Passive Co-Treatment of Acid Mine Drainage and Municipal Wastewater: Removal of Less Commonly Addressed Metals at Cerro Rico de Potosí, Bolivia

R. A. M. Peer[1], W. H. J. Strosnider[1], B. K. Winfrey[2], R. W. Nairn[3]

[1]Saint Francis University, Loretto, PA, USA; [2]University of Oklahoma, Norman, OK, USA; [3]University of Maryland, College Park, MD, USA

Extended Abstract Acid Mine Drainage (AMD) and Municipal Wastewater (MWW) are common effluents both in the developing and the developed world; their treatment is necessary to ensure clean water supplies across the globe. The feasibility of a passive co-treatment system was tested with a laboratory-scale three-stage batch reactor system.

Keywords Aluminum, Iron, Zinc, Manganese, Copper, Cadmium, Nickel, Lead, Acid mine drainage, Sewage

Zn-rich AMD from an abandoned adit on Cerro Rico de Potosí and raw MWW from Potosí, Bolivia were combined at a 5:1 ratio and introduced to the system. Four replicate systems consisting of three unit processes each: a clarifier unit, an anoxic limestone drain, and an oxidation pond, were used to assess the functionality of passive co-treatment. The unit processes were constructed using 1-L cubitainers. Commonly used in AMD experimentation, cubitainers are collapsible low-density polyethylene containers. The contaminant streams were mixed within 8 hours of collection and samples were taken within five minutes of mixing (ActMix) due to rapid reactivity of waters. The chemical composition of the theoretical influent mix (TheoMix) was also calculated with the AMD to MWW ratio. All unit processes were exposed to ambient conditions, maintaining water temperature between 8.2 and 10.3 °C throughout the system. Physiochemical data were recorded and samples were taken prior to transfer of water from one unit process to the next. The residence times in unit processes were 24 h, 24 h, and 48 h, for the sedimentation pond, limestone, and oxidation pond, respectively.

The AMD influent had pH 3.58, acidity 1080 mg/L as $CaCO_3$ equivalent, and 12, 68, 17, 550, 0.44, 0.13, 0.13 and 0.090 mg/L of dissolved Al, Fe, Mn, Zn, Cd, Cu, Ni, and Pb, respectively, among other metals/metalloids. The MWW contained 5.6 and 38 mg/L of nitrate and phosphate, respectively. The system efficiently reduced metal concentrations for common metal/metalloid contaminants as well as less commonly addressed contaminant metals/metalloids. Dissolved concentrations of common metals such as Al, Fe, Mn, and Zn decreased throughout the system by 99.7 %, 99.9 %, 4.5 %, and 33.9 %, respectively. Dissolved concentrations of less commonly addressed metals such as Ag, Cd, Ce, Cr, Cu, Gd, Ni, and Pb also decreased notably throughout the system. Among the metals removed, dissolved concentrations of Cr and Gd were decreased below detection limits in the first and second unit processes. Less commonly addressed contaminant metals were removed mostly in the clarifier unit. Notably, Ni, Pb, and Cu contaminants were removed 25.5 %, 45.9 %, and 18.3 %, respectively, primarily by the first unit process (Fig. 1). However, Cd was removed primarily in the last two unit processes, with an overall removal of 78.5 % (Fig. 1).

During the limestone incubation, concentrations of some contaminants increased. For example, Ag is removed in the clarification
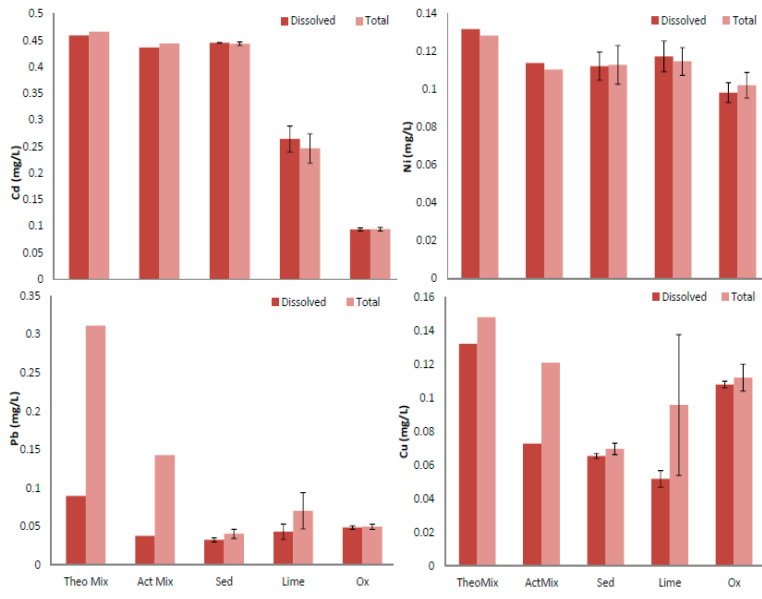
Fig. 1 *Mean concentration of the four metals of concern from initial mixing through each unit process in the system (n=4). Error bars represent the 95 % confidence interval constructed with the t-statistic. "ActMix" and "TheoMix" do not have error bars as they were a single measurement/calculation. Measurements shown for Actual Mix (Act Mix), Theoretical Mix (Theo Mix), Sed (sedimentation unit), Lime (limestone unit), Ox (oxidation unit).*

unit process, but the concentration was increased in the limestone unit process. Ca, B, Ba, K, Li, Mg, Na, and Sr concentrations also increased in the second unit process, likely due to limestone impurity dissolution. Potosí is in one of the most highly mineralized regions in the world, making the existence of impurities in local limestone unsurprising. Three rare earth metals were also tracked throughout the system. Concentrations of Nd and Pr were increasing in all three unit processes. However, La was removed from solution in all three unit processes.

The results from the experiment suggest that passive co-treatment of AMD and MWW could be a valid treatment method for streams with wide ranges of contaminants. Results from the study could be applied as a feasible solution to chronic water quality issues due to the common co-occurrence of the two contaminant streams throughout the developed and developing world. Due to lack of funding and resources in the developing world, inexpensive, non-energy-intensive, and low-maintenance solutions are essential for remediation of contaminated streams. In the developed world, passive co-treatment could result in cost and energy savings from the renewal of less efficient treatment systems currently in use. Elements of the experimental system (*e.g.* removal of phosphate with metal oxides) could be utilized to improve the performance of existing conventional AMD or MWW treatment systems. To further the knowledge of passive co-treatment, the construction of a pilot-scale system is necessary. A pilot system could provide further information on operational and maintenance costs, sustainability requirements, and the longevity of a full-scale treatment system.