EPA Hardrock Mining Innovative Technology Case Study

East Helena

Zero-Valent Iron Permeable Reactive Barrier Treatment of Arsenic in Groundwater

ABSTRACT:

The East Helena site in Lewis and Clark County, Montana operated for more than 100 years as a primary lead smelter. The decades of smelting operations at the site deposited lead, arsenic, copper, zinc, cadmium, and some 15 other hazardous substances into the soil, surface water, and groundwater. A pilot-scale zero-valent iron (ZVI) permeable reactive barrier (PRB) was first installed at the site in 2005 to treat arsenic contaminated groundwater. On site, the PRB is located just west of the slag pile, and situated down gradient about 600 feet from the main contaminant source. Preliminary evaluation of the system indicates that arsenic concentrations as high as 20 mg/L are reduced to below 0.010 mg/L within the barrier. This case study focuses on the effectiveness to date of the pilot-scale ZVI PRB in treating arsenic contaminated groundwater.

SITE BACKGROUND

East Helena
CERCLIS ID: MTD006230346

The East Helena site is located in East Helena, Montana in Lewis and Clark County. The site is the location of a primary lead smelter that also recovered zinc and other metals. The East Helena Smelter operated for more than 100 years from the late 1880s through the early 21st century. ASARCO, formerly the American Smelting and Refining Company, purchased the 160 acre site from the Helena and Livingston Lead Smelting Company in 1899. The decades of lead and zinc smelting operations at the site deposited lead, arsenic, copper, zinc, cadmium, and some 15 other hazardous substances into the soil, surface water, and groundwater. Smelting operations continued until 2001 when ASARCO placed the smelter in “indefinite closed status.” (U.S. EPA, 1999).

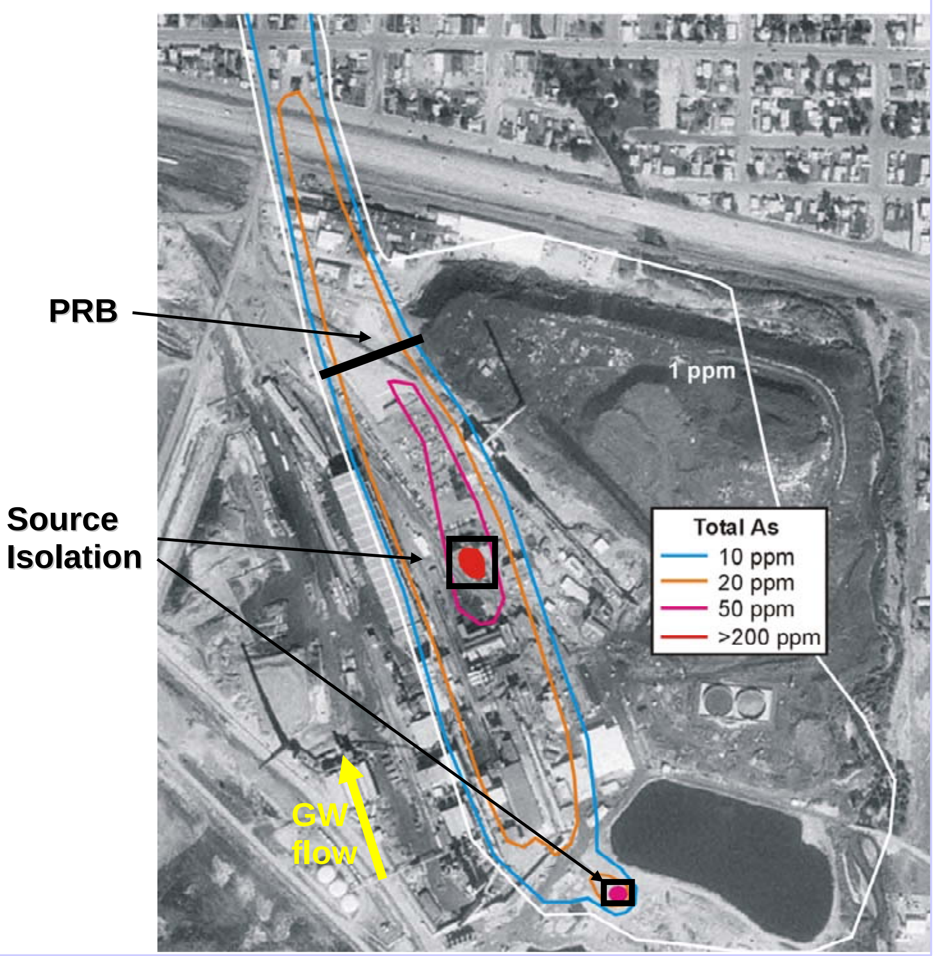

Figure 1: East Helena arsenic plume.

In 1984, the East Helena Smelter was added to the National Priorities List (NPL) because of contaminated soils in East Helena residential areas, elevated blood lead-levels in children, elevated metal levels in air, and contaminated process ponds over shallow groundwater near the plant. Process ponds at the site were identified as the primary sources of groundwater contamination which was detected in the shallow aquifer under the plant. The contamination extended into the aquifer underlying the City of Helena. Of the contaminants detected in the groundwater, arsenic is the most mobile in the groundwater system and is present in relatively high concentrations (U.S. EPA, 1999). This case study focuses on the effectiveness to date of a pilot-scale zero-valent iron (ZVI) permeable reactive barrier (PRB) in treating arsenic contaminated groundwater.

WASTE STREAM CHARACTERISTICS

East Helena was added to the NPL in 1984 partly due to contaminated process ponds located over shallow groundwater. Due to the smelting operations at East Helena that occurred for over 100 years, groundwater at East Helena has high concentrations of arsenic existing in the redox state of arsenite (As^{3+}) and arsenate (As^{5+}). The arsenic plume targeted by the PRB is roughly 450 feet wide extending 2,100 feet downgradient from the primary source of subsurface contamination (Figure 1). In the area surrounding the site, groundwater flow varies from about 0.5 to 3.0 ft/day. The average pretreatment concentration of arsenic in the groundwater is 20 mg/L whereas the maximum contaminant level (MCL) for arsenic is 0.010 mg/L (U.S. EPA, 2005).

TREATMENT TECHNOLOGY

Construction on the ZVI PRB began at the East Helena site in spring of 2005. The PRB remedial technology for treatment of groundwater can be used for a wide array of organic and inorganic contaminants. However, in designing a PRB for treatment of arsenic in groundwater, finding the correct reactive media is a major challenge. The reactive media must serve as both a long-term sink for metals while at the same time maintain permeability and hydraulic connectivity between the contaminant plume and the reactive treatment zone (Lien and Wilkin, 2005). In the past, ZVI has proven an effective reactive media for arsenic in groundwater.

Figure 2: Construction of the PRB trench at the East Helena site.
Photo courtesy of Rick Wilkin, EPA

Although ZVI is more commonly used to treat metals and halogenated organic solvents, in the past six years, a few studies have focused on using ZVI for arsenic removal because ZVI has a high arsenic removal capacity. Arsenic removal mechanisms by ZVI include sorption onto corrosion products, co-precipitation with iron sulfides and green rust (class of iron oxide compounds), and precipitation as arsenic sulfides. However, this technology is ultimately limited because of the initial removal capacity and any additional capacity that may come about after iron metal corrodes in water (Lien and Wilkin, 2005). Arsenic removal is a two-step reaction including the initial rapid removal of arsenite followed by a slower removal process that involves formation of smaller amounts of arsenate. The overall removal capacity of ZVI is estimated to be 7.5 mg arsenic/g iron (Lien and Wilkin, 2005).

A trench measuring 30 feet long, 46 feet deep and 6 feet wide was constructed perpendicular to the plume. The trench was filled with 175 tons of ZVI and coarse bedding sand (U.S. EPA, 2005). On site, the PRB is located just west of the slag pile, and situated down gradient about 600 feet from the contaminant source.

PERFORMANCE OF SYSTEM

Using data from a network of monitoring wells, including over two dozen wells within the trench, the first round of monitoring data was collected in June 2005. Preliminary evaluation of the system indicates that arsenic concentrations as high as 20 mg/L are reduced to below 0.010 mg/L within the barrier. Once construction impacts on the treatment system subside and the normal ground water flow is re-established, researchers expect reductions in the arsenic concentrations downstream from the PRB (U.S. EPA, 2005). At present, it is too early to determine if the treatment is successful as there are still many uncertainties. Full-scale implementation of the treatment system will be determined after two years of evaluating the success of the pilot system.

LESSONS LEARNED

A pilot-scale PRB was constructed at the East Helena site in the spring of 2005. Prior to installation, the unique hydrogeology of the site and the composition of the aquifer materials created some doubt as to whether installation of the PRB was possible at all. The challenging hydrogeology came from the presence of a few boulders in the subsurface. Large excavation equipment was brought in to remove the boulders.

In constructing PRBs, consideration must be given to the nature of the groundwater flow rate and the contaminant concentration. In this case, the barrier was designed to involve wider dimensions to account for the high arsenic concentrations and flow rate.

In addition, the biopolymer slurry used to hold the trench open was a success.

Although it is still too early to determine the success of the system, the researchers are hopeful the PRB will be able to control the arsenic plume and off-site migration. Ultimately, treatment of the arsenic contamination must involve source control and the PRB can only serve as part of the remedy. Currently, source control at the site includes pump and treat, isolation/containment, and in situ treatment while additional plume control includes pump and treat, air sparging, and monitored natural attenuation. By itself, the PRB cannot control the high arsenic concentration and groundwater flow rates.

KEY DATES

(U.S. EPA 1999, 2005)

1888	Smelter operations begin at East Helena.
1899	ASARCO purchases the smelter from the Helena and Livingston Lead Smelting Company.
1969	Environmental investigations begin at the site.
1984	East Helena Smelter site is listed on the NPL.
2001	East Helena ASARCO Incorporated Smelter placed in "indefinite closed status."
2003	NRMRL conducted batch and column studies on simulated ground water to assess the effectiveness of ZVI for arsenic remediation.
2005	Installation of the pilot-scale PRB is completed in five days.
	A two-year evaluation begins on the PRB to determine long-term success of reducing arsenic concentrations.

COST

For the existing pilot-scale PRB system, Region VIII estimates a construction cost of $325,000 (U.S. EPA, 2005). There are no additional operation and maintenance costs associated with the PRB.

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Lien, H-L and Wilkin, R.T. 2005. "High-level arsenite removal from groundwater by zero-valent iron." *Chemosphere. 59(3): 377-86.*