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BEAR CREEK VALLEY CHARACTERIZATION AREA MIXED WASTES PASSIVE IN SITU TREATMENT TECHNOLOGY DEMONSTRATION PROJECT - STATUS REPORT

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Abstract

Historical waste disposal activities within the Bear Creek Valley (BCV) Characterization Area (CA), at the U.S. Department of Energy (DOE) Oak Ridge Y-12 plant, have contaminated groundwater and surface water above human health risk levels and impacted the ecology of Bear Creek (Figure 1 and 2). Contaminates include nitrate, radioisotopes, metals, volatile organic chemicals (VOCs), and common ions. This paper provides a status report on a technology demonstration project that is investigating the feasibility of using passive in situ treatment systems to remove these contaminants (e.g. Figure 3). Although this technology may be applicable to many locations at the Oak Ridge Y-12 Plant, the project focuses on collecting the information needed to take CERCLA removal actions in 1998 at the S-3 Disposal Ponds site (Phase 3).

Phase 1 has been completed and included site characterization, laboratory screening of treatment media (sorbents and iron), and limited field testing of biological treatment systems. Batch tests using different Y-12 Plant waters were conducted to evaluate the removal efficiencies of most of the media. Phase 1 results suggest that the most promising treatment media are Dowex 21k resin, peat moss, zero-valent iron, and iron oxides. Phase 2 (scheduled for completion in 1997) will include in-field column testing of these media to assess loading rates, and concerns with clogging, by-products, and long-term treatment efficiency and media stability. Continued testing of wetlands and algal mats (MATs) will be conducted to determine if they can be used for in-stream polishing of surface water. Hydraulic testing of a shallow trench and horizontal well will also be completed during Phase 2.

Introduction

This project is being conducted to determine if passive in situ treatment systems can be used to meet treatment goals in BCV tributaries and/or groundwater downstream of the tributaries. Given the localized nature of known contaminant pathways and the fractured bedrock geology, the treatment system (e.g. Figure 3) will likely include a trench or horizontal well to capture and treat groundwater by means of a train of individual treatment media to remove the contaminants of concern (i.e., radionuclides, metals, organics). In accordance with treatment needs, the trench may be supplemented by any of three bioremediation technologies: constructed wetlands, MATS, or phytoremediation systems. The level of sophistication required to address the difficult subsurface matrix and the complex array of contaminants requires prudent evaluation of treatment efficiencies and operational issues to determine the optimal remedy for each pathway. The technology demonstration project consists of three phases as follow.

Phase 1: Site characterization and preliminary screening of treatment technologies. The objectives of Phase 1 are to characterize possible demonstration sites near the S-3 Ponds; to

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screen treatment media; and to conduct preliminary testing of wetlands, MATs, and phytoremediation.

Phase 2: Field evaluations of treatment technologies and hydraulics study. The objective of Phase 2 is to obtain the data needed to design treatment systems for the three pathways identified during phase 1. This will be accomplished by conducting long-term, in-field column tests and by installing two shallow trenchs or horizontal wells and conducting 30-day pumping tests.

Phase 3: Implementation of CERCLA removal action. The objective of Phase 3 is to design and install treatment systems at the three contaminant pathways. The systems will include a groundwater capture trench coupled with in situ or ex situ treatment(s) and, if appropriate, will operate in conjunction with constructed wetlands, MATs, or phytoremediation.

Purpose

This paper provides an update on the status of the project and an overview of the results of Phase 1 media screening and site characterization activities. Additional discussion of the Phase 1 results is provided in the Phase 1 Report (SAIC 1997a). The overall project scope is described in the BCV Technology Demonstration Action Plan (SAIC 1996) and the Phase 2 Workplan (SAIC 1997b). Detailed descriptions of the hydrogeology and contamination of the site is provided in the BCV CA remedial investigation report (LMES 1996). Bostick et al. (In these proceedings) also describe results of some of the iron testing conducted during Phase 1.

Site Setting

The S-3 Ponds (Figure 1) consisted of four unlined ponds constructed in 1951 on the west end of the Y-12 Plant. The ponds had a storage capacity of 40 million liters. Liquid wastes, primarily nitric acid plating wastes containing various metals and radionuclides (e.g., uranium and technetium), were disposed of in the ponds until 1983. Tetrachloroethylene (PCE) was also disposed in the ponds. Pond wastes that remained were neutralized and denitrified in 1984, and the site was capped.

Waste disposal activities at the site have created a mixed waste plume of contamination in the underlying regolith and competent shale bedrock. The ponds are located on a hydrogeologic divide. The plume is over 400 feet deep directly beneath the ponds and extends 4000 feet along geologic strike both east and west of the ponds. Contamination from the plume discharges to three tributaries of Bear Creek (i.e., NT-1, NT-2, and the upper stem of Bear Creek). The total dissolved solids (TDS) content of the groundwater plume is >40,000 mg/L near the ponds. The S-3 plume also contains elevated levels of nitrate and other ions, metals, uranium, technetium, and PCE. The plume is stratified, and the distribution of contaminants is dependent on geochemical characteristics of the contaminants and groundwater. For example, nitrate and technetium, which are not highly particle reactive, have the most extensive distribution in groundwater. Uranium and metals that are more reactive are not as deep and have not migrated as extensively away from the ponds.

Summary of Phase 1 Activities

The scope of phase 1 included the following activities:

- collecting hydraulic and geochemical information on potential S-3 trench installation locations (i.e. adjacent to tributaries NT-1, NT-2, and upper Bear Creek);
- test the ability of sorbents (e.g., zeolites, peat moss, activated carbon, Dowex 21k resin, iron oxides) to remove uranium and other metals from two Y-12 groundwater types;
- test the ability of zero-valent iron (ZVI) to reduce the concentration of uranium and other metals, technetium, nitrate, and VOCs in three Y-12 groundwater types;
- assess the effectiveness of wetlands, MATs, and phytoremediation technology in removing nitrate, uranium, and other metals from contaminated surface water; and
- select trench installation locations and the media to use in Phases 2 and 3.

Field Characterization Activities

The field characterization focused on identifying the major flowpaths for groundwater contaminants to discharge to the tributaries around the S-3 Pond area and select the target sites for trench installation. The following activities were part of the field characterization:

- conducting creek walk-overs to collect field data from surface water and identify seeps;
- on the basis of creek walk-over data, installing 30 temporary 2.54-cm-diameter (1 inch) pushprobes by means of geoprobe technology and conduct chemical analyses; and
- installing four 10-cm-diameter (4 inch) piezometers in primary seepage pathways to collect more complete chemical analyses, conducting pumping tests, and using as a source of water for long-term column tests in Phase 2.

Media Tested

The advice of nationally recognized experts was sought with regard to treatment technologies and media to test as well as potential site-specific issues. On the basis of their ideas, the screening protocols were established and treatment media agents were selected.

The technologies/media in Table 1 were tested with one or more Y-12 water types during Phase 1.

Table 1. Media Tested During Phase 1

Media category	Advantages	Products Tested
Sorbents	Predictable performance, potential low cost and low maintenance	Peat moss, activated carbon, Dowex 21k resin, iron oxides, amberlite IRC-718, zeolites, TRW coal-based sorbent, biobeads, phosphate rock, Ionac SR-4
Zero-valent iron	Extended treatment periods possible; passive; potential low cost	Masterbuilder, Fisher, palladium-coated, cercona iron foam
Biological means	Passive; affects both metals and nitrate	Wetlands, algal mats, phytoremediation

Water Types Tested

Four types of Y-12 site water were collected and used for Phase 1 testing. The water types, characteristics, and primary media tested are listed in Table 2.

Table 2. Y-12 Water Types Tested During Phase 1

Water source	Media tested	Characteristics
East End (VOCs only)	ZVI, and activated carbon	Carbon tetrachloride dominated (1 mg/L)
Boneyard/Burnyard (BYBY) water	Sorbents, Zero-valent iron	Uranium (1 mg/L), VOCs (1 mg/L PCE, 1,1,1-trichloroethane and), low TDS (<1000 mg/L)
S-3 Ponds (NT-1 piezometer)	Sorbents, ZVI, algal MATs, and phytoremediation	high TDS (up to 40,000 mg/L), nitrate (up to 20,000 mg/L), metals, technetium (>10,000 pCi/L), low pH (4-6) and PCE (<1 mg/l)
Spring SS-4	Wetlands and algal mats	Low TDS, uranium (0.2 mg/L), and nitrate (70 mg/L)

Other inorganics and their maximum concentrations at the S-3 Ponds NT-1 site are barium (380 mg/L), cadmium (4 mg/L), calcium (>10,000 mg/L), strontium (340 mg/L), zinc and nickel (20 mg/L), and copper (3.1 mg/L).

In some instances, the natural waters were spiked with higher levels of VOCs and uranium to represent possible worst-case conditions.

Phase 1 Results

Specific findings are noted in the following subsections.

Field Characterization

Field characterization efforts have delineated three primary pathways for contaminated groundwater to discharge to surface water (Figure 1) at the S-3 site.

- Two shallow pathways (pathways 1 and 2; Figure 1) conduct uranium-contaminated groundwater to the main stem of Bear Creek adjacent to the former S-3 Ponds. Groundwater in pathway 1 is also contaminated with high TDS, nitrate, technetium, and elevated levels of some metals. Groundwater in pathway 2 is primarily contaminated with uranium and has lower TDS content.
- One deeper along strike pathway (pathway 3; Figure 1) conducts nitrate, PCE, technetium, metals, and high TDS-contaminated groundwater to NT-1. This deeper along strike flow path extends to NT-2 although, at NT-2, some of the metals and VOCs are not present.

The use of trenches or horizontal wells to intercept contaminated groundwater prior to discharging to the tributaries appears feasible at all three pathways.

Treatment Technologies

Uranium removal - Most of the technologies/media from all categories showed positive results for uranium removal in low TDS water (i.e., BYBY) (Figure 4). For this water type the best sorbent performers were Dowex 21K resin (>18mg/g), peat moss (4 mg/g), and iron oxides (powdered form only). In some cases (Dowex 21K resin), the agent's loading capacity under equilibrium conditions could not be determined because the media achieved maximum uranium removal at all concentrations tested. ZVI also efficiently removed uranium through reduction and precipitation and/or through corrosion, precipitation, and sorption mechanisms. MATs (70-100% removal) and the constructed wetlands (30-46% removal) were able to remove uranium from surface water containing lower concentrations of uranium (<0.2 mg/L).

Very few media were able to provide uranium removal under the high TDS conditions in NT-1 piezometer water (Figure 4). The principle interference in NT-1 appears to be nitrate, although high calcium and aluminum concentrations also contributed to low removal by several sorbents. Peat moss had lower removal efficiencies in this water, but still provided 0.9 mg uranium removed per gram of peat moss used. Zero valent iron is also a candidate for treating of S-3 water. The long-term potential for uranium mobilization will be assessed during Phase 2 column testing.

Metals Removal - Sorbents were relatively ineffective in removing other metals from NT-1 test water. Amberlite IRC-718 and MATs removed some metals from the NT-1 water but not enough to continue as a primary treatment mechanism for the more concentrated groundwater. MATs showed promising results for removing aluminum, barium, calcium, cadmium, magnesium, manganese, nickel and strontium from more dilute surface water (e.g., SS-4 water). ZVI removed metals during batch experiments, but not during preliminary column experiments. This discrepency is attributed to pH changes and more rapid corrosion of ZVI in batch tests and the longer residence time for metals to be exposed to the iron (in comparison with residence times in column tests).

Nitrate Removal - Nitrate removal is an important consideration, as demonstrated by nitrates interference on removal of other contaminants in NT-1 water. Some nitrate reduction in the lower concentration surface water was observed in the wetlands and MATs systems, but more testing is required to establish the maximum rate of removal. In addition, the effect of biomass grown in a peat moss/ZVI environment is also being evaluated as a potential medium for nitrate removal. This combination of components appears to provide a reducing environment, a support matrix, and some degradable carbon to support nitrate removal. Further investigation of these options will be continued in Phase 2.

VOC Destruction - Both Fisher and Masterbuilder iron removed VOCs from test water but Masterbuilder iron produced a shorter half-life than Fisher iron. The half-lives of Masterbuilder and Fisher iron were <1.0 hours and >11 hours, respectively, for batch studies conducted on BYBY water containing PCE and trichloroethylene (TCE). For 1,1,1-TCA, the half-lives were 1.21 hours and 4.18 hours, respectively. Palladium coating enhanced the effectiveness of both iron forms, but the gain may be too small to compensate for the added cost of palladium treatment. The calculated half-life for palladium-coated Masterbuilder iron was 0.21 hours while the uncoated was 0.25 hour. The rate of degradation for daughter products of carbon tetrachloride (chloroform and dichloromethane) were too slow for Fisher iron to be a viable candidate for treatment of carbon tetrachloride. Further investigation of the fate of daughter products will be performed in Phase 2.

Phase 1 Conclusions

Contaminants reach Bear Creek through at least 3 discrete pathways in fractured bedrock. Conceptual treatment systems (e.g. Figure 3) for each of the contaminant pathways were developed by considering chemical, hydraulic, and waste management/discharge issues.

The following table describes the treatment media, target contaminants, and the issues to be resolved in Phase 2.

Table 3. Concerns to be resolved in Phase 2.

Media	Targets	Issues
Dowex 21K resin	Uranium	Reduced performance with elevated TDS, effective only for uranium
Peat Moss	Uranium, metals, VOCs, nitrate	Unsure of long-term performance
Zero-valent iron	Uranium, metals, VOCs	Colloid release of Uranium; VOC byproducts
Iron oxides	Uranium, VOCs	Colloid release of uranium
Algal Mats	Uranium, metals, nitrate	Requires sunlight, nitrate reduction capacity unclear, full-scale engineering needed
Wetlands	Uranium, nitrate	Fate of accumulated uranium, winter effects
TRW	Uranium	Not commercially available, effective only for uranium

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