A Review of Sulfate Removal Options from Mine Waters

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Sulfide oxidation leads to high concentrations of sulfate in contact waters. Levels of sulfate can vary from a few hundred mg L^{-1} to several thousand mg L^{-1}. At very high concentrations (> 1000 mg L^{-1}) sulfate has a purgative effect and is considered corrosive on concrete and cement. Current legislation world wide places a limit around 400-500 mg L^{-1} on ground water and 2000 mg L^{-1} on industrial effluent; consequently some treatment is often required. In many mine waters selenium as selenite is also present above regulated standards (typically 5-50 g L^{-1}) and likewise requires treatment before discharge of the contact water. Various treatment options are available for sulfates involving physical, chemical and biological processes. The selection of a treatment option is primarily dictated by sulfate and calcium concentrations. Conventional desalination techniques cannot be economically applied for treating most mine waters due to the problem of $CaSO_4$ scaling. Consequently options available include: (1) Reverse osmosis. Where water is low in calcium (<100 mg L^{-1}) and sulfate (<700 mg L^{-1}), conventional reverse osmosis can be used, although at higher concentrations of both scaling will occur. A modified special reverse osmosis has been developed to treat mine waters (SPARRO) in South Africa. (2) Ion exchange. Similar to reverse osmosis scaling of $CaSO_4$ is common in conventional circuits. To overcome these problems a modified form of ion exchange has been developed to treat Ca-sulfate waters (GYPCIX). (3) Sulfate coprecipitation. Sulfate barriers may be constructed by using an inorganic source which will produce a low solubility sulfate phase. Both lime and Ba salts have been proposed. A number of Ba salts can be used but the most commonly proposed are carbonate and sulfide. Because of the cost of Ba and its environmental toxicity it is advantageous to have a Ba recovery plant to recycle Ba salts. A typical design would be to reduce the formed Ba sulfate to barium sulfide by roasting with coal, followed by purging with CO_2 to produce a recycled batch of $BaCO_3$. Liberated hydrogen sulfide can be used elsewhere in effluent treatment by precipitating insoluble metal sulfides. (4) Biological sulfate reduction. Under anoxic conditions sulfate may be removed from the mine waters as stable sulfide precipitates. Under these conditions sulfide minerals remain stable and have extremely low solubilities. Flooded underground mine workings and open pits can be anoxic, and as such provide a suitable environment for the implementation of a sulfate reduction system. The presence of sulfides (H_2S odor) in many mine water discharges indicates that sulfate reduction is already occurring. The reduction of sulfate to hydrogen sulfide is brought about by specialized strictly anaerobic bacteria and is accomplished primarily by two genera: *Desulfovibrio* (five species) and *Desulfotomaculum* (three species). These organisms have a respiratory metabolism in which sulfates, sulfites and/or other reducible S compounds serve as the final electron acceptors, with the resulting production of hydrogen sulfide. The organic substrates for these bacteria are generally short chain acids such as lactic and pyruvic acid. In nature these substrates are provided through fermentative activities of other anaerobic bacteria on more complex organic substrates.

Due to the natural occurrence of the sulfate reducing bacteria, sulfate reduction can be utilized *in situ* for the treatment of acid rock drainage provided the correct conditions can be maintained to sustain bacterial activity. Anaerobic conditions may be enhanced by sealing shafts, adits and air vents. For conditions to be sufficiently anaerobic however, it is likely that a significant depth of water will be required. A wide variety of organic substrates have been investigated for this purpose including molasses, sewage sludge, straw, newspaper, sawdust and manure. Other possibilities are wastes, such as short chain organic acids, from chemical industries.

A Study of the Analytical Variation of Sampling and Analysis of Stream Sediments from Mining and Milling Contaminated Areas

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During an environmental study of stream sediments, large variations in metal values were noticed in contaminated sediments taken from the same site at different times. The question arose as to whether these differences were due to variations in contaminant input or merely represented the heterogeneity of the contaminated sediments at the site. Large numbers of replicate samples and measurements could be utilized to help answer the questions, but this is time consuming and costly. Random error can be estimated by the use of a duplicate analyses scheme and much use has been made of duplicate analyses in geochemical surveys and prospecting. In the work reported here, use was made of duplicate analyses to study Cu, Pb, and Zn variation in environmental stream-sediment samples. Samples were collected from three areas: (1) adjacent to the La Bajada mine along the Santa Fe River, (2) adjacent to the Pecos mine along the Pecos River, and (3) downstream from the Alamitos mill located on a tributary of the Pecos River. Both rivers are located in northern New Mexico. The mines and the mill have been inactive for many years.
ANOVA statistics were used to evaluate differences in Cu, Pb, and Zn values between contaminated sites that were