Removal of uranium from groundwater: comparing nanoparticle technology and bioremediation strategies

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Background & Purpose

Radioactive uranium contamination occurs when naturally or anthropogenically produced uranium infiltrates soil and groundwater. This contamination can accumulate due to the long half-life of uranium isotopes and slow groundwater remediation. In the environment, uranium exists in two major valences: tetravalent (IV) and hexavalent (VI) uranium. U(IV), occurin as UO_2, is insoluble and immobile while U(VI), existing as UO_2^{2+}, is soluble and mobile.

Radioactive contamination has serious health consequences, including kidney disease, increased risk of cancers, CNS damage, and birth defects. The World Health Organization has set the uranium limit in water at 15 ug/L, while the U.S.E.P.A. has set a limit of 30 ug/L. The focus of this WiSE project was to create a calibration curve for uranium using the Beckman 6000 Liquid Scintillation Counter (LSC) shown in Fig.1 and to characterize the sand media with uranium adsorption experiments.

Figure 1. Beckman 6000 Liquid Scintillation Counter

For radioactivity measurement, the LSC 6000 was used to determine the uranium concentration in solution. The LSC 6000 has several advantages, such as high sensitivity, high accuracy of counts per minute (CPM) and less time required than gas phase analysis.

Calibration Curve

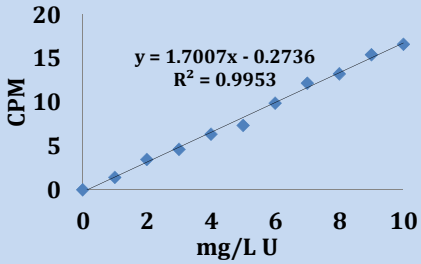

Figure 2. Calibration curve from 1 mg/L U

A standard curve for uranium was developed using the LSC 6000 in Figure 2. Sample preparation for the LSC included addition of InstaGel, made by Perkin Elmer. InstaGel is a scintillation cocktail to maximize detection of decay events by reducing "quench," or loss of CPM from interferences. However, the detection limit of the LSC was found to be 1 mg/L U, which does not meet the E.P.A. standard. Hence, there is need for radioactivity measurement techniques at lower concentrations. Current research is focusing on use of evaporation techniques to develop a calibration curve for lower levels of uranium measurement with the LSC.

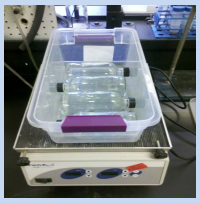

Figure 3. Initial shaker device and roller mixer

Adsorption Isotherm

Adsorption experiments were performed with six glass bottles of 20g sand and 0 to 1000 ug/L uranium. Bottles were left on shaker (Figure 3) for 72 hrs to simulate adsorption. Samples were evaporated to 1 mL for counting in LSC.

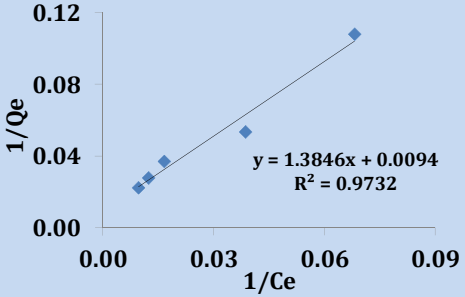

Figure 4. Langmuir adsorption isotherm for uranium using shaker

Results:

- Initial adsorption experiment suggested that uranium adsorption to sand follows the Langmuir isotherm with 90% uranium removal.
- However, shaker unit only provided planar mixing of sand due to its density, indicating that uranium adsorption may only have occurred at the surface of the sand layer.
- A roller mixer or tumbler (Figure 3) may ensure complete contact between adsorbent and adsorbate.
- Sample pH was much higher than initial pH because of sand characteristics.

Future Work

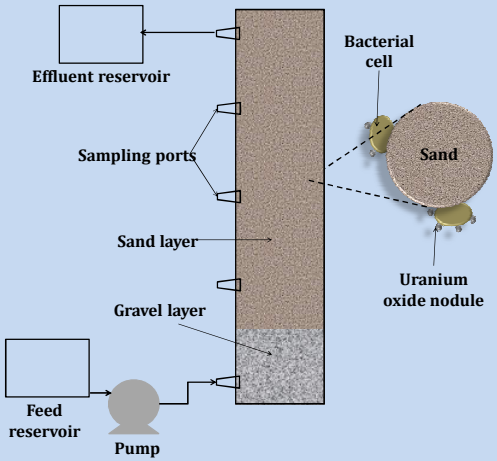

Figure 5. Schematic of bioremediation testing column

Future research will include:

- ❖ Calibration curve for lower-levels of uranium using LSC and evaporation techniques
- ❖ Improved adsorption test including implementation of roller mixer and addition of buffer for pH control
- ❖ Dynamic testing using sand columns (Figure 5) integrated with (1) sulfur-reducing bacteria, and (2) zero-valent iron nanoparticles to maximize U(VI) reduction to uranium oxide
- ❖ Comparison of uranium removal by bioremediation versus nanoparticle technology
- ❖ Application of bioremediation column as an in-situ or ex-situ treatment for contaminated sites.

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