Multi-Phase Extraction Using Fluidized Bed Reactor and Granular Activated Carbon at the Sparks Solvent/Fuel Superfund Site

Site Name: Sparks Solvent/Fuel Superfund Site

Site Location: Sparks, Nevada

Contaminants: MTBE, TPH, PCE, TCE

Media: Groundwater

Technology: Multi-Phase Extraction (MPE) using Fluidized Bed Reactor (FBR) and Granular Activated Carbon (GAC)

Technology Scale: Full

Type of Cleanup: CERCLA

Period of Operation: 1995 to present

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Site History [1,2,6,7]:

The Sparks Solvent/Fuel Site is an industrial area in Sparks, Nevada, which contains a rail yard, a bulk petroleum storage facility, and warehouses. The site is located near the Truckee River, which supplies the majority of the drinking water to the Reno-Sparks metropolitan area. In 1987, a contaminant plume consisting of petroleum hydrocarbons, MTBE, and chlorinated solvents (PCE and TCE) was identified as originating beneath the site, and extending more than one mile from the site. MTBE had been used as an additive to gasoline stored at the site. EPA, in conjunction with the Nevada Division of Environmental Protection, issued an administrative order requiring cleanup of the site.

In 1995, a groundwater extraction and treatment system was installed at the site. The system began operating in late October 1995 and operations were ongoing at the time of this report. The groundwater extraction system includes multi-phase extraction wells designed to provide source control and hydraulic containment. Extracted groundwater is treated using granulated activated carbon (GAC) and fluidized bed bioreactors (FBRs) to aerobically treat MTBE and other petroleum contaminants as well as chlorinated aliphatic solvents. This report focuses on the performance of the FBRs in treating MTBE in the groundwater.

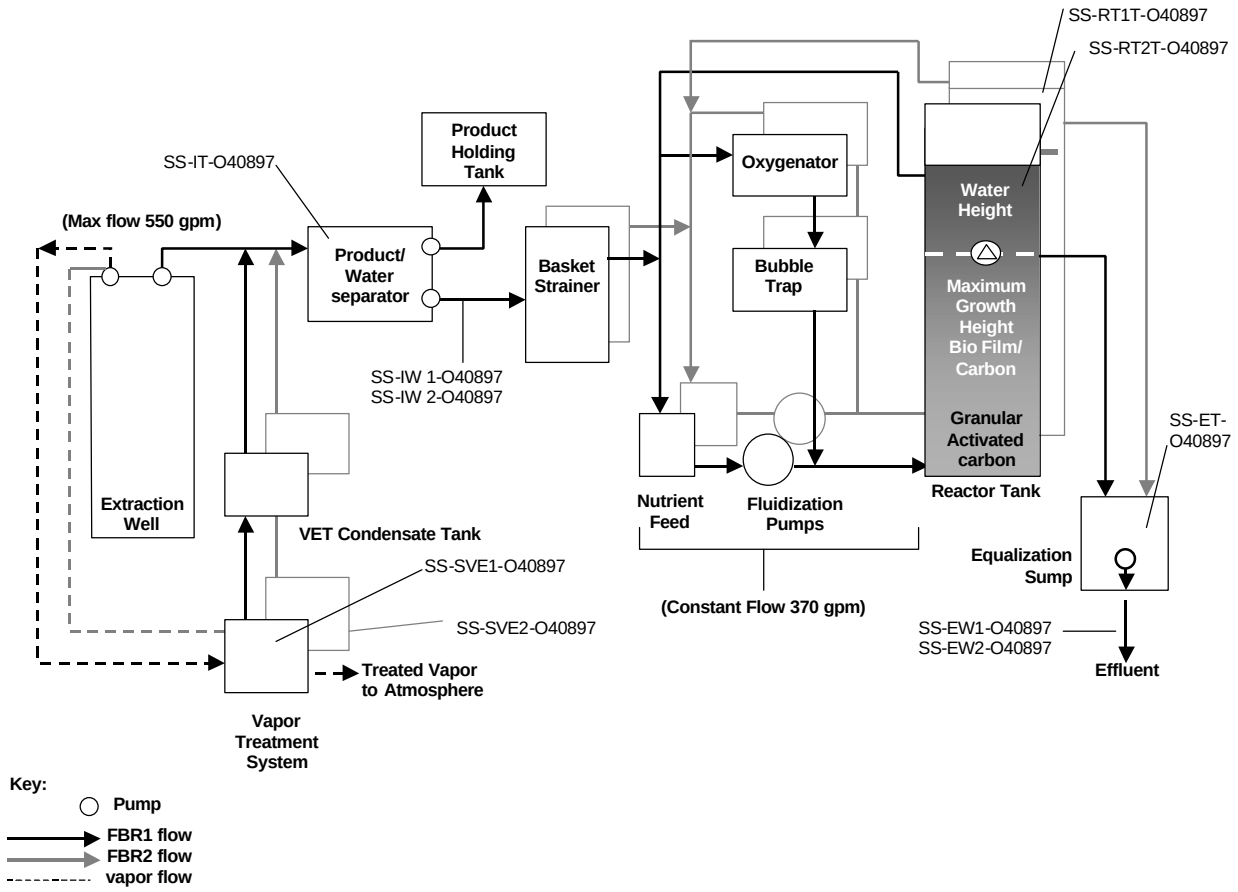
Technology Description [1,6,7]:

The groundwater extraction and treatment system used at the Sparks site is shown in Figure 1. The groundwater extraction system includes 29 multi-phase wells to extract free-product, groundwater, and soil vapor. Groundwater from the extraction wells is directed to a product/water separator where free product is recovered and sent to storage, and separated water is sent through a pretreatment system, then to the FBR system for treatment. Pretreatment includes filtering out large material using a basket filter; mixing in recycled water from the reactor and adding nutrients, as needed; then mixing in additional recycled water from the reactor tank that has been oxygenated and “de-bubbled”. Soil vapor from the extraction wells is sent to a vapor treatment unit (condenser), then to a thermal oxidizer (not shown) prior to release to the atmosphere. Condensate is collected in a holding tank, then fed back to the product/water separator.

The groundwater treatment system includes two U.S. Filter/Envirex GAC FBR reactors (FBRs) operated in parallel. The design for the treatment system capacity (total design flow is 550 gpm) was based on contaminant transport modeling performed during the conceptual design effort. The design assumed influent concentrations as follows - MTBE of 600 ug/L, BTEX constituents ranging from 108 ug/L to 1,272 ug/L, and PCE and TCE of 7.6 ug/L and 42 ug/L, respectively.

Each reactor tank is filled with GAC, which serves as the growth media for the biomass, forming a biofilm at the top of the tank. Influent water enters the bottom of the reactor tank and flows upward through the GAC/biofilm substrate where organic compounds are absorbed and degraded. As described above, water from the reactor (approximately 60%) is recycled during the pretreatment process. The remaining water from the reactor flows to an equalization tank, and then released to an abandoned gravel mine.

Figure 1. Treatment System at the Sparks Solvent/Fuel Site
Modified from [1]



Technology Performance [1,2,3,6,7]:

Performance data for the FBR system at the Sparks site are available for the first 650 days of operation (through August 1997). Figure 2 presents data on MTBE removal efficiency for each reactor by days of operation. Figure 3 presents MTBE concentration data by days of operation. Figure 4 presents data on total system flow rate and MTBE removal efficiency for the treatment system by days of operation.

At the early portion of system operation, MTBE removal efficiencies were greater than 90%. However, removal efficiencies began to sharply decrease over the next several weeks, falling to less than 10% after six weeks of operation. The initial removal was attributed to adsorption rather than biodegradation. MTBE removal efficiencies continued to be below 25% in both reactors. To accelerate MTBE degradation, 20 gallons of a GAC inoculum were added to one of the reactors (FBR1) in April 1996 (day 150). The GAC inoculum was obtained from an FBR in North Carolina and contained MTBE-degrading cultures. As shown in Figure 2, shortly after the inoculation, the removal efficiency in the reactor increased to about 40%. The removal efficiency continued to increase over the next five months to about 75%. For the reactor that did not receive the inoculum, the removal efficiency continued to remain low for another month, then began increasing to similar levels as the reactor that had received the inoculum. According to U.S Filter/Envirex, MTBE degradation activity can develop on its own. Therefore, the trend observed in FBR2 was attributed to a lag period for induction of MTBE degraders.

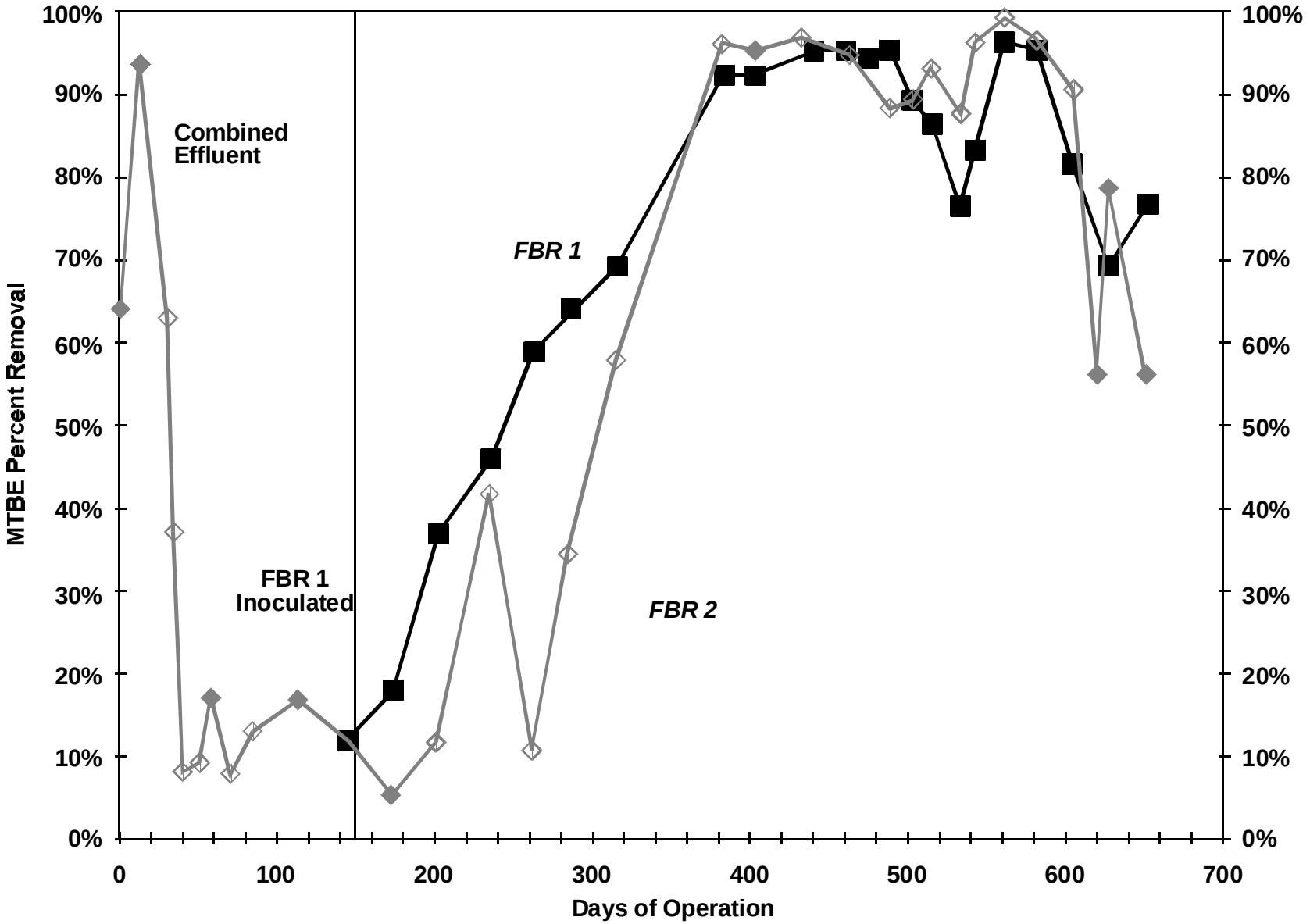


Figure 2. MTBE Removal for FBR1 and FBR2 at Sparks Solvent/Fuel Site [7]

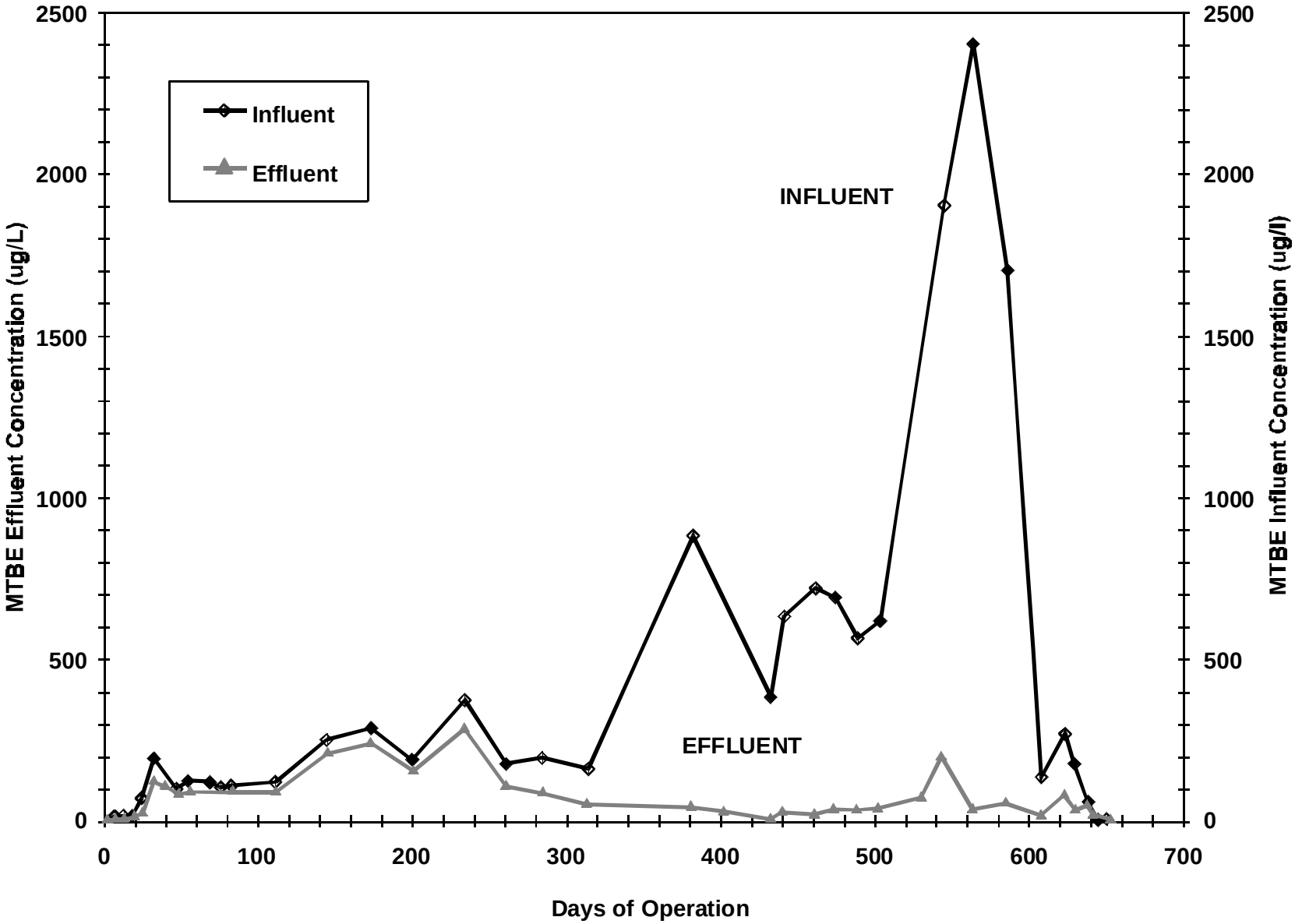


Figure 3. MTBE Influent and Effluent Concentrations at Sparks Solvent/Fuel Site [7]

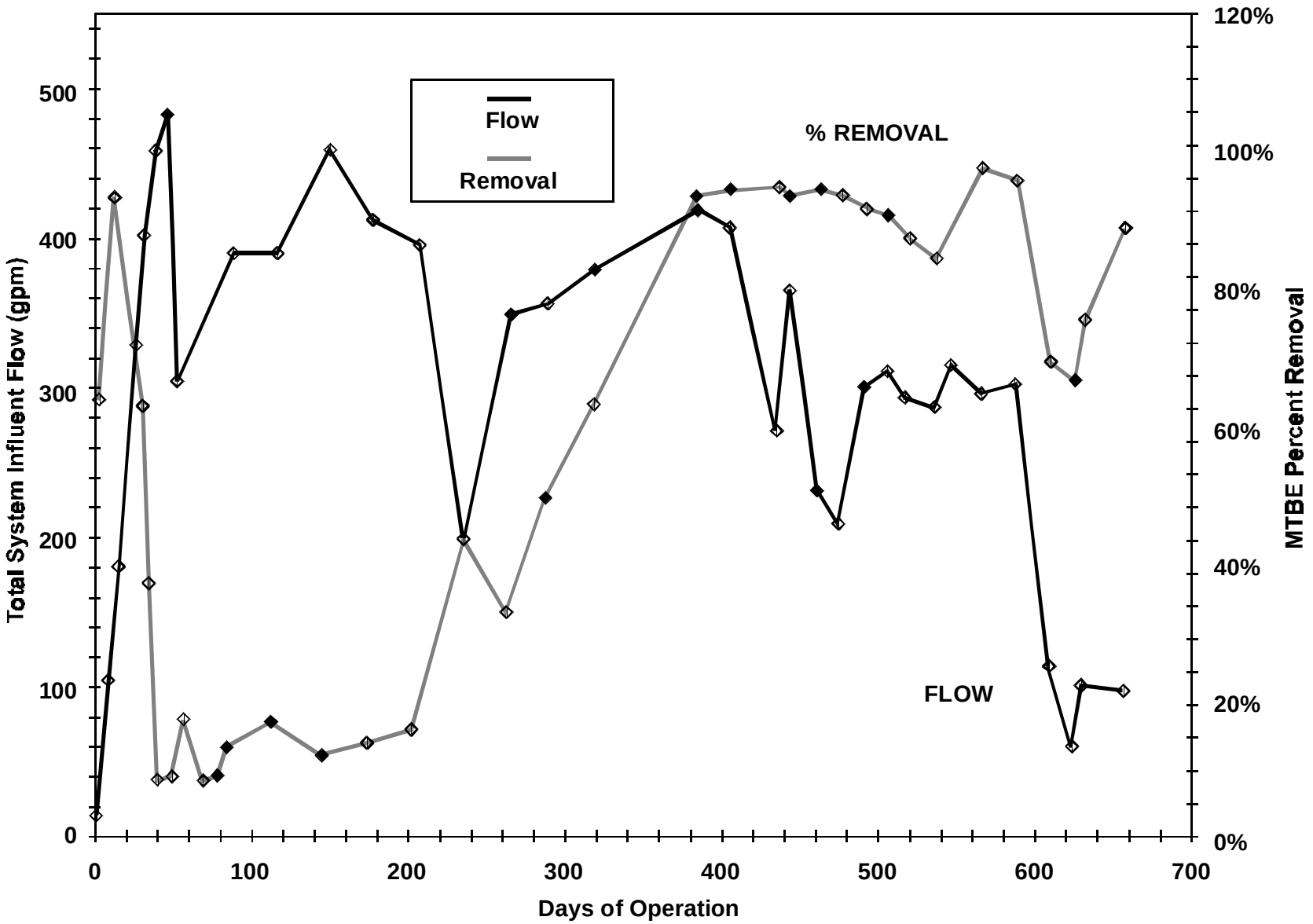


Figure 4. MTBE Removal and Flow at Sparks Solvent/Fuel Site [7]

During the first 320 days of operation (until MTBE removal efficiencies had increased and remained above 50%), groundwater extraction wells with concentrations of MTBE greater than 2,000 ug/L (high-MTBE wells) were not operated. As shown in Figure 3, MTBE influent concentrations did not exceed 400 ug/L during this period. Between days 320 and 530, groundwater extraction included "high concentration" MTBE wells, and the influent MTBE concentrations increased, reaching a peak of 2,400 ug/L on day 530. Between days 320 and 530, the MTBE removal efficiencies in both reactors was consistently above 90%.

Between days 530 and 600, there was a sharp decrease in influent MTBE concentrations, to 10 ug/L, and decrease in removal efficiency to about 70% in FBR1 and 55% in FBR2. The decreases were attributed in part to the results of a flooding event on day 430 (January 1, 1997), which impacted groundwater conditions at the site (raising the water table) and damaged four of the highest flow pumps. System flow rates were reduced from 400 gpm to 280 gpm. System flow rates remained relatively constant from January to June 1997 (day 430 to 600), when wells were taken off-line for rehabilitation, resulting in a decrease in flow rate to less than 100 gpm.

Between days 600 and 650 (July and August 1997), mass loading and influent MTBE concentrations had dropped. MTBE influent concentrations decreased from about 300 ug/L to below 10 ug/L. A corresponding decrease in the system MTBE removal efficiency to below about 70% was observed (Figure 4). According to CDM, this indicated that the relatively lower mass loading of the reactors reduced the MTBE removal efficiency.

Data for August 1997 (day 650) show an increase in the system MTBE removal efficiency to about 90%. The MTBE concentrations are below10 ug/L in the effluent from the FBR system.

Data for BTEX, TPH, and chlorinated solvents was provided for the first year of operation. Data for PCE and TCE showed an overall removal rate of approximately 50%. According to CDM, the likely biodegradation mechanisms were anaerobic dechlorination for PCE and aerobic cometabolism for TCE, with BTEX serving as the primary energy substrate. However, the relative role of volatilization versus biodegradation could not be established as no abiotic control test was conducted. The overall removal rate for BTEX was >99% and for TPH 78%.

In 1997, EPA conducted an evaluation of the groundwater treatment system at the Sparks Solvent/Fuel Site to evaluate the efficiency of the FBRs in removing contaminants from extracted groundwater including MTBE, BTEX, TCE, and PCE. EPA directed the Superfund Technical Assessment and Response Team (START) to perform the evaluation. The results are presented in Appendix A of this report.

Technology Cost:

No cost data are available for this application.

Observations and Lessons Learned [6,7]:

According to CDM and U.S. Filter/Envirex, the following observations can be made about the performance of GAC FBR in treating MTBE from extracted groundwater:

- GAC FBR can achieve high removal rates for MTBE as a result of aerobic degradation
- Seed carbon from reactors previously acclimated to MTBE will accelerate removal in the GAC FBR
- Naturally occurring bacteria can be acclimated to remove MTBE in the GAC FBR
- Mass loading of the reactors will affect MTBE removal rates

According to CDM and U.S. Filter/Envirex, the initial increase in MTBE removal efficiencies to 90% followed by the sharp decrease to <10% indicated that the MTBE initially was being removed by adsorption by the GAC rather than by biodegradation. Once the adsorption capacity of the GAC had been reached, the MTBE removal efficiencies decreased rapidly.

References:

1. U.S. Environmental Protection Agency, Region 9, Superfund Technical Assessment and Response Team (prepared by Ecology and Environment, Inc.). *Sparks Solvent/Fuel Site Groundwater Bioremediation System Evaluation Sparks, Nevada*. July 1997.

2. U.S. Environmental Protection Agency, National Risk Management Research Laboratory (prepared by Dynamac Corporation). *Assessment of the Environmental Consequences of Oxygenated Fuels*. Draft, October 1997.

3. Division of Environmental Chemistry. *Division of Environmental Chemistry Preprints of Extended Abstracts*. April 1997.

4. Record of telephone conversation, Steve Michener, Tetra Tech EM Inc. and Dirk Cochrum, Camp, Dresser and McKee Inc. Obtain Information on Sparks, NV site. October 14, 1999.

5. Record of telephone conversation, Steve Michener, Tetra Tech EM Inc. and Eric Noack, NV Division of Environmental Protection. Obtain Information on Sparks, NV site. October 12, 1999.

6. Michael E. Miller, et al, Bioreator Treatment of MTBE and TCE in Contaminated Groundwater. Undated.

7. Jacquelin Buratovich-Collins, CDM Engineers & Constructors Inc, and Robert D. Hines, U.S. Filter/Envirex, GAC-Fluidized Bed Reator Aerobic Biological Treatment of MTBE in Contaminated Groundwater.

APPENDIX A – RESULTS OF START TESTING

The results of the START evaluation, conducted in April 1997, are summarized below.

The process parameters measured during the START testing in April 1997 are shown in Table 1. The total influent and effluent flow of the system was 295 gpm. The recycle ratio was 1 to 1.7 for the North reactor and 1 to 1.3 for the South reactor. The flow rate within the FBR system is maintained at a constant rate of 370 gpm.

Table 1. Reactor Parameters in April 1997 (average readings before and after sampling) [1]

Process parameter	North Reactor (gpm)	South Reactor (gpm)	Design Parameters (gpm)
Influent Flow Rate[1]	141	156	0-370
Recycler Flow Rate[2]	281	254	0-370
Pressurized Bubble Chamber Flow Rate	107	107	not specified
Reactor Flow Rate	381	361	370
Dissolved Oxygen - Influent Water	0.0 ug/L	0.0 ug/L	0.0 ug/L
Dissolved Oxygen - Effluent Water After Oxygenation	2.5 ug/L	2.5 ug/L	2.5 ug/L

1 - Flow rate of water out of the product/water separator
2 - Flow rate prior to introduction of oxygenated water; includes influent and recycled water

Sampling for the START evaluation was conducted on April 8, 1997. Samples were collected from various process locations, shown in Figure 1, and analyzed for MTBE, total hydrocarbons, and other organics. The results are summarized in Table 2. The efficiency of the FBR system and each of the reactors is shown in Table 3. The efficiency of the entire system was determined by calculating the reduction in contaminant concentrations between the product/water separator (influent tank) and the effluent from the reactor. The efficiency of each reactor was determined by calculating the reduction in contaminant concentrations between the estimated reactor were not collected intake and reactor effluent. Because it was not possible to sample the water stream entering the reactor, the contaminant concentrations in the stream were estimated by determining the amount of influent water that was mixed with recycled effluent water (reported as a recyle ratio and as % estimated volume).

As shown in Table 3, the removal efficiency of the system during the START evaluation was 88.5% for MTBE and ranged from 85 to 99.5% for aromatics and short chained hydrocarbons (purgeable). The removal efficiency for the system for chlorinated and long chained hydrocarbons (extractables) ranged from 8 to 60%. As shown in Table 2, influent concentrations of MTBE of 463 to 480 ug/L were reduced to 52 ug/L in the effluent.

In addition, in March and April 1997, CDM collected and analyzed samples from the influent and effluent sampling ports. The results, shown in Table 2, show MTBE influent concentrations of 610-620 ug/L and effluent concentrations of 52-90 ug/L.

Table 2. Summary of Data from April 8, 1997 START Sampling and from CDM for March and April 1997 (ug/L) [1]

Sample Location	Sample ID	MTBE	Total Purge-able Hydrocarbons	Total Extractractable Hydrocarbons	Ben-zene	Tol-uene	Xy-lenes	Tricloro-fluoro-methane	TCE	TCA	1,2 DCE	cis 1,2 DCE	Ethyl ben-zene	Ace-tone
START DATA														
Influent Tank	SS-IT-040897	480	750	1,600	122	ND	9.5	15.7	7.8	13	3	3	8.3	ND
Influent Pipe	SS-IW1-040897	463	650	2,000	110	ND	9.1	14.9	7.7	13.2	3	3	8.0	ND
Influent Pipe (duplicate)	SS-IW2-040897	465	670	2,400	109	ND	9.1	14.4	7.7	13.1	3	3	8.1	ND
SVE condensate water - unit 1	SS-SVE1-040897	14	ND	36,000	1	ND	ND	ND	ND	ND	ND	ND	ND	29.8
SVE condensate water - unit 2	SS-SVE2-040897	ND	ND	1,100	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
North reactor tank (effluent)	SS-RT1T-040897	54	ND	710	ND	ND	ND	15.5	5.4	12.5	ND	ND	ND	ND
South reactor tank (effluent)	SS-RT2T-040897	54	ND	760	ND	ND	ND	14.8	5.7	12.8	ND	ND	ND	ND
Effluent holding tank	SS-ET-040897	55	ND	850	ND	ND	ND	8.4	5.0	9.9	ND	ND	ND	ND
Effluent pipe	SS-EW1-040897	52	ND	660	ND	ND	ND	8.7	5.2	11.1	ND	ND	ND	ND
Effluent pipe (duplicate)	SS-EW2-040897	61	ND	690	ND	ND	ND	10.3	6.1	12.7	ND	ND	ND	ND
CDM DATA														
CDM influent (March)	5832-IN-WS	610	420	2,300	100	ND	14.1	12	9.4	14	ND	3.6	7.3	NA
CDM influent (April)	5832-IN-WS	620	280	220	64	ND	4.0	10	7.5	10	ND	3.5	5.3	NA
CDM effluent (March)	5832-ED-WS	55	ND	580	ND	ND	ND	7.7	6	11	ND	ND	ND	NA
CDM effluent (April)	5832-ED-WS	90	ND	100	ND	ND	ND	1.2	2.7	3.8	ND	ND	ND	NA

Table 3. FBR System Efficiency (% Reduction) [1]

Compound	FBR System	North Reactor (recycle ratio 1:1.7 - 37% influent; 63% effluent)	South Reactor (recycle ratio 1:1.3 - 43% influent; 57% effluent)
MTBE	88.5	74.0	75.5
Purgeable petroleum hydrocarbons	91	90.5	91.5
Extractable petroleum hydrocarbons	57	44	45
Benzene	99.5	99	99
Xylenes	94.5	86.5	88
Ethylbenzene	94	85	86.5
Trichlorofluoromethane	39.5	0	0
TCE	28	13.5	13
PCE	8.5	2	1
DCE	8.5	66.5	70