

COST AND PERFORMANCE REPORT

Electrical Resistive Heating at the
ICN Pharmaceutical Site
Portland, OR

February 2004

SITE INFORMATION

IDENTIFYING INFORMATION

Site Name: ICN Pharmaceuticals Incorporated
Location: 6060 NE 112th Ave., Portland, Oregon
Regulatory Context: Oregon Department of Environmental Quality (DEQ) oversight
Technology: Electrical resistive heating (ERH)
Scale: Full-scale

TECHNOLOGY APPLICATION

Period of Operation: May 2000 to December 2001

Type/Quantity of Material Treated during Application [4]: Source zone - Estimated 48,000 to 65,000 cubic yards based on a treatment area of three-quarters to one acre in size and a depth of 40 ft.
Groundwater - Plume size estimated to be 120 ft by 80 ft

BACKGROUND [1,2]

The ICN Pharmaceuticals site, located in Portland, Oregon, was used as a clinical laboratory from 1961 to 1980. The laboratory used a variety of organic and inorganic compounds with wastes from laboratory operations disposed in a dry well which was about 20 ft deep. In 1980, the laboratory was shut down and materials and machinery were removed. In 1993 and 1994, the laboratory building and associated structures were removed from the site. Results of groundwater investigations at the site identified the former dry well as the source of groundwater contamination. The groundwater in the vicinity of the former dry well was determined to be contaminated with volatile organic compounds (VOCs) including trichloroethene (TCE), cis-1,2-dichloroethene (DCE), vinyl chloride (VC), benzene, and toluene. TCE, DCE, and VC were detected in the groundwater at concentrations greater than 1% of their solubility, suggesting the presence of dense non-aqueous phase liquid (DNAPL). On August 23, 1999, a record of decision (ROD) was signed for the site to address the groundwater contamination in the area of the dry well. ERH, in conjunction with SVE, was implemented at the site to treat the DNAPL source and dissolved phase VOCs in groundwater.

CONTACTS

Technology System Vendor:
Jim Jeffs
Current Environmental Solutions
Applied Process Engineering Laboratory
350 Hills St.
Richland, WA 99352
Telephone: (509) 371-0905
Email: jjeffs@cesiweb.com

Contractor:
Michelle Peterson
AMEC Earth and Environmental, Inc.
7376 SW Durham Road
Portland, OR 97224
Telephone: (503) 639-3400

State Contact:
 Jennifer Sutter, Project Manager
 Oregon DEQ
 2020 SW Fourth Avenue
 Portland, OR 97201-4987
 Telephone: (503) 229-6148
 Email: Sutter.jennifer@deq.state.or.us

MATRIX DESCRIPTION

MATRIX AND CONTAMINANT IDENTIFICATION [1,2]

Type of Media Treated: Source zone (saturated and unsaturated)

Primary Contaminant Groups: Chlorinated solvents - TCE, cis-1,2-DCE, VC

SITE HYDROGEOLOGY AND EXTENT OF CONTAMINATION [2,4]

The site geology consists of fluvial and lacustrine depositional sequences (Overbank) to a depth of approximately 60 feet bgs. Silts and sands are discontinuously interlayered throughout the Overbank deposits. The water table is encountered in the Overbank at approximately 8 ft bgs. Troutdale Gravel Aquifer (TGA) underlies the Overbank formation and consists of unconsolidated and cemented gravels of the Troutdale Formation. The TGA is approximately 175 feet thick in the site area (60 to 235 feet bgs). A confining layer encountered at a depth of 235 ft bgs at the base of the TGA consists of sand, silt, and clay of lacustrine origin and is approximately 100 feet thick at the site.

DNAPLs were present in the Overbank, with dissolved phase VOCs present in both the Overbank and TGA layers. The areal extent of the DNAPL source in the Overbank was estimated to be three-quarters to one acre in size, extending about 120 ft to the south of the dry well with a width of about 80 ft.

Table 1 lists the matrix characteristics affecting technology cost and performance for this application:

Table 1. Matrix Characteristics Affecting Technology Cost or Performance [1,2,4]

Parameter	Value
Soil Classification	Silts and sands
Clay Content and/or Particle Size Distribution	Upper 15 feet of the Overbank consists predominantly of silts. Silts and sands are discontinuously interlayered throughout the Overbank Deposits.
Depth to Groundwater	The water table was encountered in the silts at approximately 8 ft bgs
Hydraulic conductivity	The transmissivity of the Overbank ranges from 5 to 11 gpd/foot. The conductivity ranges from 2.6x10 ⁻⁵ to 5.2x10 ⁻⁵ cm/sec.
Air permeability	Not available
Porosity	Not available
Presence of NAPLs	Suggested presence of DNAPL
Total organic carbon	Not available
Electrical resistivity of soil	Not available

Table 1. Matrix Characteristics Affecting Technology Cost or Performance [1,2,4] (continued)

TECHNOLOGY SYSTEM DESCRIPTION

TREATMENT TECHNOLOGY

Electrical Resistive Heating (Six-Phase Heating™)

TREATMENT SYSTEM DESCRIPTION AND OPERATION [1,4,5]

The ERH system at the site was operated from May 2000 to December 2001. The initial ERH system consisted of 60 electrodes installed to a depth of 58 feet. The electrodes were placed in hexagonal arrays of 6 electrodes each, with a seventh neutral electrode in the middle of each array. The annular spaces in the boreholes into which the electrodes were installed were packed with steel shot to improve conductivity and increase the effective diameter of the electrodes. In addition, impermeable seals were placed in the annular spaces to prevent hot vapors and liquids from escaping through the boreholes. Each electrode was capable of directing power to three zones in the Overbank: 20-30 ft bgs, 34-44 ft bgs, and 48-58 ft bgs. A 95 kW transformer was used to convert standard three-phase electrical power to six separate phases. The system was monitored using 13 subsurface pressure monitoring points and 8 subsurface thermocouples. The treatment system began operating in May 2000. The initial heating was limited to the bottom interval (45 to 58 ft bgs) to establish a "hot floor" and prevent downward migration of contamination. No information was provided about how long this initial heating was conducted or when heating in other zones began.

During the operation, steam and hot water were observed outside the treatment area. In addition, steam and hot water at the surface of the site were identified as a health and safety hazard at the site. In December 2000, 50 "electrode vents" screened from 25-35 feet bgs were placed along the perimeter of and throughout the treatment area to control the migration of steam and hot water. In addition, because the steam and hot water were contaminated, the treatment area was expanded in May 2001. The additional treatment areas were located along the eastern, southern, and northern portions of the initial treatment area where contaminated steam and hot water had been observed.

Nine electrodes, four "electrode vents", two groundwater monitoring wells, and one thermocouple were installed in the eastern portion of these expanded treatment areas. In the southern portion, 4 electrodes, 11 "electrode vents" screened from 25-35 ft bgs, two groundwater monitoring wells, and two thermocouples were installed. In the northern portion 2 "electrode vents" were installed.

In August 2001, a blower failed, and steam and vapors could not be removed from an unspecified portion of the treatment area. The system was turned off in this area. A new blower was installed in September 2001 and the treatment was restarted.

When the ERH remediation area was expanded, in December 2000 and May 2001, electrodes were placed within close proximity to the security fence that surrounded the perimeter of the ERH remediation area. As a result, an induced voltage was detected during a routine step-and-touch voltage survey on the security fence gate. The voltage on the fence was an induced voltage caused by the fence crossing through the electro magnetic field (EMF) generated by the power transfer between the different phased electrodes. This condition was further enhanced by the concurrent operation of two separate treatment zones at least 100 yards apart, where the same perimeter fence encircled both zones. This configuration caused an increased difference in voltage potential at any point where the fence was broken (e.g., at a gate). This problem was remedied by making sure that the fence line remained unbroken, so that it formed one continuous loop. This corrective action was accomplished by grounding the gates to a wire mesh screen that was buried beneath shallow soils, and attached to both adjacent fence sections. The fence was also grounded on both sides of the site (i.e. separate treatment zones) to help decrease the voltage potential at the fence. Before these two corrective actions were implemented voltage at the fence was as high as 40 V at any point where the fence line was broken, after the fixes the voltages were below 12 V for the remainder of the project.

A soil vapor extraction (SVE) system was used to recover the steam and contaminant vapors from the unsaturated region immediately above the heated region. The initial 53 vapor extraction wells were screened from 5-10 feet bgs. The SVE system was designed to separate the vapor and liquid phases and separately treat the two effluent streams. The vapor treatment system consisted of a heat exchanger/condenser, followed by granular activated carbon and potassium permanganate treatment. Recovered water was discharged to a municipal sewer. As of September 2002, the SVE blower remained in operation, at the request of the DEQ, to collect any remaining vapors generated from the subsurface. Groundwater monitoring is continuing, with data available through June 2002.

TIMELINE

- | | |
|----------------------------------|--|
| • August 1999 | ROD signed for the site |
| • May 2000 | Full-scale operation began |
| • December 2000 | 50 "electrode vents" added |
| • May 2000 | Treatment expanded with the addition of 13 electrodes and 19 "electrode vents" |
| • December 2001 | Remediation completed; ERH system was shut off |
| • December 2001 - September 2002 | Groundwater monitoring performed |

TECHNOLOGY SYSTEM PERFORMANCE

PERFORMANCE OBJECTIVES [2]

The Remedial Action Objectives for this site, specified in the Record of Decision (ROD), were to:

- Prevent and contain migration of separate-phase DNAPL during treatment
- Reduce contaminant groundwater concentrations to levels that indicate DNAPL has been removed or treated

The ROD specified that the primary goal of the action was to remediate DNAPL and that the residual risk to human health and the environment and the need for further remediation would be assessed following

remediation of the DNAPL. No numeric clean-up levels for contaminants were identified in the ROD, therefore the cleanup goals were based on Oregon maximum contaminant levels (MCLs).

TREATMENT PERFORMANCE [1,4]

Figure 1 shows the location of the shallow, intermediate, and deep monitoring wells at the site, relative to the area that was treated. TCE, DCE, and VC concentrations were monitored in the Overbank area and DCE, VC, and benzene concentrations were monitored in the TGA layer. Table 2 shows the maximum groundwater contaminant concentrations before treatment, when the ERH system was shut down (December 2001), and six months later (June 2002). As of December 2001, maximum groundwater contaminant concentrations in the Overbank area had been reduced from 150,000 µg/L to 100 µg/L for TCE, from 370,000 µg/L to 1,300 µg/L for DCE, and from 24,000 µg/L to 50 µg/L for VC. Through June 2002, TCE concentrations decreased to 8.11 µg/L while DCE and VC concentrations were unchanged. The concentrations of all three contaminants were above Oregon MCLs.

Figure 1. Application and Monitoring of ERH at the ICN Pharmaceuticals Site in Portland, Oregon [1]

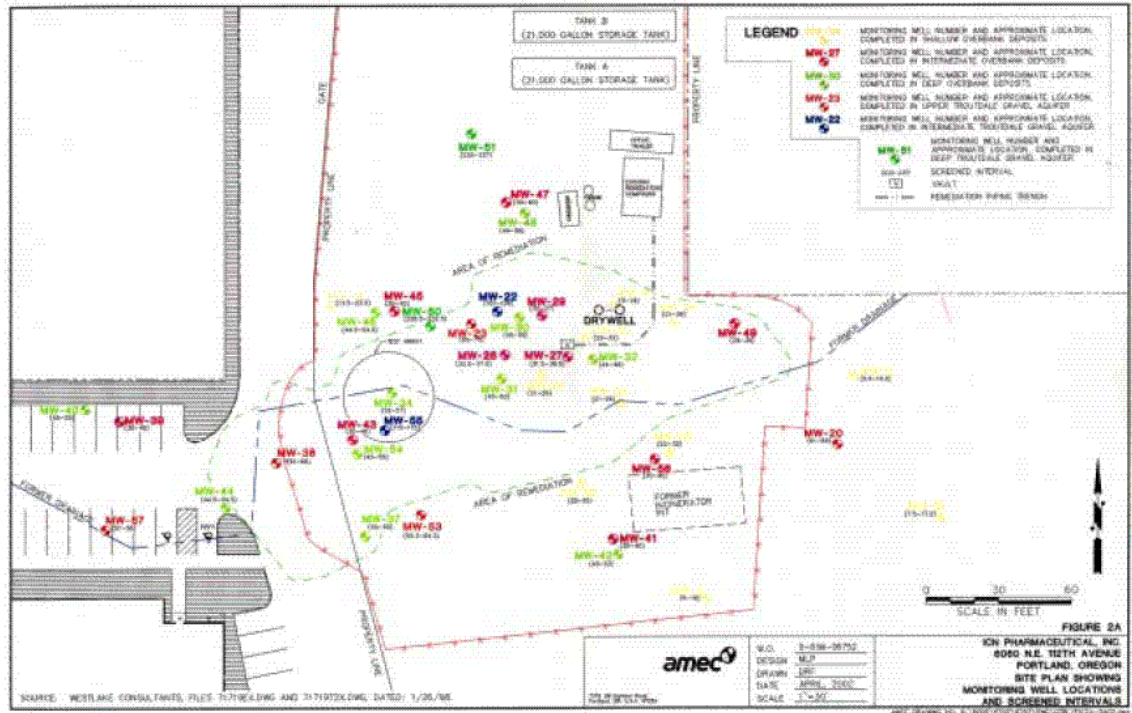


Table 2. ERH Groundwater Monitoring Results, Maximum Concentrations Measured [1,4]

Contaminant	Oregon MCLs (µg/L)	Concentrations in Overbank (µg/L)			Concentrations in TGA (µg/L)		
		Initial Concentrations Before ERH Treatment	December 2001 (when system was shut down)	June 2002 (6 months after system shut down)	Initial Concentrations Before ERH Treatment	December 2001 (when system was shut down)	June 2002 (6 months after system shut down)
TCE	5	150,000	100	8.11	ND	Not available	Not available
DCE	70	370,000	1,300	1,300	1.71	49.5	ND
VC	2	24,000	50	50.5	2.11	ND	NA
Benzene	Not available	51	Not available	Not available	5.98	200	>0.35
Toluene	5,600	Not available	Not available	Not available	16.4	Not available	Not available

Initial contaminant concentrations in the TGA layer were at or below the Oregon MCLs. As of December 2001, the concentrations of DCE and benzene had increased to 49.5 µg/L and 200 µg/L, respectively. VC concentrations decreased from 2.11 µg/L to not detected. According to the vendor, the increase in benzene concentrations indicated a possible compromise in 3 well casings which provided a conduit for contamination migration from the Overbank layer. These wells were abandoned in April 2002. As of June 2002, benzene was detected at levels above the PRG of 0.35 µg/L.

Because dissolved phase VOCs remained above DEQ generic risk-based screening levels at various locations at the site, biosparging was planned for September 2002, as part of the IRAM. Groundwater monitoring at the site is continuing. Information was not provided about whether the biosparging was implemented and any potential results of the biosparging.

Figures 2 through 5 show the concentrations of DCE over time in the source zone (intermediate well MW-28 and deep well MW-31), the treated area outside the source zone (MW-25), and downgradient from the treated area (MW-53). As shown in these figures, DCE concentrations in the source zone treatment area wells decreased following ERH treatment of the source, with the concentrations in the downgradient wells remaining relatively level.

COST OF THE TECHNOLOGY SYSTEM

COST DATA

No cost data were provided for this application.

Figure 2. ICN Site: cis-1,2-DCE Concentrations in Source Zone (MW-28)
 May 1996 - June 2002 (log scale) [1]

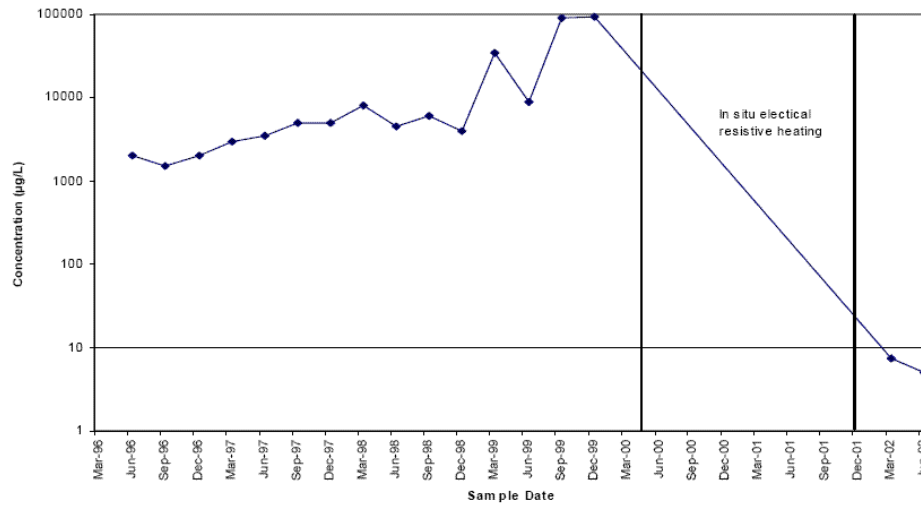


Figure 3. ICN Site: cis-1,2 DCE Concentrations in Source Zone (MW-31)
 May 1996 - June 2002 (log scale) [1]

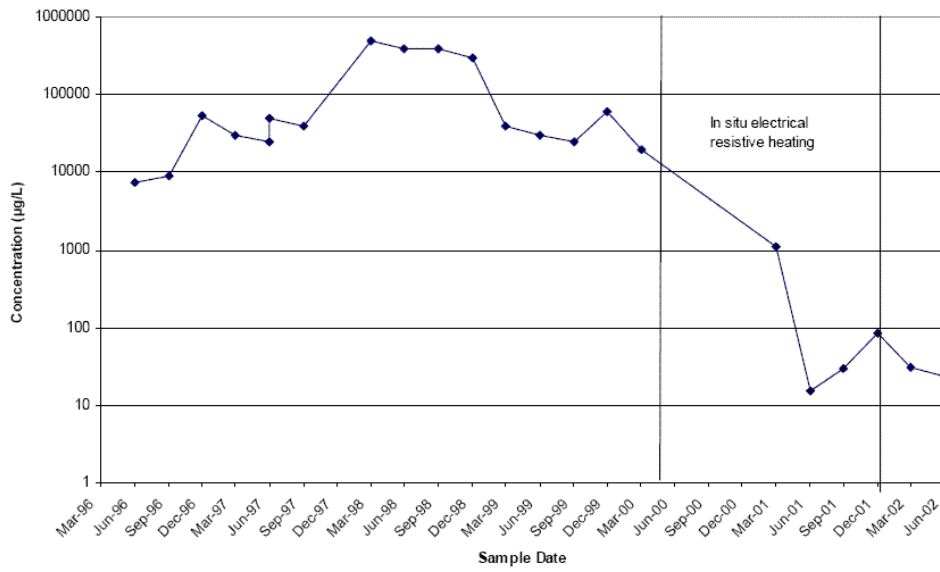


Figure 4. ICN Site: cis-1,2-DCE Concentrations in Treatment Area (MW-25)
 May 1996 - June 2002 (log scale) [1]

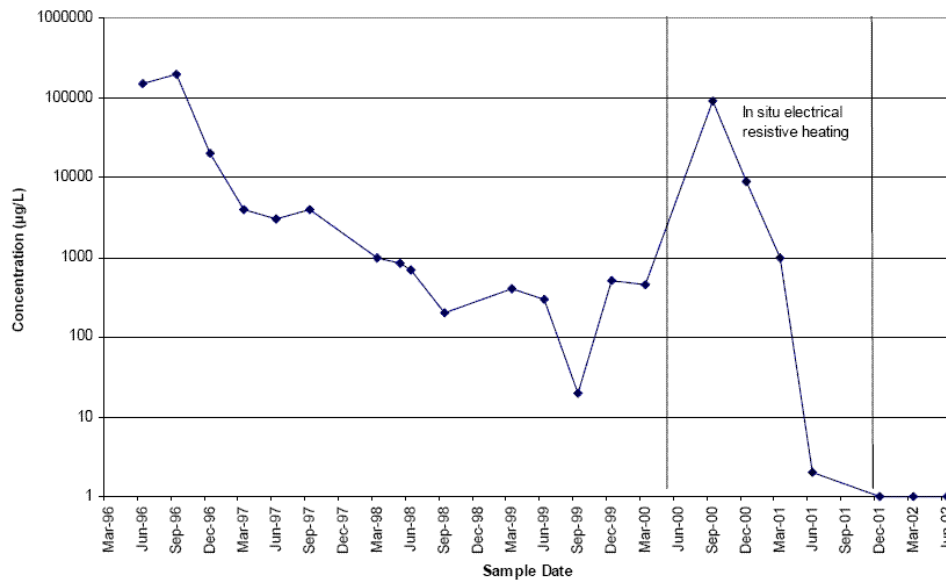
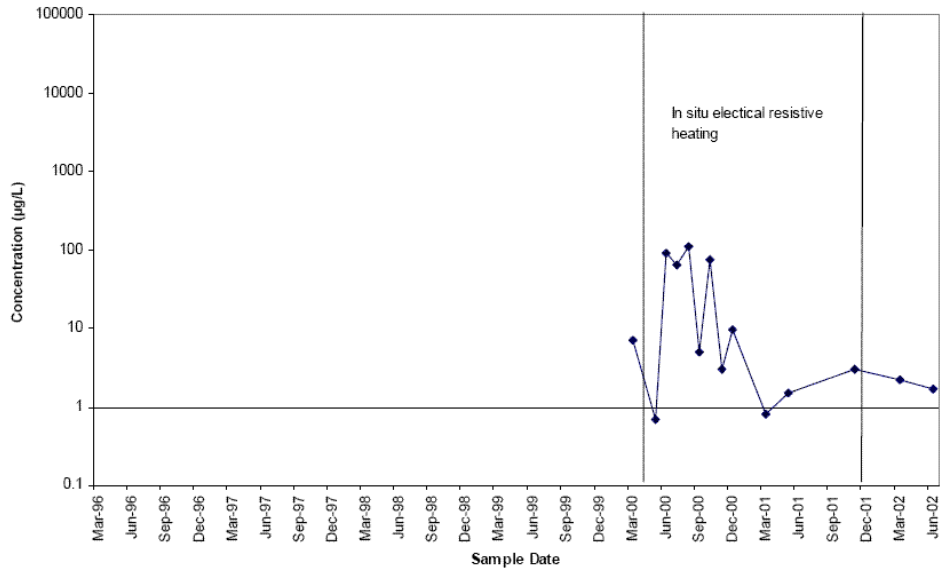


Figure 5. ICN Site: cis-1,2-DCE Concentrations in Downgradient Area (MW-53)
May 1996 - June 2002 ((log scale) [1])



OBSERVATIONS AND LESSONS LEARNED

OBSERVATIONS AND LESSONS LEARNED

ERH reduced concentrations of TCE, DCE, and VE in the source zone by more than 99 percent. However, after 18 months of treatment, contaminant concentrations remained above the state MCLs. Further treatment using biosparging was planned to address these elevated concentrations.

The vendor provided the following observations:

- At some locations, steam pressures built up inside monitoring wells to the extent that some wells vented steam for several hours. The steam moved out laterally along more permeable pathways. Vertical movement upward was inhibited by cooler temperatures within 20 feet of the surface and by less permeable soils, creating a high pressure zone. Removal of a well cap could release the pressure and cause steam and hot water to flash up the well casing. As a solution, existing 3/8-inch diameter vent lines from the electrodes were replaced with larger (1-inch diameter) tubing. These electrode vents were also connected to the vapor extraction system.
- Several modifications to the system were required as a result of the high temperatures achieved during the remediation and modifications needed to handle boiling water. These included replacing PVC in wells with CPVC to minimize heat damage, replacing bentonite with concrete as a seal, and modifications to groundwater sampling using bailers.
- Biological growth increased significantly during heating. The condenser/heat exchanger required frequent cleaning. As a solution, a knockout tank was added to the system to remove some of this material before it entering the heat exchanger. The heat exchanger still required frequent cleaning, but the problem was reduced.

REFERENCES

1. AMEC Earth & Environmental, September 2002. "Quarterly Monitoring and Project Status Report, ICN Pharmaceuticals, Inc. Site, June 2002".
2. Record of Decision, Selected Remedial Action for ICN Pharmaceuticals, Inc. DNAPL Contamination, Multnomah County, Oregon, August 23, 1999.
3. Notice of Selected Environmental Cleanup Method, ICN Pharmaceuticals DNAPL Contamination, September 1, 1999.
4. ITRC Team Case Study Report, ICN Pharmaceuticals Site, Portland, Oregon, Undated.
5. Jennifer Sutter, Oregon DEQ. E-mail comments to James Cummings, EPA. ICN Stray Voltage Discussion. January 5, 2004.