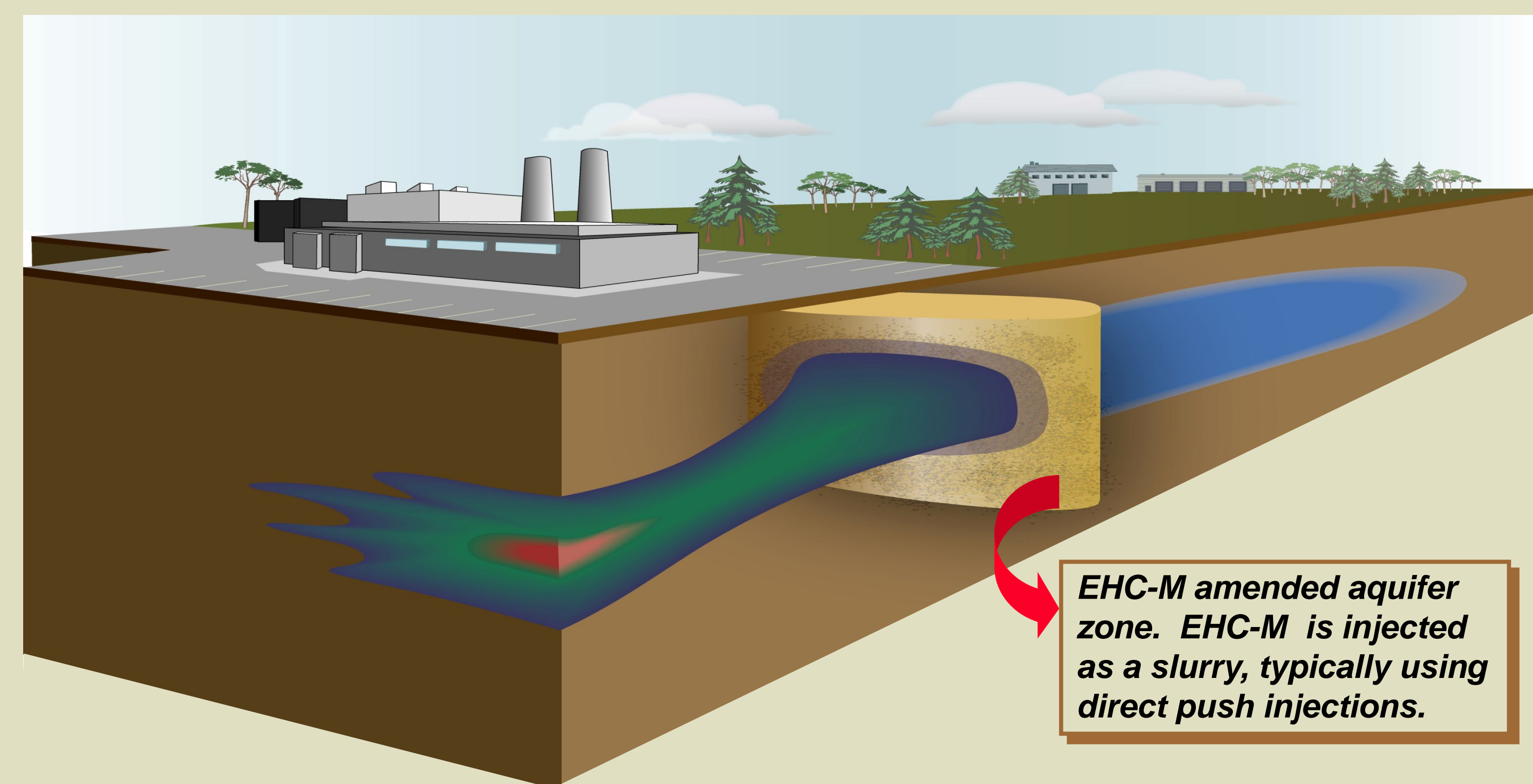


In Situ Chemical Reduction (ISCR) Technology for Treatment of Heavy Metals and Persistent Organic Compounds in Groundwater

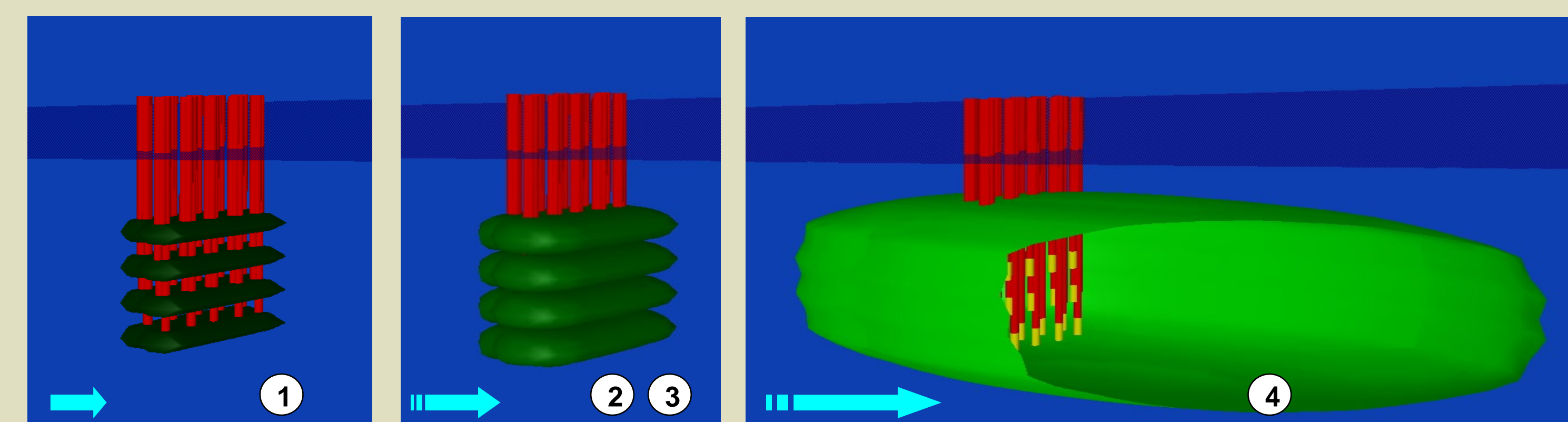
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BACKGROUND

EHC-M[®] is a specially formulated integrated treatment material containing controlled-release organic carbon, zero valent iron (ZVI), a source of sulfate, and other additives designed for treatment of dissolved trace metals as well as mixed plumes containing chlorinated volatile organic compounds (cVOCs) and metals. The two main reactive components of EHC-M, ZVI and organic carbon substrate, are well-established reactive materials used for in-situ reductive treatment of different types of metals and organics in groundwater. EHC-M can be applied to the subsurface environment in a number of ways to reduce the concentration of dissolved contaminants in a safe and timely manner.



EHC-M Influenced Reductive Treatment Zone

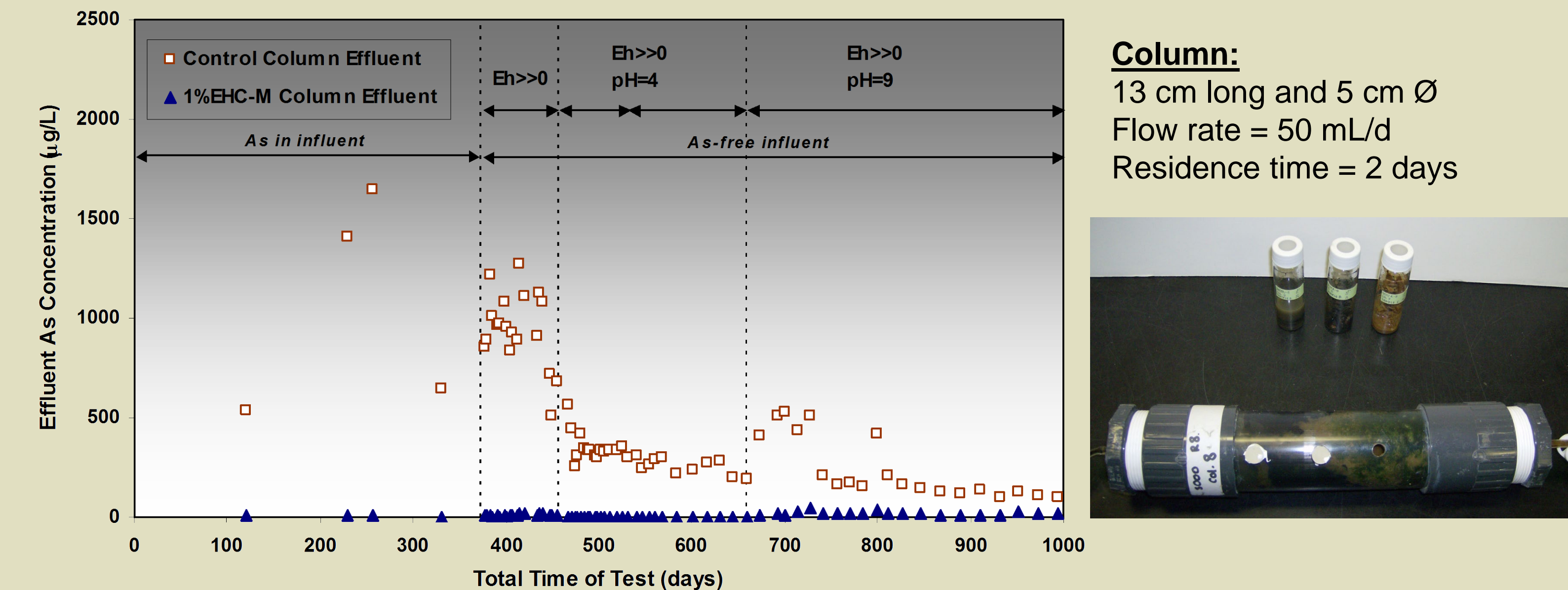


- 1 Direct ZVI corrosion effects
- 2 Indirect ZVI effects (H₂ gas and iron corrosion product generation)
- 3 Carbon substrate fermentation produces volatile fatty acids (VFAs), sulfate released from EHC-M
- 4 Biostimulation of the aquifer zone by the dissolved components

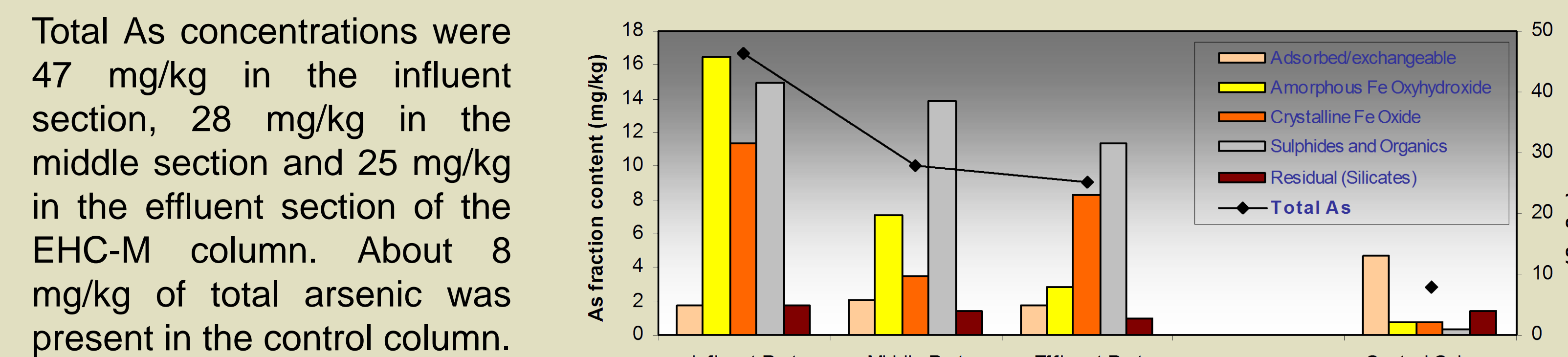
Contaminant	Treatment Mechanisms in the EHC-M zone
cVOCs	Chemical and microbiological dechlorination stimulated by a combined effect of the organic components and ZVI contained in EHC
As (III, V)	Reductive precipitation with oxidized iron minerals. Precipitation as As sulfide and mixed Fe-As sulfide
Cr(VI), Mo(VI), Se(IV,VI), U(VI)	Reductive precipitation with oxidized iron minerals and adsorption to iron oxides.
Me ²⁺ (Cu, Zn, Pb, Cd, Ni)	Metal cations precipitate as sulfides, following stimulated heterotrophic microbial sulfate reduction to sulfide. Adsorption to iron corrosion products (e.g.; iron oxides and oxyhydroxides).

Long-Term Column Test for Arsenic Treatment

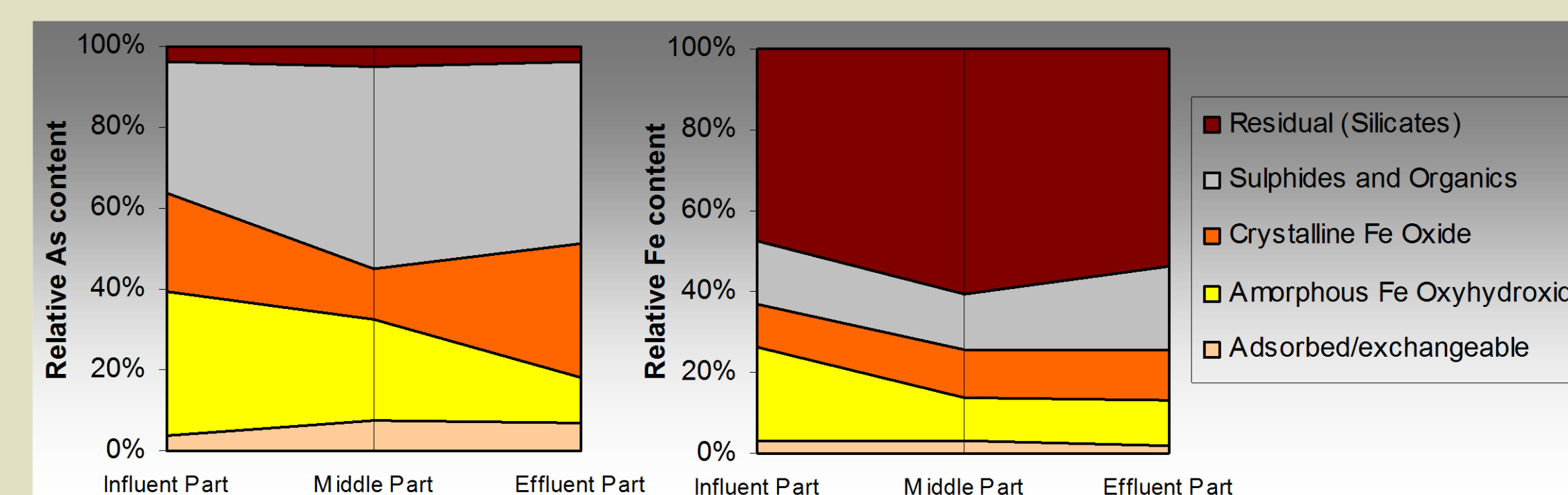
A column was packed with 1% EHC-M with As-contaminated sand and then exposed to groundwater spiked with arsenic (0.5-0.7 mg/L) for 380 days. About 35 mg of As was immobilized in the column containing 5.2 g of EHC-M. Subsequently, arsenic-free water was introduced to the column to determine the potential remobilization of the sequestered arsenic under varying Eh and pH conditions. The As has not leached from the EHC-M column over a 670 day observation period. The test is ongoing.



After 1,000 days of operation the column material from the EHC-M column and control column was sampled and analyzed for As and Fe speciation using sequential extraction.



The majority of As in the EHC-M column was bound in sulfide and iron oxide/oxyhydroxide phases, while most of As in the control column was present in an adsorbed/exchangeable form. The observed changes in solid arsenic and iron distribution along the column confirm the importance of a source ferrous iron from ZVI present in EHC-M. That is, continuous formation of Fe oxide layers protect the precipitated reduced As mineral phases and also aid in precipitation and/or adsorption of any As that is potentially mobilized under extreme changes in geochemical conditions.



Treatment of Other Metal Using EHC-M

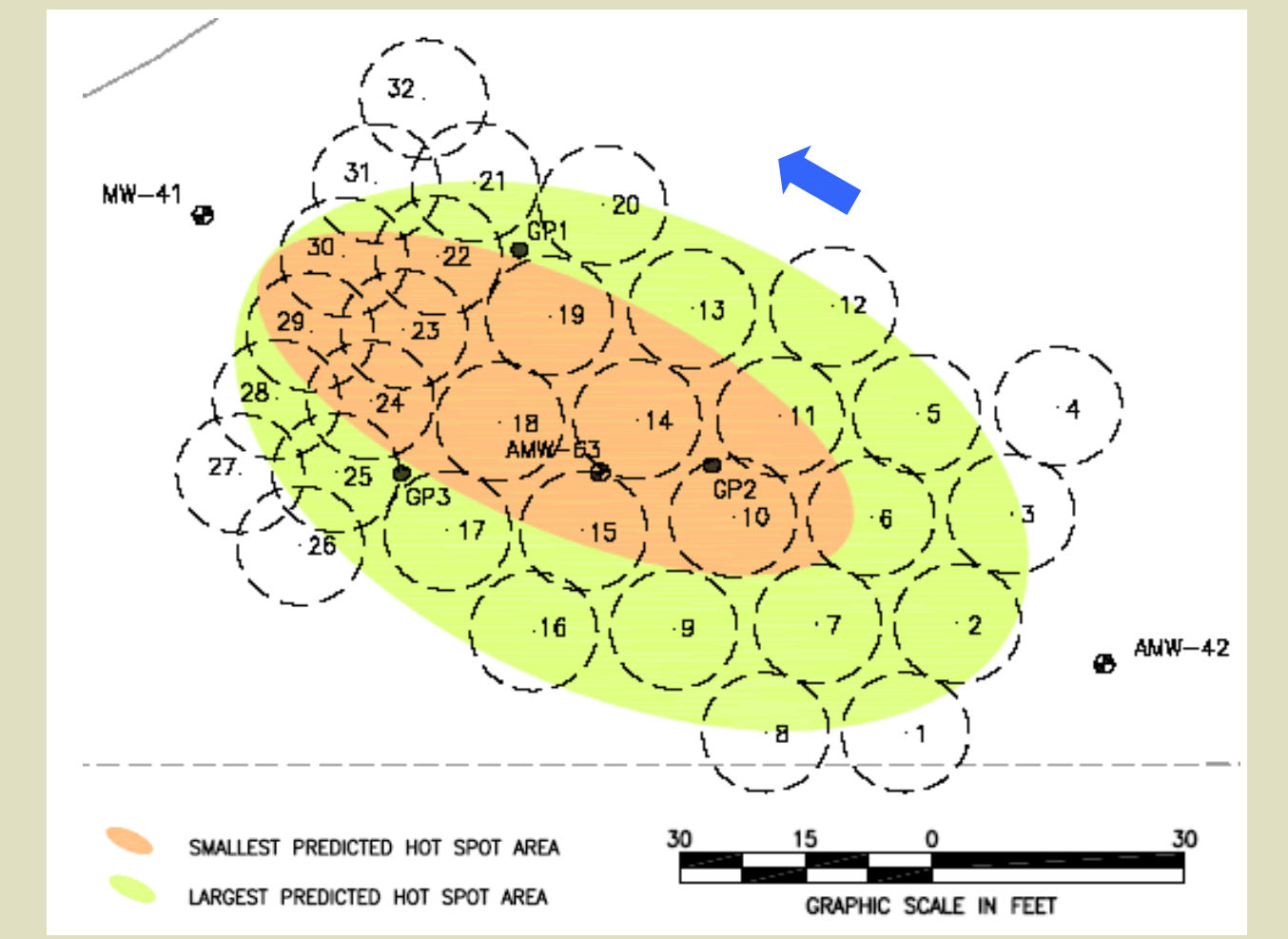
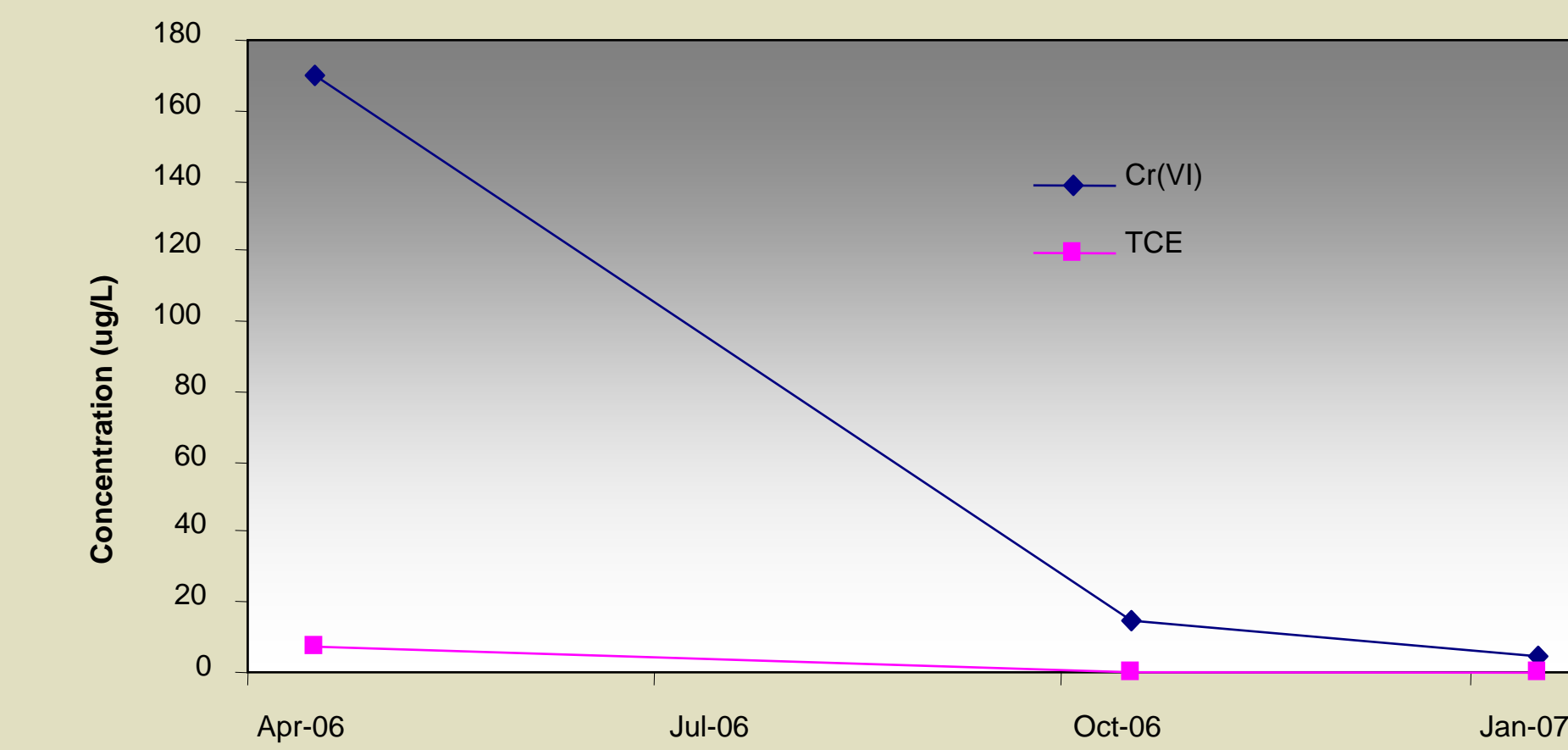
Compound	Influent Concentration Range (mg/L)	Observed Removal Efficiency
Arsenic	0.5 - 2.5	98 - 100%
Chromium	0.4 - 30	87 - 99%
Lead	64	99%
Zinc	4.5 - 50.4	92-100 %
cVOCs	Up to 400	90-100 %

FIELD APPLICATIONS

Site 1: Washington State, Sept. 2006

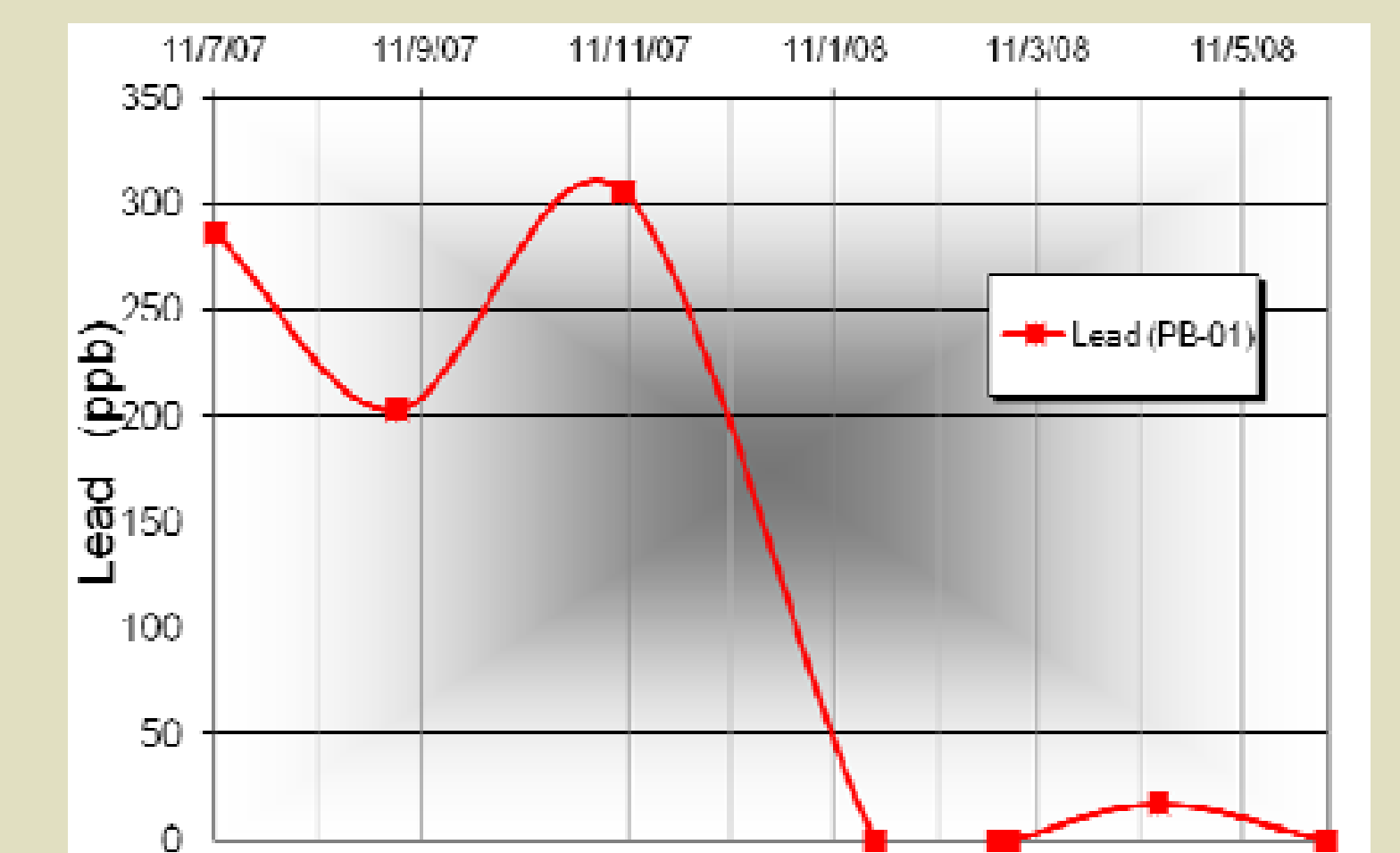
EHC-M was injected into the suspected hot-spot area upgradient of an extraction well from 75 to 85 ft bgs. A total of 9,600 lbs of EHC-M was injected into the area, resulting in an average application rate of 0.15% to soil mass.

Cr(VI) was reduced to below the detection limit of 5 ppb within four months. TCE was non-detect and Cr was measured at 9.5 ppb at this new well in January 2007.



Site 1: Brazil, July 2007

Groundwater was impacted by lead up to 600 ppb. Baseline conditions were relatively oxid with a DO of 2 to 6 ppm and ORP generally in the range of 80 to 400 mV and pH as low as 2.5 and A mixture of EHC-M, dolomite and water was injected into 12 injection points spaced 3 m on centers using direct push technology. The pilot study area measure an estimated 12 m long x 9 m wide x 10 m deep.



Performance monitoring showed Pb below the detection limit of 10 ppb at the pilot study well PB-01, which represents a >97% decrease in soluble Pb from the November data of 306 ppb. Subsequent monitoring has also confirmed that the injections have been successful in establishing reducing conditions and a significant increase in the aquifer pH. The redox potential has remained around -100 mV since January 2008. The pH in the upper aquifer increased from a baseline value of around 4 to a maximum of 13 measured in January 2008; the pH has since decreased to just below 10 measured in the latest sampling round conducted in June 2008. pH in the lower aquifer remained between 7 to 8. Continued monitoring is expected to show that *in situ* chemical reduction using the EHC-M technology offers a safe, effective and cost-efficient remedial solution for similarly impacted environments.

Summary: Treatment of Metal Using EHC-M

- Encourages the precipitation and adsorption of dissolved metals
- Controlled release carbon and ZVI
- Arsenic precipitates as Iron/Arsenic Sulfide
- Low redox/ZVI → Cr(6+) precipitates as Cr(3+)
- Trace metals (Cu, Zn, Ni, etc.) immobilized as metal sulfides
- Can be used for treatment of mixed plumes (Metals + cVOCs)

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