Pore Water Extraction Test Near 241-SX Tank Farm at the Hanford Site, Washington, USA – 14168

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ABSTRACT

A proof-of-principle test is under way near the Hanford Site 241-SX Tank Farm. The test will evaluate a potential remediation technology that will use tank farm-deployable equipment to remove contaminated pore water from vadose zone soils. The test system was designed and built to address the constraints of working within a tank farm. Due to radioactive soil contamination and limitations in drilling near tanks, small-diameter direct push drilling techniques applicable to tank farms are being utilized for well placement. To address space and weight limitations in working around tanks and obstacles within tank farms, the above ground portions of the test system have been constructed to allow deployment flexibility.

The test system utilizes low vacuum over a sealed well screen to establish flow into an extraction well. Extracted pore water is collected in a well sump, and then pumped to the surface using a small-diameter bladder pump. If pore water extraction using this system can be successfully demonstrated, it may be possible to target local contamination in the vadose zone around underground storage tanks. It is anticipated that the results of this proof-of-principle test will support future decision making regarding interim and final actions for soil contamination within the tank farms.

INTRODUCTION

A proof-of-principle pore water extraction test is being conducted near the 241-SX Tank Farm in the Hanford Site 200 West Area. The purpose of this test is to determine if pore water extraction using tank farm-deployable equipment is a viable technology for soil remediation within a tank farm. This paper presents an update to information provided on characterization and potential remediation approaches to vadose zone contamination at the Hanford Site 241-SX Tank Farm [1]. Specific questions to be answered by the pore water extraction test include the following:

> Can soluble contaminants in liquid phase pore water be removed using narrow diameter direct push holes?
>
> What equipment configuration and operating parameters are required to extract liquid phase pore water containing contaminants through a direct push hole?
>
> Is additional testing of this technology warranted?

Pore water extraction is a unique remediation technique with the potential to remove soluble and mobile contaminants from the vadose zone before they migrate into the groundwater. Deployment involves establishing a low vacuum (approximately -20,700 Pa [-3 psig]) over a select vadose zone interval that exhibits elevated moisture content. Water is collected in a well sump and then pumped to the surface for collection and disposal. If this technique can be implemented using tank farm-deployable equipment, it shows promise for application inside the Hanford tank farms where mobile contaminants from tank releases are found in partially saturated zones beneath the tank farms. Pore water extraction differs from more common vadose zone remediation techniques like desiccation, which evaporates the pore water by moving air through the pore space, or soil vapor extraction, which removes volatiles from pore space under high air flow and high vacuum conditions. Neither desiccation nor soil vapor extraction target the contaminants dissolved in the water that is present in partially saturated vadose zone soils. The advantage of pore water extraction is that it actually focuses on the removal of vadose zone pore water and the associated contaminants.

BACKGROUND

While conducting soil desiccation tests near the BC Cribs and Trenches in the Hanford 200 East Area, the U.S. Department of Energy, Richland Operations Office (DOE-RL) and its contractor CH2M HILL Plateau Remediation Company (CHPRC) found that unexpectedly high nitrate, chloride, sulfate, sodium, calcium, magnesium, and technetium-99 (Tc-99) concentrations were in extracted pore water [2]. It was concluded that this was the result of extraction of water droplets, rather than evaporated water, as was expected [2]. This testing showed that under certain conditions, soluble contaminants (including nitrate, Tc-99, and other cations and anions) could be removed from the soil in addition to water.

The testing at BC Cribs and Trenches was performed using wide-diameter boreholes. A test of soil vapor extraction using narrow-diameter direct push holes was also performed by CHPRC to extract carbon tetrachloride from the vadose zone in the Hanford 200 West Area near the 216-Z-9 Crib [3]. In this test, carbon tetrachloride was successfully extracted from holes with an exterior diameter of approximately 0.038 m (1.5 in.), screened between approximately 17.7 m and 19.5 m (58 and 64 ft) below ground surface. In addition, Pacific Northwest National Laboratory conducted laboratory-scale tests and performed numerical modeling confirming that pore water extraction from unsaturated soils should be possible.

The DOE, Office of River Protection (ORP) and Washington State Department of Ecology (Ecology) personnel had many discussions regarding the testing at BC Cribs and Trenches and near the 216-Z-9 Crib. These discussions resulted in the creation of a Hanford Federal Agreement and Consent Order (HFFACO) milestone for conducting a contaminant removal/soil desiccation test in the area of the 241-SX Tank Farm in the 200 West Area. HFFACO Milestone M-045-20 required that a work plan for this proof of concept testing be submitted for approval by Ecology. A work plan was developed and approved by Ecology to meet HFFACO Milestone M-045-20 [4]. The results of the 241-SX Pore Water Extraction proof-of-principal testing will be documented in a report. This report will then support a decision by ORP and Ecology to either continue with soil desiccation/contaminant removal testing or perform other interim measures, such as construction of an interim surface barrier over the 241-SX Tank Farm.

The general location of the test at 241-SX Tank Farm is specified in Milestone M-045-20. This location was chosen due to the presence of relatively shallow, moist geologic layers containing mobile contaminants such as Tc-99 and nitrates. A specific area south of 241-SX Tank Farm, outside the tank farm fence, was chosen for the test to allow greater operational flexibility than would be possible if working within the actual tank farm. Although no Tc-99 was found in the test area during characterization activities, sufficient nitrate concentrations were found to conduct the test. The absence of Tc-99 simplifies testing and system repairs by lessening restrictions placed on staff performing the test.

DESCRIPTION

Test Configuration

The proof-of-principal test equipment was designed and configured as a mobile system for field deployment. The above grade portion of the system is contained within a small utility trailer to provide a controlled environment for the system as well as a convenient deployment platform. Major system components include the extraction well that is sealed above and below the target extraction zone, the vacuum system, and a small diameter sample pump to remove water from the well.

Numerical modeling was performed with site-specific soil properties to provide design input and establish nominal air flows and water production rates for equipment sizing and selection [5]. The expected nominal operating parameters identified through the numerical simulations, are for a water production rate of approximately 0.015 cubic meters per day (4 gallons per day) and a soil gas flow rate of approximately 0.01 cubic meters per minute (0.4 cubic feet per minute).

While the pore water extraction system has components that are similar to a vapor extraction system, the design conditions for pore water extraction are substantially different. The target vacuum level to effect pore water extraction is -20,700 Pa (-3 psig), with a soil gas flow rate contingent on subsurface conditions but typically less than 0.028 cubic meters per minute (1 cubic feet per minute) based on the geologic conditions near the 241-SX Tank Farm. Provisions are also provided in the above grade portion of the system to accommodate contamination. Air exhausted from the vacuum pump is filtered through a high-efficiency particulate air filter prior to discharge, and the water collection drums are stored on a spill containment pallet. See Figure 1 for the above grade test setup.

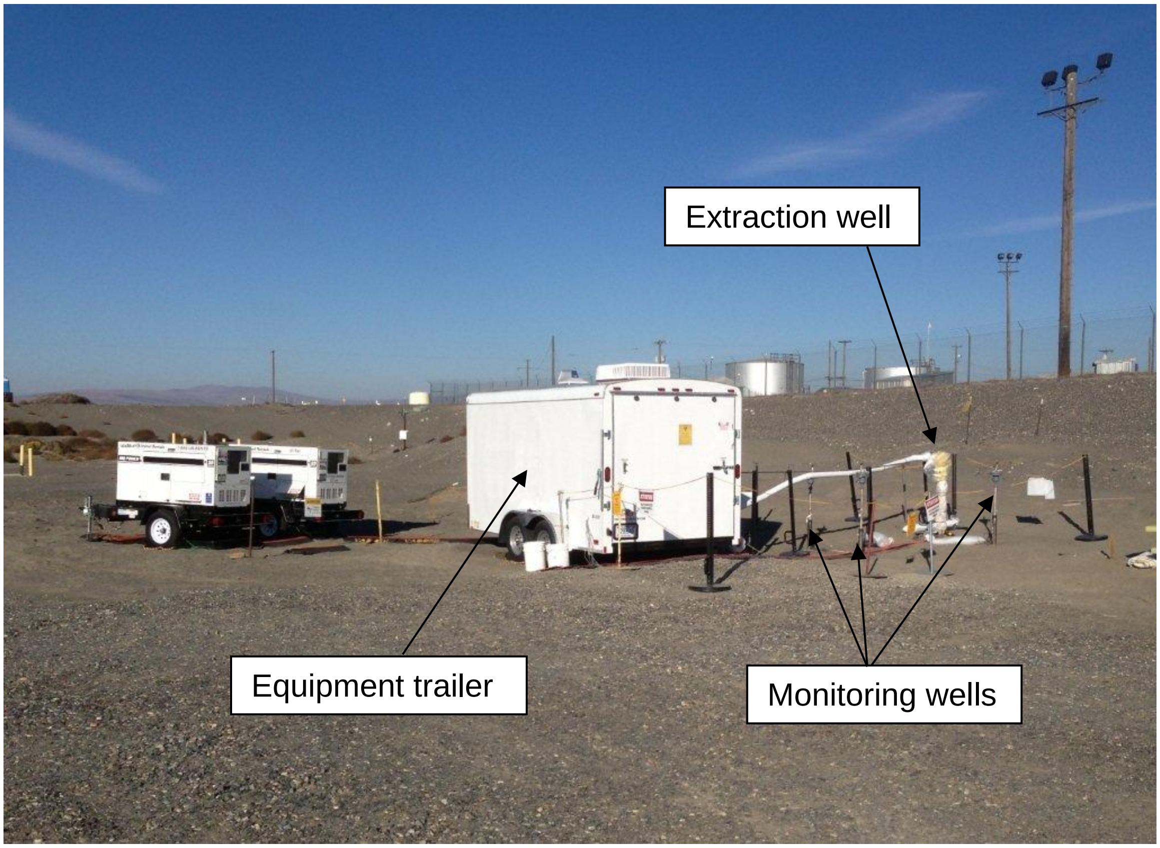

Figure 1. Pore Water Extraction Above Grade Test Setup.

Boreholes

Direct push technology is used throughout the tank farms for subsurface investigations that include geophysical logging, equipment placement, and sample collection activities. Direct push technology is used at tank farms due to its low cost, rapid hole placement, and the fact that it does not produce excavated soil that can lead to increased worker exposure and additional waste disposal costs. In addition, the direct push hydraulic hammer is a relatively small unit compared to other drilling equipment and can be placed in locations where placement of a larger drill rig would be problematic. Direct push technology was chosen for this test because it best represents what would be used in an actual tank farm deployment.

Characterization to choose a test location was performed at two potential test locations south of 241-SX Tank Farm. The two potential test locations were chosen based on moisture content determined from previous characterization work conducted in the area. Sampling and logging boreholes were pushed at each of the potential test locations in early 2013; samples were taken for “quick turn-around” analysis, and spectral-gamma and moisture logging was performed in these locations. The results were used to reach agreement among ORP contractor Washington River Protection Solutions (WRPS), Ecology, and ORP on a final test location.

In the final test location, four monitoring/extraction wells were constructed. As a risk mitigation measure, all four wells were constructed so that they could function as either extraction or monitoring wells. Due to uncertainties in constructing wells using the small diameter direct push boreholes, this approach maximized chances of constructing a usable extraction well. A rectangular arrangement of the wells was also used to allow appropriate spacing of the monitoring wells, regardless of which well was chosen as the extraction well.

The largest challenge of the well design was to develop a screen and packer assembly that would fit down the inside of the drive casing and still allow for a 0.025 meter (1 inch) diameter riser pipe. Through mockup and testing of different combinations, the project developed a sump/screen/packer design that would fit down the inside of the drive casing. Due to the need to seal the well at the bottom edge of the wells screen, early plans to use a packer for the lower seal were abandoned and a grout lower seal was used instead.

Due to difficulties in calculating exactly how much grout would be needed to provide the lower seal, a number of mockups using clear plastic tubing, grout, and simulated packer assemblies were conducted at an offsite test facility. The grout delivery system for the bottom seal was modified and tested several times, and a design was chosen. The design was thought to provide the best chances of successfully achieving a grout seal at the bottom of the well screen.

To construct the monitoring and extraction wells, a 0.067 meter (2 5/8 inch) borehole was driven to the target depth of approximately 40.8 meters (134 feet) below ground surface. Approximately 18.3 meters (60 feet) at the bottom of each borehole was logged using a neutron-neutron moisture tool to identify the specific target extraction zone. See Figure 2 for the downhole test setup.

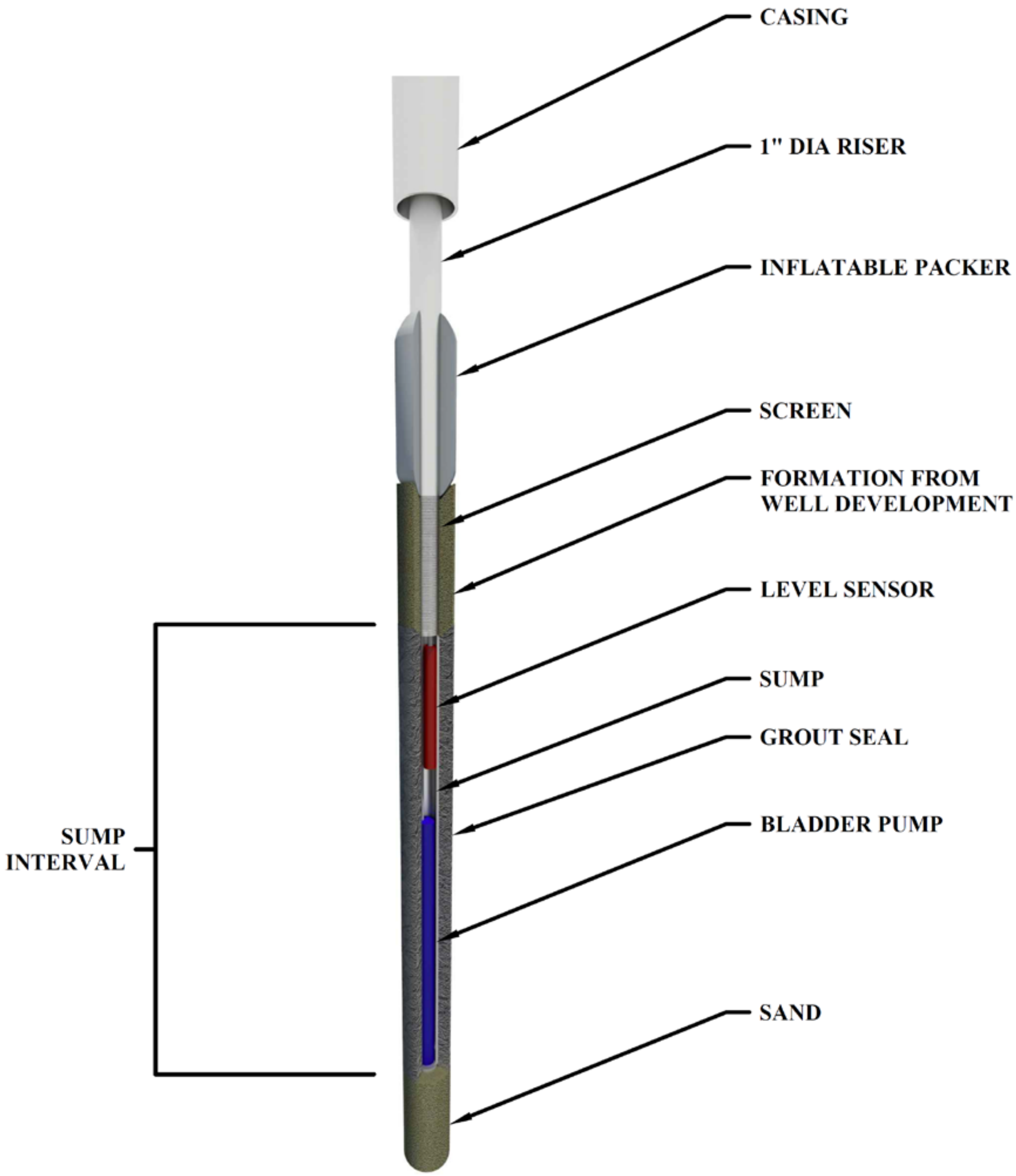

Figure 2. Pore Water Extraction Downhole Test Setup.

A core barrel sampling tool was utilized to remove soil ahead of the primary casing through the zone of interest to minimize the compaction of the formation as the outer casing was being driven. The wells were constructed in each of the four boreholes. Well development was then performed to establish contact between the formation and the well screen. This process resulted in two wells that could be used as either extraction or monitoring wells, and two wells that could only be used for monitoring purposes.

The above ground portion of the well includes pipe fittings and bulkhead-type fittings to maintain a seal on the well while providing pass through for the compressed air for pump operation; tubing for vacuum on the well; tubing for pore water extracted; instrumentation for level measurement; and nitrogen for maintaining packer inflation.

Above Ground Equipment

The above ground portion of the system provides the equipment to establish a controlled vacuum in the well and to collect the extracted pore water. The pore water that seeps through the well screen and drops into the sump below the screen is pumped to the surface using a small-diameter, air-driven bladder pump operated via a pump controller located at the surface. To accommodate a wide range of soil gas flow rates, two vacuum pumps were included in the test set up and were configured to operate individually or in parallel.

The test system was instrumented to provide control of the vacuum during testing start up and to collect sufficient data to assess system performance. A data logger was included in the system design to collect data during test operations. Parameters of interest to assessing system performance include vacuum levels, air flow rates, temperatures, nitrate levels in extracted water, and volume of water extracted.

The above grade equipment is housed in a small utility trailer with heat and air conditioning. These features, along with heat trace and insulation on the water line routed from the extraction well into the test trailer, provide a mobile deployment platform and allow for year-round test operations.

Below Ground Equipment

The size of the extraction well limited the pump options during test design. A small-diameter, air-driven sample pump, coupled with a water level meter, were configured to work in a drawdown mode to initiate pumping when the well sump filled with extracted water. Commercially available air-driven sampling pumps are not suited to pumping out of a well under a vacuum when the vacuum exceeds the hydrostatic head above the pump intake. For this test, the pump controller was modified to vent the bladder pump to the same vacuum level applied to the extraction well.

Testing Operations

Test operations were initiated in early October on the primary extraction well. The primary extraction well was selected based on moisture content, thickness of the high moisture zone, and the as-built condition of the well. The initial vacuum and air flow response from the extraction well showed good agreement with the numerical modeling predictions. A vacuum of -20,700 Pa (-3 psig) was established on the well with a soil gas flow rate of approximately 0.0057 standard cubic meters per minute (0.2 standard cubic feet per minute). Shortly after initiating test operations, the prototype well packer failed for unknown reasons. System modifications were made to modify the bladder pump controller function and attempt to seal the extraction well using bentonite pellets. Test operations were resumed, and the system operated for approximately 72 hours before the well vacuum decreased and the air flow increased, indicating a problem with the well seal and/or equipment. A decision was made to relocate the extraction well to one of the monitoring wells (secondary extraction well) located approximately 1.2 meters (4 feet) east of the first extraction well. The secondary extraction well had a lower moisture content and thinner moisture zone than the primary extraction well.

Following startup of test operations on the secondary extraction well, the system has operated for a period of approximately three months. Over the course of the test various vacuums were applied up to approximately 31,050 Pa (-4.5 psig) in an effort to increase water production without compromising the extraction well. Although the soil gas flow rates are in agreement with modeling predictions, water extraction rates have remained far lower than the expected extraction rate of 15 liters a day (4 gallons a day). The low extraction rates may be due to the moisture content and geology around the extraction well screen, or the extraction process may be limited due to poor contact between the well screen and the formation.

Analysis of the pore water samples collected during testing showed positive results for the presence of nitrate. Analysis results showed nitrate concentrations of approximately 0.5 milligrams/liter (mg/L) . The nitrate concentrations were significantly lower than expected based on the analysis of soil samples collected during well construction. Nitrate concentrations on the order of 50 mg/L were expected. This is likely due in part to the volume of deionized water used during well development to break down the compacted formation at the well screen and the deionized water left in the system piping following an equipment rinse. For example, a total of 0.17 cubic meters (46 gallons) of water was placed into the well over a number of surge and purge cycles. A total of 0.12 cubic meters (33 gallons) was removed from the well leaving a total of 0.05 cubic meters (13 gallons) of deionized development water in the formation surrounding the well.

CONCLUSIONS

Water production rates have remained well below expected values throughout the test. Production was reduced even more when the well-packer in the primary extraction well failed, and extraction had to be switched to the back-up extraction well. The other two wells constructed for the test could not be used as extraction wells because the prototype packers in those wells failed.

Operating parameters for soil gas flow as a function of applied vacuum showed good agreement with predictive modeling throughout the test. A drop in soil gas flow following initial startup indicates moisture migration toward the screened interval. Evaluation of the test data is ongoing and will be documented in the final test report scheduled for completion during fiscal year 2014. A number of lessons learned were identified relative to the equipment and instrumentation that could be improved if additional field testing is performed.

Downhole construction of a sealed extraction well using the standard direct push casing provided a number of challenges. Limited space required special processes and equipment to seal above and below the screen. Larger diameter wells would provide for improved construction and the ability to install a filter pack around the well screen, reducing the uncertainty associated with well development to break down the compacted zone around the well screen.

Additional Testing Planned

Testing will be conducted specifically to determine if well construction using direct push with a larger diameter borehole is possible. Tubing of approximately 0.098 meter (3.875 inch) outer diameter will be pushed at a suitable test location to help determine the viability of constructing extraction and monitoring wells of larger diameters. It is believed that the larger diameter wells will simplify well construction, and information on this construction will be needed to support future decisions regarding future pore water extraction applications at the Hanford Site.

Depending on the viability of pushing larger diameter wells in Hanford Site soils, a second field test may be recommended at a location suited to pore water extraction.

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