OSMRE National Technology Transfer Team (NTTT), **Applied Science Fact Sheet***
U.S. Department of the Interior, OFFICE OF SURFACE MINING RECLAMATION AND ENFORCEMENT

LOW-COST, GREEN TECHNOLOGY TO IMPROVE WATER QUALITY IN MINING-IMPACTED ECOSYSTEMS, PHASE I – MODEL DEVELOPMENT AND OPTIMIZATION

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Project Description and Objectives:

The overall goal of this Phase-1 study was to develop low-cost green technologies to remediate and restore acid mine drainage (AMD) and impacted soil. Tab-Simco located in southern Illinois, home to an old abandoned coal mine, that produces nearly 35000 gallons of AMD per day, having low average pH (2.54-2.81), high metal (Fe, Al, Mn) and sulfate concentrations, was selected as the host site to collect the AMD and impacted soil sample to be investigated in this Phase-I study. The primary objectives that were pursued to accomplish the stated project goal included (1) identification of the most suitable locally available drinking water treatment residuals (WTR) and its application rate for pH neutralization and efficient reduction of the heavy metal content of the AMD water and impacted soils, (2) identification of the most suitable hyper-accumulator plant(s) for the phytoremediation of the AMD water and impacted soils, as well as, the erosion control of the impacted soil. Because a sulfate reducing bioreactor (SRB) is already operating at the Tab-Simco site, an additional objective adopted during this study was the performance comparison of the effectiveness of the proposed green technologies with that of the SRB currently operating at the Tab-Simco site.

Applicability to Mining and Reclamation:

Acid mine drainage (AMD) is one of the major sources of surface water contamination. Without adequate remediation, AMD can adversely impact nearby water bodies and land areas resulting in water contamination, vegetation loss and erosion. The AMD generated at the Tab-Simco site upstream of the existing SRB is characterized by low-pH and high concentrations of sulfate, iron, aluminum and manganese ions. Other metals present at various concentrations include the RCRA 8 metals. Existing remediation technologies that meet surface water quality standards are mostly expensive and environmentally unsustainable. Using the Tab-Simco abandoned coal mine site in southern Illinois as the host site, this study aimed to develop lower cost, green alternatives for passive treatment of AMD and impacted soil for any old high sulfur coal mine site in Illinois and elsewhere.

Methodology:

To accomplish the above mentioned project objectives, the entire project exercise included laboratory studies, green-house studies and finally simulated field studies.

- Two sets of AMD water and impacted soil samples were collected from two strategic locations: the AMD seep area upstream of the operating SRB and the Oxidation pond area, downstream of the SRB. The collected soil samples were air-dried and sieved through a 2 mm sieve for subsequent soil physicochemical characterization study. The collected AMD water was analyzed for pH, oxidation-reduction potential, conductivity, acidity and elemental concentrations of sulfate, Fe, Al, Mn and the RCRA 8 metals. Three WTR samples were collected from

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three different drinking water treatment facilities located in southern Illinois area that used different type of coagulants for their treatment operations.

- Batch sorption studies were performed in the laboratory to identify the WTR that offers the best adsorption capacity and to obtain rate and equilibrium data. A continuous upward flow column filtration system was designed to maintain a fluidized bed of ultrafine WTR particles with enhanced media/AMD contact after the initial failures of a downward flow tube filtration system.
- A greenhouse column study was conducted at SIU to investigate the adsorption and long-term immobilization of metal ions in AMD impacted soil by WTR amendments and the use of phyto-remediation technique using two hyper-accumulator plants: Vetiver and Pokeweed. A factorial experimental design was conducted by varying three factors: WTR amendment rates in the range equivalent of 50 to 100 tons/acre, manure application and liming rates, both in the range of 10 to 15 tons/acre.
- A simulated field study was conducted to investigate the effectiveness of the Vetiver plants and WTR amendments in controlling the soil erosion and metal leaching from the AMD impacted soil under actual Illinois weather conditions at SIU's Energy Park (in Carterville, IL) utilizing the best soil amendment conditions identified from the greenhouse study. This study lasted for 12 weeks.
- A simulated hydroponic field study was conducted on the SIU campus to demonstrate the dissolved metal uptake by Vetiver and Pokeweed in outside environment. Both hyperaccumulator plants were grown in separately prepared untreated AMD and WTR filtered AMD tanks. The study period was 30 days.

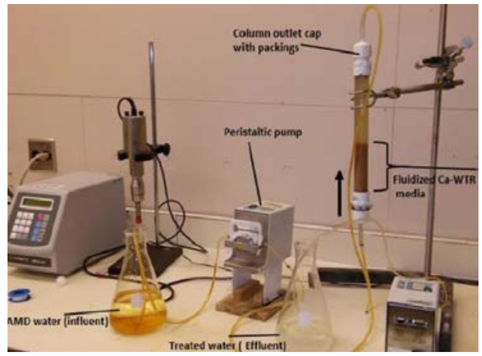
Highlights:

The WTR amendment of AMD impacted soils demonstrated positive influence on the leachability of considered metal ions from the soil. Oxalate extractable metals from the WTR amended soils was also observed to have significantly reduced compared to the untreated soil. In the simulated field study, Vetiver growth in the treated soil was observed to be higher than that in the untreated soil. The growth of the Vetiver ensured a reduction in the rate of soil erosion. In the continuous flow column, the effluent metal and sulfate concentrations were significantly lower than influent concentrations and pH was increased to near neutral. The simulated field study of Vetiver and Pokeweed hydroponic system in a typical southern Illinois environmental condition, showed some growth in the root and shoot of the hyper-accumulators and subsequent metal uptake in the filter column effluent (filtered AMD water). The hyper-accumulators however did not survive in the untreated AMD even for two weeks.

Results and Findings:

- The Fe-WTR and Ca-WTR was among the best types of locally available WTR found in this study. Batch sorption studies conducted with WTR showed 99.8% removal of aluminum and 99.85% of iron from AMD water. The percent of Cu, Zn, As and Cd metal ions removed were 84.9%, 95.5%, 80.26 and 86.8% respectively. Removal of Ni and Co was minimal, but only 9.6% of manganese level reduction was the lowest even though the AMD pH had been increased from 2.64 to a near neutral point of 6.74.
- The 21-day incubation tests of the AMD impacted soil with Fe-WTR, showed a higher acid neutralization capacity of this WTR. The acidity of the oxidation pond soil (pH≈3.48) was increased to between 6.95 to 7.39 by the various application rates. Likewise, the AMD seep area soil (pH≈3.12) was neutralized to between 6.91 to 7.49.

- Analysis of leachate following leaching protocol with deionized water adjusted to simulate rain water conditions in Illinois showed very low concentrations of heavy metals from both soil samples integrated with either Vetiver or Pokeweed phytoremediation.
- In the simulated field hydroponic study using Vetiver, Mn in the WTR treated water was further reduced by 56.9%, Fe by 44.4% and Cobalt by 55.7%. Other considered metals that exhibited varying levels of reduction from the Vetiver hydroponic system included Ni (54.1%), Cu (16.5%), Zn (28.4%) and As (8.6%). The uptake of metals by pokeweed was also significant. The dissolved manganese in the column effluent used was further reduced by 31.8% whilst the concentration of iron was reduced by 48.7%. Significant reduction was also measured in cobalt (26.1%), nickel (24.8%) with the least amount of reduction in copper (3.5%).
- A comparison of the oxidation pond water quality with that of the effluent produced from the WTR filtration followed by phytoremediation techniques investigated in this study indicated that metal concentrations of both compared well. However, the SRB remediation system costs in the range of $0.43 to 0.70 per 1000 gallons of AMD water treated. On-site testing of the proposed method will help generate an estimate of the respective cost of AMD remediation. However, WTR being a waste material and being readily available at the local water treatment plants, it is believed that the proposed technologies may most likely provide lower cost and environmentally benign alternatives for the AMD remediation in the abandoned coal mine area in Illinois and elsewhere.



(a) WTR adsorption study

(b) Greenhouse column study

(c) Simulated field study to check soil erosion and metal leaching

(d) Hydroponic field study to check plant metal uptake

Fact Sheet Contact Information

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