

Enhanced delivery of reactive sulfide reagents in porous media by biopolymer solutions for in situ remediation of mercury-contaminated soils

Mercury, stabilization, biopolymer, in situ remediation, soil heterogeneity

Mercury is released from both natural (rock erosion, volcanic eruptions) and anthropogenic sources. Currently, humans are primarily responsible for mercury pollution, through power plants, industrial processes, or the extraction of certain mercury ores. In soils, mercury remediation can be technically challenging and costly, depending on the subsurface mercury distribution, the types of mercury species, and the regulatory requirements. The chemical stabilization approach uses sulfur-containing compounds to react with elemental mercury (Hg^0) in contaminated soil to form mercury sulfide (HgS) which is a stable and insoluble compound. However, it can be challenging to deliver in situ the reactive compounds using traditional Newtonian fluids in heterogeneous soils. Here, we show how injecting biopolymer can improve the delivery of sulfide micro-particles and reagents. The main objective is therefore to develop a biopolymer and sulfide-based solution to stabilize the elemental mercury but also to study the feasibility of injecting in situ such a solution into polluted soil.

The delivery of sulfide micro-particles is experimentally studied in order to develop a biopolymer solution capable of transporting pyrite (FeS_2) particles in polluted soils. Two biopolymers were tested for their known non-Newtonian behavior (xanthan gum and carboxymethyl cellulose). Then, the experiments were carried out in a graduated cylinder to study the stability of biopolymers in solutions with and without micro-particles of pyrite (FeS_2). The biopolymers have been characterized in order to obtain more information about their rheological behavior using a rheometer. Xanthan gum was chosen as the non-Newtonian fluid for its capacity to maintain the particles in suspension, and its strong non-Newtonian behavior. Different combinations of the xanthan biopolymer, micro-particle of pyrite, and a sulfide-containing reagent (thiosulfate, xanthate, and sodium sulfide) mixtures were tested in small glass vials for their capacities to stabilize mercury. We placed a small drop of Hg^0 at the bottom of the vial and mixed it with the prepared solutions. Finally, a 1D column (30 cm long and diameter of 4 cm) packed with dry sand (0.7-1 mm) was used to study the potential of the solutions to deliver the micro-particles.

The batch tests show that the solutions with xanthate, sodium sulfide, and thiosulfate are capable of stabilizing mercury with or without a biopolymer-based solution. This statement is based only on significant changes in the color of these solutions. To draw more conclusions, chemical analyses are under investigation to quantify the reaction. We found that the addition of pyrite particles and sulfide-based reagents reduces the bulk viscosity of the mixture while maintaining still good shear-thinning behavior. The column experiments show that the xanthan biopolymer is suitable for injecting the mixture of pyrite particles and the sulfide-containing reagent into the soil. On the contrary, conventional water injection is not suitable to deliver the pyrite micro-particles. Viscous fingerings were observed for the solution with 2 g/L of xanthan despite the effectiveness of the injection. At three pore volumes of injection, the relative density of the solution at the column outlet was 60%. By increasing the concentration of polymer up to 4 g/L, a stable displacement front was observed. At the end of the injection, we were able to find 85% of the relative density of the solution initially injected at the outlet of the column.

This study found a method to deliver a solution that can stabilize the elemental mercury in polluted soils using a non-Newtonian liquid loaded with micro-particles and a reactive sulfide compound.