

Technology Demonstration Report
PolyGuard®
Guardian Environmental Technologies, Inc.

Prepared for

The Massachusetts Strategic

Envirotechnology Partnership

STEP

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Preface

The STEP technology assessment process is designed to identify those technologies that will support the economic and environmental/energy goals of the Commonwealth of Massachusetts and may benefit from STEP assistance. The process is meant to be one of screening, in which technologies are evaluated by independent technical specialists. Recommendation from this process does not constitute an endorsement of the technology or of the absolute validity of the technology. Rather, STEP technical assessments attest only that, through the screening process, the reviewers feel there may be benefit to the Commonwealth of Massachusetts.

Project Funding

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Technology Innovation

PolyGuard® is a granular absorption media used to remove hydrocarbon contaminants from liquid and vapor streams. PolyGuard's mode of action depends upon the ability of the active material to selectively absorb molecules with suitable solubility characteristics directly into its internal structure to form a stable, solid solution. Such a mechanism allows PolyGuard to absorb very large quantities of molecules, which have compatible solubility characteristics. Contaminants in water or air waste streams are partitioned into soft or glassy regions of the medium. These regions have a strong affinity for hydrocarbons, chlorinated hydrocarbons and many other non-polar organic compounds. PolyGuard has very little affinity for molecules whose solubility characteristics are very different from those of the active PolyGuard polymer. PolyGuard may not readily absorb inorganic compounds and some organic compounds that have high water solubility from aqueous streams.

Company Description and Projected Market Impact

Guardian Environmental Technologies (GET) is a Connecticut corporation, founded in 1992 by the present majority owner, and has been located in Kent, Connecticut, since that time. The basic technology was developed as a result of the development of families of polymeric absorbents, with a high affinity for hydrocarbons and chlorinated compounds. GET estimates that the total U.S./Worldwide market potential, which uses absorption or adsorption technology, is in excess of \$24 billion, with a predicted continued growth rate in selected market segments of 4% to 6% per year, through 2001. Because the most widely used method of environmental and industrial process water cleanup is carbon adsorption, GET has selected those industries where the use of carbon is most common. Of the leading types of volatile organic compound treatment equipment used for air pollution control, carbon is near the top in order of market share.

Prior Research Results

Lab testing has been performed on PolyGuard with several priority pollutants. Some of these unpublished studies demonstrate that PolyGuard absorbent can absorb more than twice its weight of diesel fuel or home heating fuel. Laboratory studies with iso-octane demonstrated a loading capacity for PolyGuard of greater than 4:1 (grams of contaminant per gram of PolyGuard).

Product Demonstration Objectives

This experimental pilot program was conducted in conjunction with the Commonwealth of Massachusetts Strategic Envirotechnology Partnership (STEP). The primary objectives of this pilot were: i) to demonstrate removal of organic compounds associated with gasoline contaminated ground water utilizing PolyGuard absorbent ii) to quantify the absorption potential of PolyGuard specifically for MTBE in conjunction with other organic contaminants associated with gasoline contaminated ground water, iii) to quantify the absorption potential of PolyGuard for BTEX compounds,

iv) to evaluate the stability of the spent PolyGuard material providing information on disposal alternatives, and v) to monitor the hydraulic performance of PolyGuard under pump and treat remediation operation.

Experimental Methodology

The test demonstration methodology was designed in cooperation with GET and Environmental Compliance Services (ECS, Agawam, MA) the cleanup site operator. The demonstration site was a gasoline release at gas station located in Bellingham Massachusetts with high levels of MTBE and BTEX. Contaminant levels were reported for BTEX and MTBE as 75 and 125 mg/L respectively, prior to initialization of the demonstration. These concentrations decreased during the course of the experiment by a factor of 3 or more and were beyond the control of the site operator. The basic design premise of "Pump and Treat" was established by ECS and system configurations were established based on GET design criteria. The core design consideration used by GET to achieve its goals was a minimum residency time of 15 minutes. PolyGuard vessels were constructed in series to provide the minimum residency time and redundancy to lengthen the period between change outs at operating rates up to 3 GPM. Three PolyGuard system configurations were used at the option of ECS and GET. The design changes were attempts to assess changes in filter bed geometry on system performance.

The pretreatment system developed by ECS included a fractionation tank, diffuser and final post treatment GAC unit. Phase 1 of the pilot was conducted with two standard 110-gallon drums containing 11 cubic feet each or 418 pounds of PolyGuard (GET 1 and 2). The PolyGuard vessels constructed in Phase 2 included two 56-gallon fiberglass columns, 14" in diameter by 120" in length (Nick 1 and 2). During this test one column was rebedded with fresh material resulting in three reported columns (Nick 3). Phase 3 included eight absorber vessels constructed using 8" diameter by 120" long schedule 40 PVC pipe (ECS 1-8). Phase 3 operation included the Phase 2 vessels preceding the Phase 3 vessels, although the phase 2 vessels were not freshly rebedded at the beginning of Phase 3. The pump and treat system was fully?

Water samples were taken on the influent and effluent side of each set of contactors and the effluent side of the GAC filter beds when used. Sampling frequency was required to follow the minimum specified by MA DEP. It was recommended that samples be taken at a minimum of once every 5 days. Water samples were analyzed using standard EPA methods for BTEX and MTBE.

Results

Results from this pilot demonstration are reported for the period between August 25, 1997 and December 24, 1998. During this period treated groundwater volume and contaminant concentrations were monitored to assess the removal efficiency and mass removal capacity of PolyGuard for BTEX and MTBE. The data from this period of monitoring is segregated into three phases, which reflect three distinct operating conditions on the site. In reporting the results from these tests, deviations from the original system configuration provide somewhat less detailed information on the properties of PolyGuard. These data, however, indicate trends that may be useful for developing additional field models. In this analysis the data are better described as qualitative, since the planned replication operating conditions do not allow for controlled statistical comparisons.

Phase 1 of the pilot demonstration operated between August 25, 1997 and September 6, 1997. Mass flow to the system was 22,203 gallons. Average flow was 0.98 GPM over the duration of the test. Average MTBE influent concentration over the sampling period was 263 mg/L (s=147 mg/L, n=5). Removal efficiency for MTBE decreased during the course of the test from 100% to 71% at the close. Average column mass removal efficiency during this test was 56% and 78% for GET 1 and GET 2, respectively. The mass loading to the PolyGuard material was approximately 15% on a weight per weight basis. Average BTEX influent concentration over the sampling period was 36 mg/L (s=25.3 mg/L, n=5). Average mass removal efficiency during this test was 95% and 100% for GET 1 and GET 2, respectively. BTEX mass loading based on this method totaled 5.2 lbs. of which the PolyGuard columns removed 100%. The mass loading was approximately 1% on a weight per weight basis because of premature termination of testing. It can safely be assumed that BTEX capacity would have been at or near predicted levels.

Phase 2 of the pilot demonstration operated between October 27, 1997 and December 3, 1997. Mass flow to the system was 40,707 gallons. Average flow of 0.63 GPM over the duration of the test. Average MTBE influent concentration over the sampling period was 85.6 mg/L (24.8 mg/L, n=9). Removal efficiency for MTBE decreased during the course of the test from 100% to 21%. Average column mass removal efficiency during this test was 42% (n=6), 58% (n=7) and 44% (n=1) for Nick 1, 2 and 3, respectively. MTBE mass loading during this test period totaled 28.1 lbs. of which the PolyGuard columns removed 15.1 lbs. The mass loading to the PolyGuard material was approximately 4% on a weight per weight basis. Average BTEX influent concentration over the sampling period was 30.3 mg/L (s=10.8 mg/L, n=9). Removal efficiency for BTEX decreased minimally and less than that observed for MTBE during the course of the test. Average column removal efficiency during this test was 98 to 100% for all three Nickerson columns. On one instance, November 18th, removal efficiency dropped to 81% in Nick 2. However, it is unclear whether an analytical error occurred on that data rendering a sample (date) concentration bias. Mass removal was calculated as previously

described. BTEX mass loading based on this method totaled 10.35 lbs. of which the PolyGuard columns removed 99.6%. The GAC column removed BTEX, which passed through the Nickerson columns. The mass loading to the PolyGuard material was approximately 3% on a weight per weight basis.

Phase 3 of the pilot demonstration was implemented June 17, 1998 and data is reported up until August 31, 1998. Total mass flow pumped though the system during this test was 51,951 gallon with an average flow of 0.44 GPM over the duration of the test. Average MTBE influent concentration over the sampling period was 38.3 mg/L (s=14.0 mg/L, n=11). Removal efficiency for MTBE decreased during the course of the test from 100% to 39%. The vessels from Phase 2 used in Phase 3 did not remove any appreciable amounts of MTBE during this test. Average system mass removal efficiency during this test was 82%. MTBE mass loading totaled 14.9 lbs. of which the ECS PolyGuard columns removed 13.1 lbs. The mass loading to the PolyGuard material in the ECS columns ranged from 1 to 7% on a weight per weight basis. Average BTEX influent concentration over the sampling period was 14.6 mg/L (s=7.0 mg/L, n=11). Removal efficiency for BTEX remained at 100% during the course of the test. Average column mass removal efficiency during this test ranged from 3% to 100%. BTEX mass loading based on this method totaled 6.82 lbs. of which the Nickerson columns removed 6.81 lbs. Based on the useful data, apart from the non-detects, it is estimated that the ECS columns removed 0.01 lbs. of BTEX. The mass loading to the PolyGuard material in the system was approximately 1% on a weight per weight basis. The Nickerson columns had a slightly higher mass-loading rate of 3% on a weight per weight basis.

System performance demonstrated removal rates for BTEX up to 100% during the operation of each of the phases. The removal rates for MTBE were lower ranging from 3% to 100% for any individual column during each interval, while average system removal was 91, 41 and 82% for Phases 1, 2, and 3, respectively.

Under the study operating conditions system hydraulic performance did not present any limitations to use. A qualitative assessment of the hydraulic performance suggests that under the operating rates observed in this study, the system configuration and system construction, PolyGuard is capable of handling flows as high as 2 GPM or higher without significant effort to increase operating pressures.

No information regarding product stability or disposal costs was available from these studies. Disposal costs reported by GET indicate approximate costs of \$275 per 55-gallon drum for hazardous material disposal and \$89 per 55-gallon drum for non-hazardous material disposal. Proposed disposal may include fuel blending and or incineration.

A preliminary cost analysis was performed to assess the per pound cost to remove MTBE using PolyGuard. This analysis was made using total estimated contaminant removed and material cost of PolyGuard. Operational and capital cost was excluded from this analysis because under piloting conditions these costs do not reflect full commercial deployment of the technology. Cost per pound of MTBE removed with PolyGuard for all three phases ranged from \$49 to \$59 per pound of MTBE for that portion of the test for which useable data was generated. Lowest costs were realized during Phase 1 at \$59/lb and the highest mass-loading rate. These data suggest that PolyGuard may be cost competitive with GAC under conditions of high MTBE mass loading and that further cost analysis should be performed under optimized PolyGuard systems developed in the future.

Conclusions

In this pilot, one of the target contaminant was MTBE, which has a lower affinity for PolyGuard than other non-polar contaminants. As such, an absorption capacity 75% for MTBE was used as a goal in the design calculations. The absorption "rate" was estimated at 60%. A capacity of 150% was calculated for the BTEX portions of the influent with a removal rate of 99%.

The three tests conducted during this study reflect different operating conditions for the use of PolyGuard. The first test had the highest average flow rate, at 0.98 GPM and the highest average influent concentrations for MTBE, 263 mg/L. Under these conditions, PolyGuard demonstrated the highest absorption capacity of 15%. During this test removal efficiency was 93% on a mass basis. The second test had an average flow rate of 0.63 GPM and an average influent concentration of 86 mg/L MTBE. System absorption capacity for MTBE was 4% on a mass basis. The MTBE removal efficiency of this PolyGuard system was the lowest at 41%. Test three had the lowest average flow rate and influent MTBE concentration, at 0.48 GPM and 38 mg/L, respectively. In all test cases the PolyGuard system never reached capacity and continued to remove MTBE at 71%, 54% and 39% efficiency for tests 1, 2, and 3 respectively. Due to constraints placed on the site operator for discharge limits all the tests were ended before capacity of the system was reached. Discharge limits were exceeded due to site operator's failure to install specified system components (GAC). Therefore this Phase of the test, which could have been successfully concluded with reliable data, was prematurely and arbitrarily terminated by operator.)

With respect to BTEX removal, all three tests demonstrated excellent BTEX removal. Influent concentrations did not vary as much between tests with average influent concentrations of 36, 33, and 15 mg/L BTEX for tests 1, 2, and 3 respectively. Capacity for BTEX was never reached since system absorption of BTEX was 100% in each test. Due to the solubility characteristics of the BTEX constituents relative to MTBE, high absorption to PolyGuard was expected. Changes in system configuration, operating flow rates and influent concentrations add additional uncertainty to the results of these tests. Further, the applicability of the performance characteristics to operating conditions not defined by those in these studies is limited.

Data from this study suggests that PolyGuard has greater potential for MTBE removal when concentrations are greater than 100 mg/L. These data also indicate that, except with virgin PolyGuard, removal efficiencies are not suitable for treatment of MTBE in aqueous systems to concentrations at or near drinking water standards. This feature tends to suggest that PolyGuard is useful as a bulk contaminant remover and not a final polishing agent. It is useful to identify costs associated with remediation technologies. The USEPA provides guidance for documenting and cost and performance information for remediation projects under a similar title (USEPA, 1998). However, under piloting conditions it is difficult to develop accurate cost analysis for full deployment of a commercial application. The protocol for this demonstration was not developed with these guidelines and therefore does not conform to those standards. Cost data was not made readily available for this report and tests conducted under this study were not carried out to completion. Therefore capacity data do not reflect the ultimate capacity of PolyGuard or the minimum cost associated with contaminant removal. Because the cost analysis data is incomplete and true operations and maintenance data could not be collected in this first demonstration of PolyGuard, STEP cannot confirm or disprove GET's competitive advantage claims when compared to GAC systems, the current industry standard.

Further studies are recommended based on inconclusive results from this study. Foremost, isotherm analysis under a variety of operating conditions will assist in quantifying absorption rates, especially where concentration varies. Furthermore, investigations of complex solutions under controlled conditions may assist in understanding competitive absorption phenomena hypothesized herein. Additional investigation into system fouling and microbial activity is also recommended since they are major factors in GAC systems. Field studies under alternative conditions to those reported in this study may assist in developing full scale operating parameters, but may be less useful for broader applicability to diverse sets of operating conditions.

The potential strengths and weaknesses of PolyGuard compared with GAC should also be further explored. The potential for cost savings may be an advantage for PolyGuard. Full life cycle costs, including capital costs, O&M, and disposal need to be more fully characterized for operational systems, following EPA methodologies. The inability to regenerate PolyGuard and requirement that it is disposed of as hazardous waste are potential drawbacks. Disposal of carbon demonstrates the same problems. Regenerating carbon still produces contaminants that must be dealt with. These are significant costs and cannot be ignored. Disposing of PolyGuard, even in the case of BTEX is a significant cost saving over carbon. Even taking disposal costs of PG + disposal, you have better economies than GAC + regeneration, for almost any compound.

Liquid Phase Comparison Calculation

Input Data

System Flow Rate, gpm	100.0
Average Contamination Loading, ppm	2000.0
Total Daily Flow, gpd:	144000
Daily Contamination Loading, lbs.:	2400.00
Desired Residence Time, minutes =	10
Media Bed Size, gallons	15,000
Media Bed Size, ft ³	2,000
Media bed weight, lbs:	
PolyGuard	36,000
Carbon	58,000
Media Bed Absorption Capacity, lbs/lb,	
PolyGuard	175%
Carbon	7.0%
Bed Absorption Capacity, lbs:	
PolyGuard	63,000
Carbon	4,060
Media Bed Life-Days	
PolyGuard	26.25
Carbon	1.69
Total Flow Treated, gallons	
PolyGuard	3,780,000
Carbon	243,600
Cost to treat 1 gallon	
PolyGuard =	\$0.087
Carbon =	\$0.226

Cost to treat one pound

Cost to treat per pound w/ PolyGuard	\$4.99
Cost to treat per pound w/carbon	\$13.57
Maximum Disposal Cost per pound	\$0.87
Maximum Disposal Cost per gallon treated	\$0.01
Disposal Costs	\$54,545

Disposal Costs

Pickup company	TBD
Cost per 55 gal drum disposal (incineration)	\$275
Pickup fee per drum (6+ drums)	\$25
Pickup fee (less than 6) one time cost	\$55

Weight spent material/55 gallon drum # 347