Wetlands Treatment Of Mine Drainage

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Wetlands treatment has been demonstrated to be a technologically feasible and cost-effective method of treating acid rock drainage and other metal-laden water. Previous studies have included both natural wetlands and constructed wetlands, although the US EPA considers that only constructed wetlands have been adequately demonstrated. However, natural wetlands have the significant advantage of already being an established, stable anaerobic environment. . Wetlands treatment has been used for municipal wastewater treatmentfor over twenty years, and for landfill effluent for about a decade, but application to mine drainage is more recent.

Wetlands provide an organic rich environment that is typically anaerobic, except within the shallow near surface. The principal mechanisms that have been identified for the removal of metals are summarized as follows. Studies suggest that the first two mechanisms are predominant in an anaerobic environment.

LIMITATIONS OF WETLANDS TREATMENT

The long-term effectiveness is unknown as wetland aging may be a problem which may contribute to a decrease in contaminant removal rates over time;

Shifts in equilibrium for natural wetlands with new metal and sulfate source and possible related physical affects;

Fluctuations in flow and temperature affect wetland function and can cause inconsistent contaminant removal rates. High flows can overload the removal mechanisms while dry periods can damage plants and severely limit wetland function; and,

Colder conditions slow the rate at which the wetland is able to remove contaminants, an important concern especially at Andean sites.

REMOVAL MECHANISMS AND CHARACTERISTICS

Adsorption of metals (ion exchange)

Adsorption of metal ions implies desorption of other metal (typically Ca, Mg, Na, K) and hydrogen ions;

Limited amount of metal that can be adsorbed (amounts vary significantly between materials). Adsorption of manganese, zinc, and cadmium is difficult;

Most effective at pH greater than 4 to 6 depending upon metal ion; therefore, other processes must be present to raise the pH of acidic drainage (peat does provide signifi cant buffering capacity);

The reaction is reversible and so if conditions change, there can be desorption of the metals.

Sulfate reduction (microbial action, precipitation of metal sulfides)

Sulfate reduction raises the pH of highly acid waters and forms highly insoluble sulfide precipitates with cadmium, copper, iron, lead, and zinc. Manganese sulfide is more soluble and therefore not as easily removed;

Limited by sulfate availability and, in the long-term, could be limited by organic matter availability;

If conditions return to aerobic (due to water level fluctuations or other factors) the reactions will reverse and the wetlands will become a source of sulfates and metals.

Aerobic precipitation (ferric & manganese hydroxides)

Since oxidation and precipitation generate hydrogen ions, some other process must operate to raise the pH. In peat wetlands where soil waters remain acidic, there is little possibility of manganese removal;

Oxidation and sulfate reduction cannot simultaneously occur which can necessitate a two-stage system (anerobic followed by aerobic);

Manganese is more difficult to remove than iron and requires about 3 times more wetlands area for the same loading.

Adsorption of metals (ferric hydroxides)

Iron and aluminum hydroxides scavenge metal ions. Good polishing or final stage.

Metal uptake by living plants

In addition to direct uptake, root systems create microenvironments that promote reduction and oxidation and generate biomass to support other wetlands processes.

Adsorption by Organic Rich Substrate

Adsorption occurs via an equilibrium (reversible) ion-exchange reaction with humic and fulvic acids which are abundant in wetlands, especially with peat. Adsorption effectively increases residence time, thereby allowing other processes to convert dissolved metal ions into insoluble forms (precipitates). Without these other processes, the capacity of a wetland to increase pH and retain metals would soon be saturated.

Sulfate Reduction

Sulfate reduction is favored by low Eh and low pH, where sulfides are the thermodynamically stable forms of sulfur. These are exactly the conditions that predominate in a wetlands environment. Sulfate reducing bacteria use the energy created by sulfate reduction in such environments and these bacteria are generally hardy and able to accommodate wide variations in pH and temperature, but will not tolerate long periods of aerobic conditions. While bacterial activity is greatly reduced below a pH of 5 the bacteria can control their microenvironment by regulating the pH via sulfate reduction.

Precipitation of Ferric and Manganese Hydroxides

Due to mechanisms for pyrite oxidation, acid rock drainage typically contains Fe^{+2} and Mn^{+2}, which are far more soluble than those of Fe^{+3} and Mn^{+4}. Efficient removal by hydroxide precipitation requires oxidation, which can occur via microbial catalysis in the aerobic zone of wetlands. At a pH of 5 or more, there are a large number of bacteria that can oxidize iron using organic material as a nutrient source; however, bacteria that oxidize manganese do not appear to be significant in wetlands.

Adsorption of Metals by Ferric Hydroxides

Iron and aluminum hydroxides form gelatinous solids whose scavenging properties have long been used in wastewater treatment. It is believed that the surface of the hydroxides operates as a weak acid which attracts hydroxide ions making a negatively charged surface which in turn attracts positively charged metal ions. The pH of the solution must be greater than 6.5 to 8.5 (for iron hydroxide). In the final portions of the wetlands where hydroxide precipitation may be significant, these will help to coagulate suspended material and remove metal contaminants.

Metal Uptake by Living Plants

Metal uptake by living plants generally accounts for a small but important part of total metal accumulation. In addition, the root systems appear to create microenvironments that promote reduction and oxidation processes. The other significant role of plants is to provide a supply of biomass for the other microbial processes and metals adsorption.

TYPICAL EVALUATION PROGRAM

Laboratory testing

Analyze for metal adsorption, presence of sulfide-reducing bacteria, sulfate reduction and metal sulfide precipitation rates, organic carbon content, hydraulic conductivity (vertical and horizontal), moisture content, bulk density, specific gravity and their variation with depth.

Hydrologic & hydrochemical studies

Evaluation of source water flow rates and chemistries (mass loadings), seasonal variations, water collection/conveyance, and runoff diversion requirements.

Field-scaling testing

To establish long-term permeability, viable loading rates and flux capacities for sufficient time periods (6 to 12 months) that cell geochemistry and hydrology is well understood.

Preliminary design

The results of the previous testing would be evaluated to determine the feasibility of large scale construction considering available land area, maximum loading rates, costs, etc.

Pilot-scale testing

To test functionality of system components and provide modifications for final system design. At least one-year duration to monitor the four seasons.

Feasibility Evaluation

Sulfate reduction is the predominate process for metals removal and pH improvement; therefore, an anaerobic environment is required. Natural wetlands generally support very limited subsurface flow since permeability decreases with depth and hydraulic gradients are horizontal, and hence flow through the anaerobic zone is more difficult to achieve. Subsurface flow may be facilitated where the depth of the organic mass is relatively deep (e.g., some Andean sites are known to have peat and organics in excess of 25 meters depth). This, considerably greater area can be required to develop a natural wetlands area than a constructed wetlands. In either case it is important to note that this technology doesn't destroy metals, but rather accumulates them in one place. The processes that create this accumulation are subject to potential future disruption and the consequent release of the accumulated metals.

While a proven technology in the wastewater and landfill industries, this is relatively new to mining. Wetlands are passive treatment systems that can be applicable to a wide range of sites and drainage conditions. For sites with moderate ARD or metal-loading problems, one- or two-stage wetlands can be the complete solution. For severe sites a wetland program might be an integral part of a larger, overall system that includes both passive and active components.

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