

# Young's Service Station

## Surfactant Flushing—In Situ Chemical Oxidation

**Site Name:** Young's Service Station

**Site Location:** Bixby, Oklahoma

**Technology Used:**

- Surfactant Flushing
- In Situ Chemical Oxidation (ISCO)  
(Fenton's Reagent)

**Regulatory Program:** Oklahoma Corporation Commission (OCC) Petroleum Storage Tank Program

**Remediation Scale:** Full

**Project Duration:** December 2002 to March 2003

**Site Information:** Young's service station was a convenience store that operated from 1950 to 1999. The station had nine underground storage tanks located in three tank pits. A free-phase mixture of gasoline and kerosene was discovered in 2002. The treatment approach involved surfactant flushing to mobilize the non-aqueous phase liquids (NAPL) to extraction wells followed by an oxidant to meet benzene, toluene, ethylbenzene, and xylenes (BTEX) cleanup levels.

**Contaminants:** The contaminants of concern are gasoline and kerosene, and benzene, toluene, ethylbenzene, and xylenes are the principal risk drivers. A 150-ft by 110-ft pool of free product existed at the site. The release produced a 210-ft by 150-ft dissolved-phase groundwater plume.

**Hydrogeology:** The lithology at the site consists of fluvial sands, including fine sand to about 16 ft below ground surface (bgs) followed by medium- to coarse-grained sand below that depth. Groundwater occurs at approximately 9 to 11 ft bgs.

**Project Goals:** The remedial action goals were to remove free product and fuel residuals and attain site-specific target levels (SSTL) of 5.6 mg/L for benzene, 17.9 mg/L for toluene, 5.4

mg/L for ethylbenzene, 101 mg/L total xylenes, and 50 mg/L total petroleum hydrocarbons (TPH). The SSTL of 50 mg/kg for TPH in soil was intended to protect construction workers.

**Cleanup Approach:** Although flowable free product can generally be removed by induced groundwater pumping, which creates a cone of depression that draws the free product into the recovery well, it cannot address residual contamination. Residual contamination was above the site's SSTLs.

Surfactant flushing was selected for the source zone due to the permeable nature of the soil and the fact that the groundwater table serves as a barrier to downward movement. In general, surfactant technology is capable of removing most of the contamination caused by light fuels; however, to ensure that the SSTLs were met, ISCO was added as a polishing step.

The surfactant system (Figure 1) blended disodium dialkyl diphenyloxide disulfonate and sodium dioctylsulfosuccinate without alcohol and injected 1.5 pore volumes (120,000 gallons) of 0.94% (by weight) surfactant. Phase behavior was optimized by adjusting the electrolyte activity with sodium chloride. Eight injection wells and 16 extraction wells were used for the surfactant flushing. The injection wells were approximately 22 ft apart and were 25 to 28 ft from the extraction wells. The wells were constructed using two-inch PVC casing, and they were inserted with a Geoprobe®. The surfactant mixture from the mixing tanks was manifolded to the injection wells, allowing flow rates at individual wells to be adjusted separately. A centrifugal pump was used for the injection.

Submersible pumps were used to pump effluent from the extraction wells to a separator tank where the gasoline/kerosene mixture and the

surfactant solution were allowed to separate. As with all such ultralow, interfacial tension ( $< 0.01$  mN/m) systems, no treatment was required to affect the oil/water separation. Separation occurs spontaneously under these conditions. The fuel from the tank was stored in a product tank for recycling or disposal. The surfactant solution went to an air stripper designed not to generate foam to remove the dissolved fuel. The surfactant solution from the air stripper was stored in a frac tank and recycled during the preparation of additional surfactant mixture. At completion, the remaining surfactant solution was disposed of in the aquifer. There, it acts as an electron donor to stimulate bacterial growth. This procedure greatly reduces remediation time since it eliminates any need to flush residual surfactant from the subsurface. It also reduces waste disposal costs.



Figure 1. Surfactant Tanks

Courtesy Surbec Environmental, LLC

For 24 hours prior to surfactant flushing, recycled water was injected while the extraction system was operating to allow for equilibration of injection and extraction rates. This procedure assists in maintaining hydraulic control of the injected surfactant solution. After a predetermined surfactant volume was injected, the remaining NAPL and surfactant were then removed via recycled water flushing to push the NAPL and surfactant to the extraction wells.

About 158,000 gallons of groundwater was extracted and treated during flushing. The remain-

ing contaminant and surfactant were recovered via recycled water flushing. About 173,500 gallons (two pore volumes) of recycled water were injected during the recycled water-flush phase, and about 250,000 gallons of groundwater were extracted and treated for reuse.

Three additional injection wells were installed for the chemical oxidation treatment. About 112,500 gallons of a 0.6 % by weight chemical-oxidant solution was injected into selected wells for seven days. Thereafter, an additional 7,500 gallons of a 2.0% Fenton's Reagent solution were injected over two days.

Thirty-two soil samples, collected prior to remedial activities, established the baseline soil contamination level. Fifteen soil samples, collected during the remediation, verified progress. Six samples were collected after the operation to confirm that cleanup goals had been met.

Perimeter wells were installed prior to the injection and sampled before and after the operation. Their purpose was to determine whether contamination had escaped the extraction wells and reached new locations.

#### **Project Time Line:**

December 2002—Installed surfactant injection and recovery system  
 January 2003—Began water injection  
 February 1 to February 13, 2003—Conducted surfactant injection and recovery operation  
 February 19 to February 25, 2003—Injected first round of Fenton's Reagent  
 March 4 to March 5, 2003—Injected second round of Fenton's Reagent  
 March 19, 2003—State confirmed sampling

**Project Results:** Initial free-phase gasoline on the water table was as thick as 2.6 ft, based on levels in the monitoring wells, and the free-phase gasoline covered about 11,200 ft<sup>2</sup>. After completing surfactant flushing, the monitoring wells showed no evidence of free product anywhere at the site. No well in the original free product zone showed any sign of free product

after completion of the two flushes, and there was no evidence of free product in soil cores.

Groundwater samples were collected from injection and extraction wells, and from existing wells scattered throughout the contaminant plume. Table 1 shows the groundwater analytical results for three of these wells located in the heart of the original free-product plume. These samples were collected prior to remediation (1/21/03), during surfactant flushing (2/5/03), after completing surfactant flushing (2/17/03), and after the chemical oxidant injection (3/5/03). The groundwater quality improved, as shown in the table, and the contaminant concentrations were below the state SSTL values.

**Sources:**

Surbec Environmental, LLC. Undated. Surfactant-Flushing Followed by Chemical Oxidation:

The Young's Service Station Case Study Bixby, Oklahoma.

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Table 1. Concentrations of BTEX and TPH Before, During, and After Treatment							
Well Number	Sample Date	Groundwater Contaminant Concentrations, mg/L					
		Benzene	Toluene	Ethylbenzene	Xylene	TPH GRO <sup>1</sup>	TPH DRO <sup>2</sup>
OCC SSTLs		5.6	17.9	5.4	101	50	NA
SMW-3	1/21/2003	2.3 ft of apparent free product in monitoring well					
	2/17/2003	2.67	0.145	4.00	12.8	119	158
	3/10/2003	1.29	0.502	3.70	10.7	88	16
MW-10	1/21/2003	1.4 ft of free product in monitoring well					
	2/25/2003	1.25	0.27	3.69	7.24	84	63
	3/19/2003	0.10	0.118	0.092	0.681	6	ND
MW-12	1/21/2003	2.5 ft of free product in monitoring well					
	2/17/2003	3.60	3.12	1.73	29.0	667	50
	3/19/2003	0.475	0.118	0.311	1.79	11	ND

<sup>1</sup> EPA Method 8015B gasoline range organics; <sup>2</sup> EPA Method 8015B diesel range organics