Deep Vadose Zone Contaminate Immobilization via Foam Transport

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Background:

Hanford, Washington, is one of the nations oldest nuclear manufacturing locations. Over 354 waste disposal sites have been recognized by the EPA on the Hanford Site, all within a few miles of the Columbia River. The EPA added the Hanford site to the National Priorities List of hazardous waste zones in 1989 for nuclear contaminates such as uranium and technetium. These nuclear contaminates, along with other hazardous wastes have seeped into the deep vadose zone underneath Hanford and have entered groundwater supplies which lead to the Columbia River endangering humans and ecosystems.

Introduction:

In conjunction with Pacific Northwest National Laboratory, Oregon State University's Groundwater Lab is conducting experiments on three dimensional flow geometry of foam transport. The foam is a phosphate based compound that reacts with radionuclides to immobilize their transportation within the natural hydraulic cycle. Foam is hypothesized to be the material of choice for deep vadose contaminate remediation due to it's high volumetric percentage of air. Liquid remediation techniques at this depth have the potential to further mobilize contaminates into groundwater supplies and are therefore rendered too dangerous to conduct. Ideally, foam transport will overcome the gravitational field and provide enough surfactant to react with contaminates while withholding from further drainage of contaminates to groundwater supplies.

Experiment:

In a field-level application of foam remediation technology, foam would be pumped in through an injection well and expand in a radial flow pattern. This experiment simulates the radial flow pattern by testing a cross-sectional slice of the injection well's flow pattern. Foam was injected at the nose of the model and dispersed through the sediment-filled cross section. Post-injection, the model was quickly core sampled to determine properties of the foam's physical state and flow pattern.

The foam was generated using a high-speed blender with a modified carafe for surfactant and air injection as well as foam extraction. The foam's stability is significantly decreased by heat and therefore the blender was equipped with a cold-water circulation cooling system.

Test 1: Small Wedge

Foam Generation: 90% Quality (V_{air}/V_{foam})

Pumping Characteristics:

- to blender carafe: 4 mL/min Surfactant, 55-162 mL/min Air
- to 3D wedge: Variable - Foam

Test 2: Large Wedge

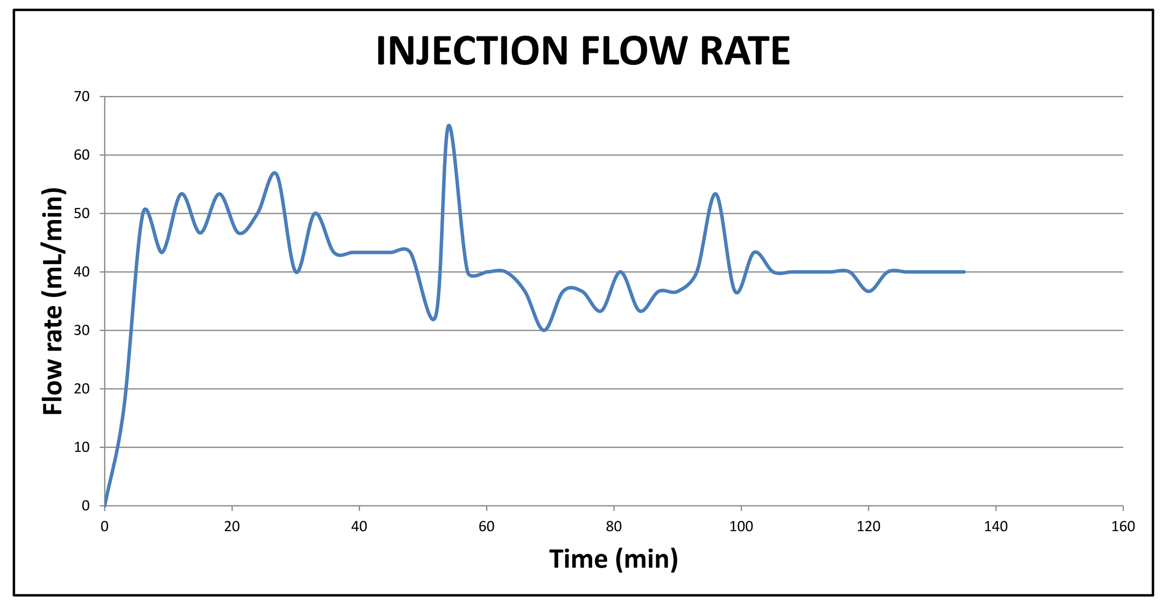
Foam Generation: 89% Quality (V_{air}/V_{foam})

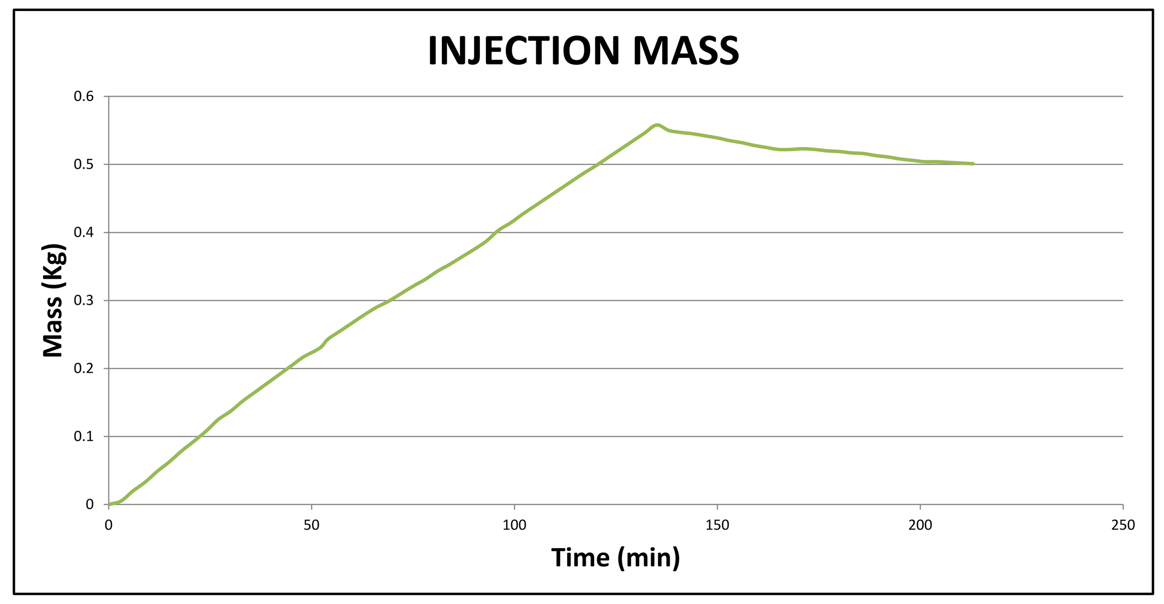
Pumping Characteristics:

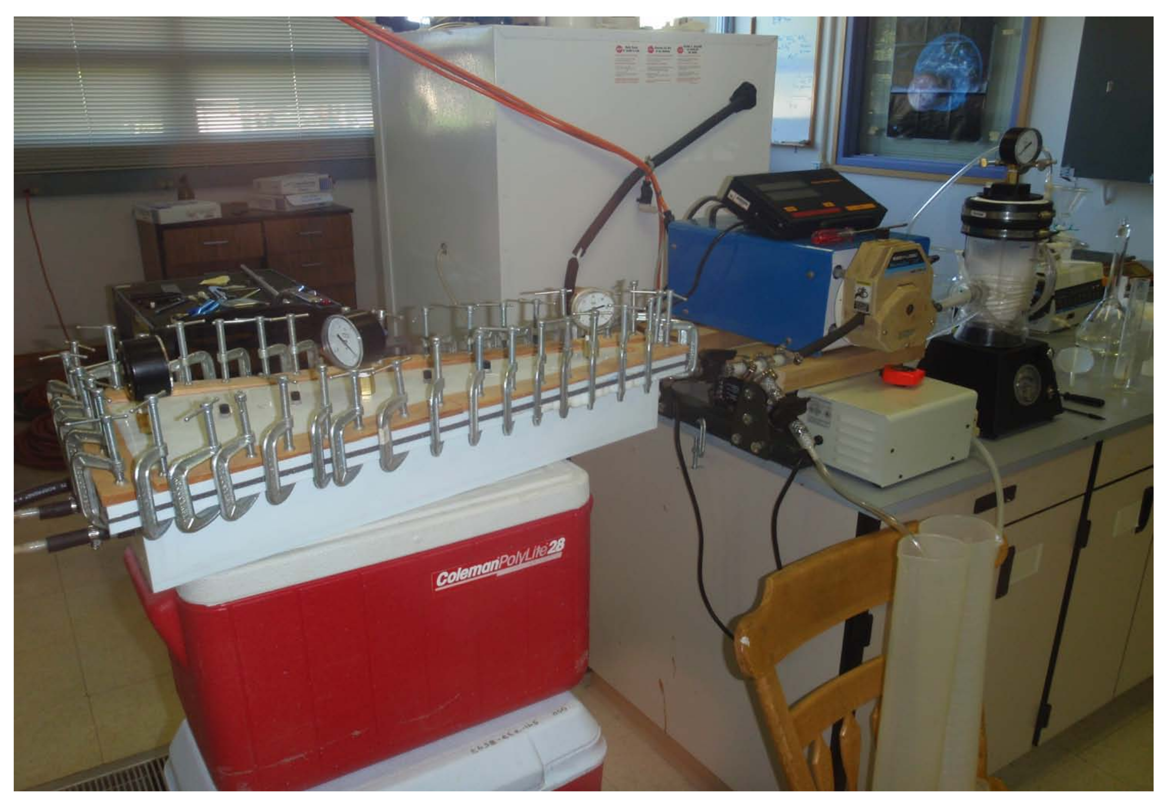
- to blender carafe: 7 mL/min Surfactant, 70 mL/min Air
- to 3D wedge: 80 mL/min Foam

Results:

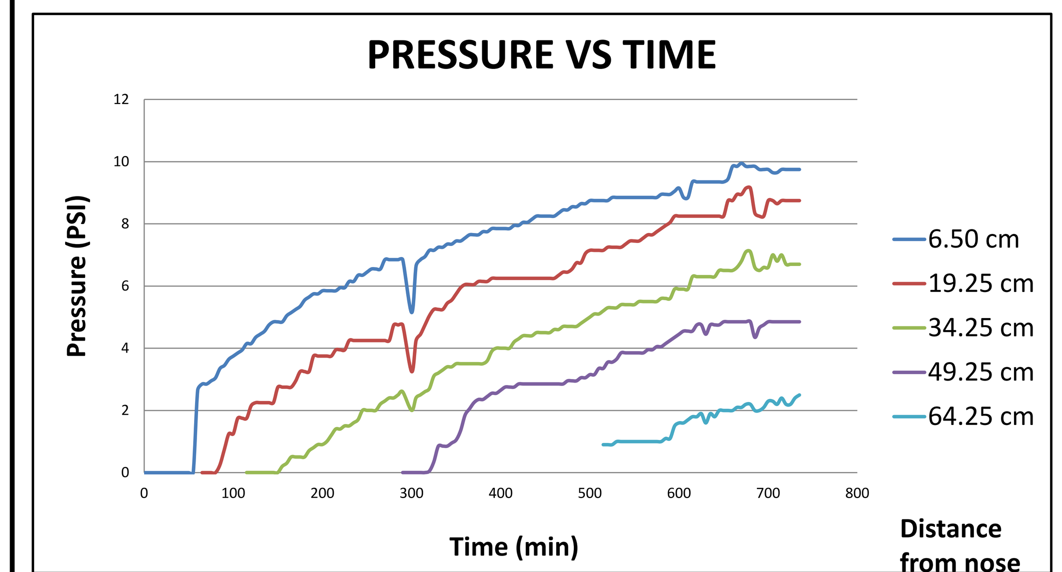
Small Wedge

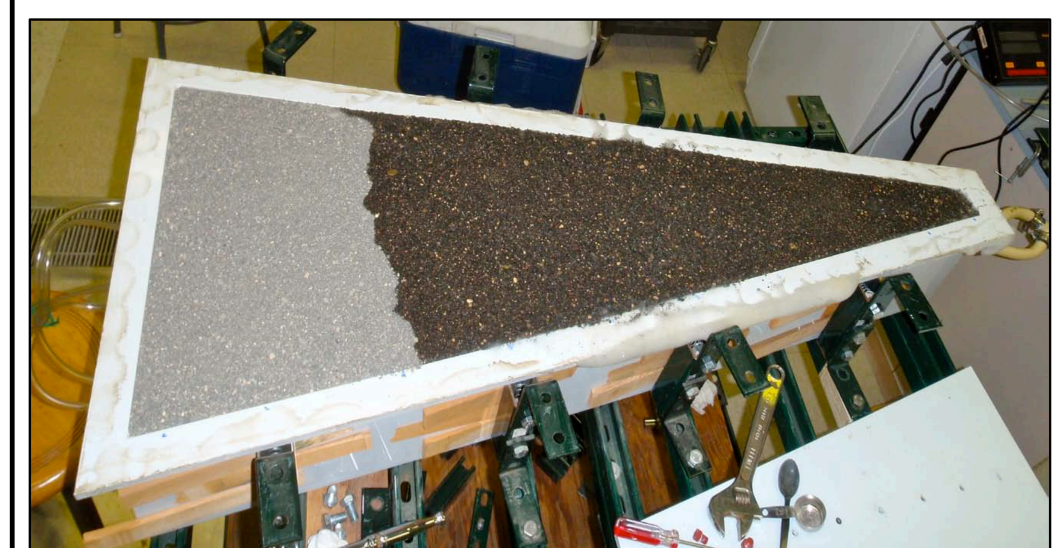


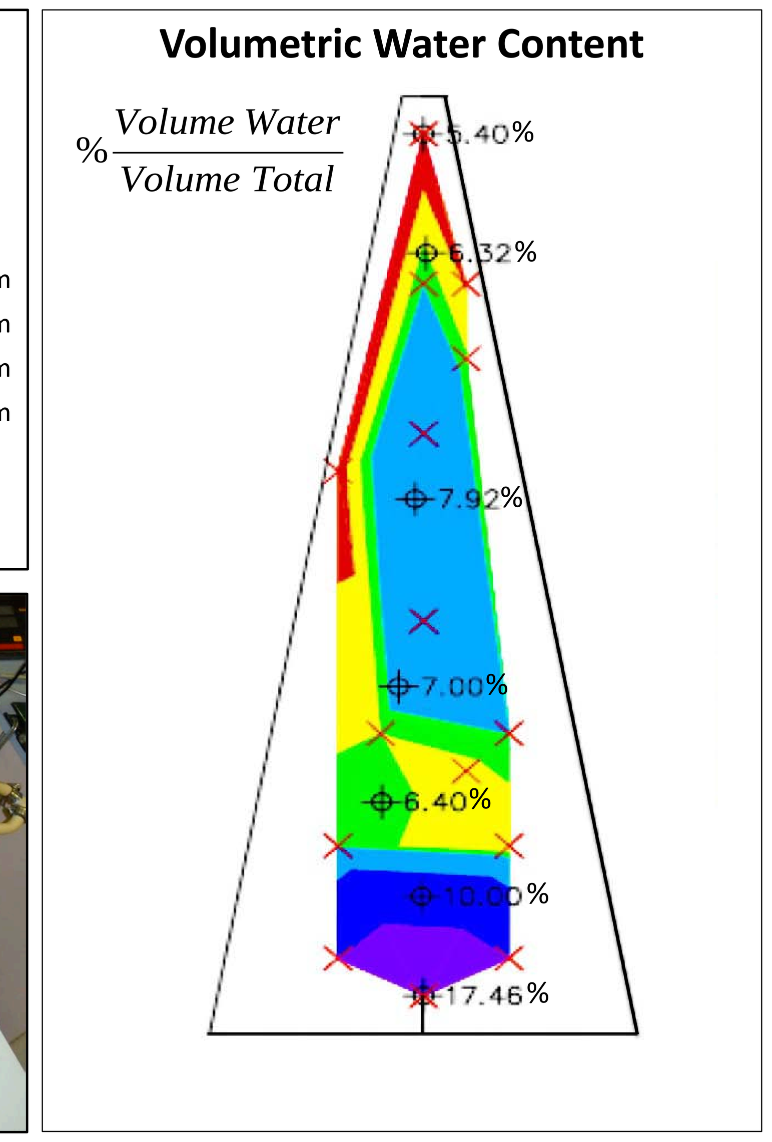


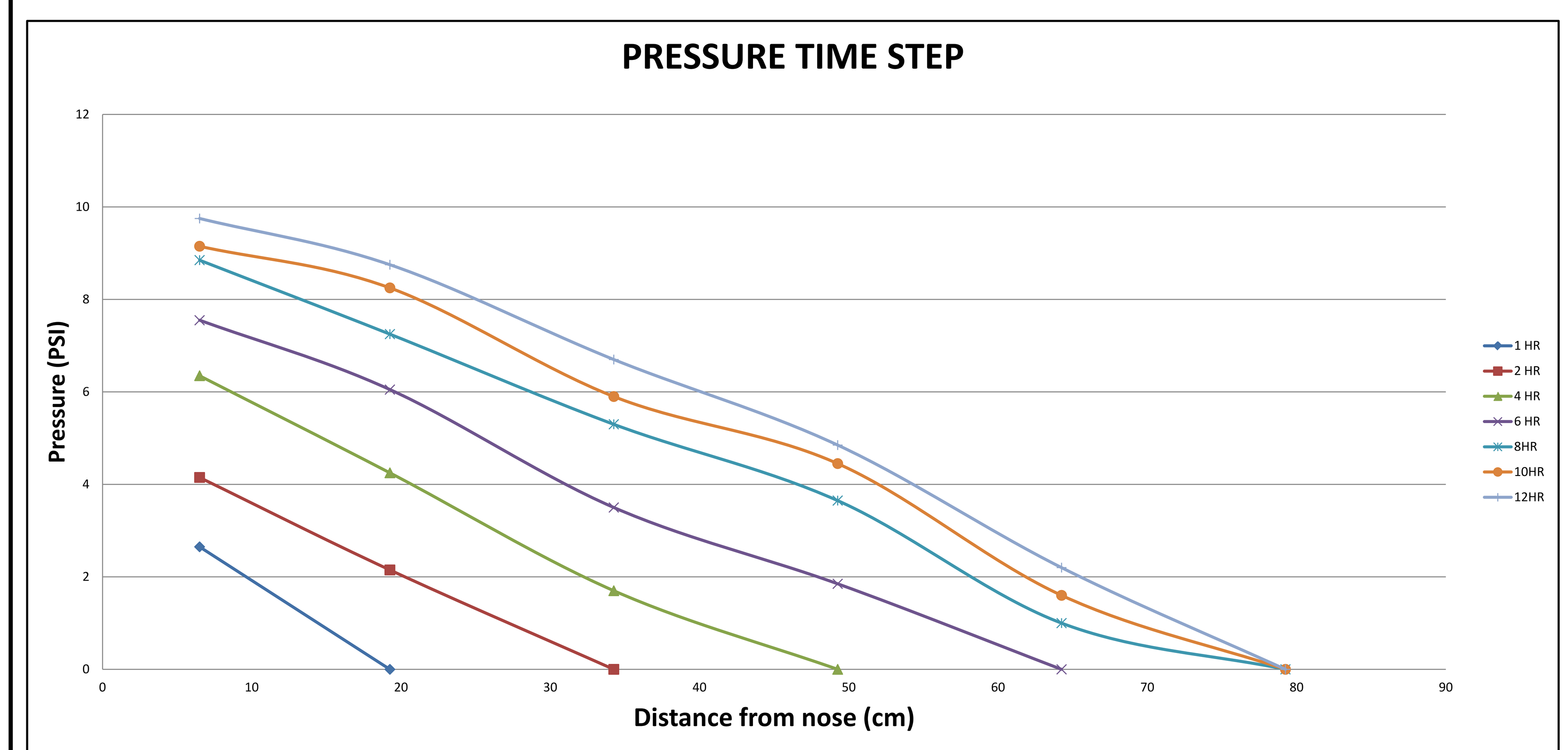


Large Wedge









Analysis & Conclusion:

The small wedge, pumped by an analog peristaltic pump at a constant setting, accepted the injection of foam in cycles rather than continuously. Measuring the injection mass of the wedge showed that once foam began to purge the model, more foam was leaving the wedge than was entering. It is expected that the purge lines of the wedge contained a lower quality of foam, or a more liquid-based foam.

The large wedge showed a maximum pressures of 10 psi., much less than pervious column tests had shown. Differentially, pressures plots at different distances from the nose of the wedge did not approach each other. Likewise, pressures decreased linearly away from the nose of the wedge, rather than an expected logarithmic decay. The volumetric water content data reveals saturated conditions at the front of the foam flow. Behind the front of the foam flow, the volumetric water content decreases towards the injection port at the nose. It is possible that surfactant from the foam was being absorbed to granules of the sediment and leaving water to pass and/or drain. However, the pressure values of the three-dimensional modeling hold promising results for the possibility of field implementation.

Further testing needs to be done to analyze the liquid front that seems to appear in both the small and large wedges as well as the composition of foam transport at different stages within the wedge models. Also, geochemical spectra analysis is needed in order to view possible mobilization of chemical contaminates and their reacted states after passage of foam transport.

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