolved Fe, and Al, Mg, and Mn concentrations of 30-100 mg/L. Sulfate concentrations are also high, ranging from 500-1000 mg/L. Sediment cores show high levels of amorphous Fe oxyhydroxides near the surface and some amorphous reduced inorganic sulfur (RIS) in deeper layers. Taken together with a decline in porewater SO_4 with depth, the data suggest that bacterial SO_4 reduction is occurring. All sediment cores display an increase in porewater SO_4 with depth in their top sections, often forming a subsurface peak, which could be attributed to oxidative dissolution of RIS at the redox boundary. However, the increase in SO_4 is also accompanied by a rise in porewater pH. Desorption experiments yielded up to 8 Wt% SO_4 in these top layers suggesting that pH dependant sorption is an active SO_4 removal mechanism along with the precipitation of Fe oxyhydroxysulphates, which also removes dissolved Fe. The maximum treatment efficiency of the wetland is 25% for the removal of dissolved Fe, and the retention of other species is equally poor. Comparison with other wetland systems suggests that poor performance is due to the low pH and high dissolved metal concentration of the drainage together with deterioration in the wetland over time, as a result of reduced active surface area and retention time.

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Reference

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Procedures

Monitoring was conducted over a six month period at a five-year old constructed wetland and attached settling pond; the wetland was constructed to remediate the acid mine drainage of an ironstone spoil heap in central Scotland. Sediment samples were collected from the inlet and outlet of the wetland, and water samples were taken at regularly spaced intervals along the wetland. Samples were analyzed for SO_4, Al, Mg, Mn, and Fe. Outlet samples were compared to inlet samples, and downstream samples were compared to upstream samples, respectively, to determine the effectiveness of the constructed wetland in remediating acid mine drainage. These results were compared to results from other wetland systems to isolate the site-specific conditions responsible for decreased remediation efficiency.

Results

All dissolved species show a similar trend in surface water concentration across the wetland system: concentrations decrease through the settling pond and into the top of the wetland, increase slightly after the top of the wetland, and proceed to decrease gradually downstream for the remainder of the wetland. Overall, the trends exhibited by the wetland inlet sediment cores resemble those in the top sections of the wetland outlet sediment cores, suggesting that the same geochemical processes are active at both sites. At the wetland outlet, however, those trends and, therefore, the causal processes occur over a greater depth interval. Specifically, summer outlet sediment samples show all species increasing in concentration from the surface to a depth ranging from 1.5 cm to 4.5 cm, followed by steady decrease with depth. Winter outlet sediment samples, however, show species following different trends. SO_4, Fe, and Mg increase in concentration to subsurface peaks deeper than those found in summer (6.5 cm, 6.5 cm, and 13.5 cm, respectively), followed by a steady decrease. Mn steadily decreases in concentration throughout the sample, while Al suddenly decreases in concentration; both of these species show no subsurface peaks. In the inlet sediment samples, SO_4 and Fe increase with depth, while Mg, Al, and Mn show subsurface peaks at 8.5 cm. In addition, pH increases with depth in all samples.

The treatment efficiency of the wetland was calculated for each species and compared with efficiencies observed in other wetlands. Metal removal efficiency was consistently low, around 20%, with Fe being the most successful and Ca being the least successful. The wetland was more effective at removing pollutants during the summer, especially Fe, due to higher temperatures in summer and higher rainfall in winter. The removal efficiency of the wetland (31% Fe removal efficiency) is considerably lower than those found at similar wetlands (49.5%-98% Fe removal efficiency).

Conclusions

Woulds and Ngwenya concluded that site-specific conditions were responsible for the decreased remediation efficiencies at the Benhar wetland. First, the comparatively high contaminant concentrations at this site inhibit the remediation process. The extremely low pH of the acid mine drainage increases the solubility of Fe oxyhydroxides, inhibiting their precipitation and suppressing SO_4 reduction. The fact that the Benhar wetland is only half as extensive as it was designed to be reduces its remediation efficiencies of acid mine drainage pollution. Finally, deterioration of the wetland over the past five years has reduced its remediation efficiency. Specifically, channels have formed that breach the straw bale dykes, reducing the residence time of the water; much of the wetland area has dried out, again reducing the residence time of the water; and few of the original plants have survived, hindering sulphate-reducing bacteria dependant on a constant supply of reactive organic matter, and therefore limiting SO_4 reduction rates.

This study highlights the importance of site-specific conditions in regulating the effectiveness of a constructed wetland for remediation. Original contaminant concentrations and the pH of the drainage impact wetland remediation efficiency; wetland construction should therefore be altered to account for original pollution conditions. Wetland deterioration has also been demonstrated after only five years, contradicting earlier studies that concluded wetland maintenance would be unnecessary for the first 10 years (Gschlossl and Stuible 2000).