

METALS TREATMENT: SIMPLE AND EFFECTIVE!

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EXECUTIVE SUMMARY/ABSTRACT

During an investigation of an electronics manufacturing facility located in a predominantly residential area of Morris County, New Jersey, metals contamination was identified in the groundwater beneath the site. The site was approximately 15.5 acres and included a pond classified as State Open Water, and a low-lying area, which was designated as freshwater wetlands. The investigation was performed pursuant to New Jersey's Industrial Site Recovery Act (ISRA). Due to its proximity to residential properties, its relationship with the community, and its on-site use of groundwater as a potable water supply, the facility's objective was to quickly and efficiently remediate the groundwater to New Jersey's groundwater quality standards (GWQS).

To address the contamination, an aggressive delineation program and innovative remediation technology were implemented at the site. The remediation was initiated and completed within a seven (7) month period utilizing a pilot system consisting of groundwater recovery and treatment using Forager™ Sponge Technology under a temporary permit-by-rule issued by the New Jersey Department of Environmental Protection (NJDEP). Subsequent monitoring of the groundwater for one year confirmed the successful remediation of the groundwater. Following the confirmation monitoring, the NJDEP issued an Unrestricted Use/No Further Action letter for the site, which fulfilled the client's objectives.

Operations began at the site in the 1930's and included manufacturing electronic assemblies for the radio broadcast, telecommunications, and test/measurement industries. From approximately 1968 to 1980, operations included printed circuit board manufacturing and assembly; metal finishing operations, printing and silk screening. During historic operations, waste streams at the site were discharged to on-site septic systems and a lagoon.

The investigation of the septic systems identified cadmium in one area. The area was subsequently evaluated and delineated using groundwater probes and temporary well points. The concentrations of cadmium ranged from 14 to 58 parts per billion (ppb), which were above the groundwater quality standard (GWQS) of 4 ppb.

An evaluation of remedial alternatives was performed to determine an appropriate strategy for addressing the cadmium contamination. Traditional metals treatment processes, such as precipitation and ion exchange, were evaluated. However, given the site-specific characteristics (type, level and location of contamination), limited space, maintenance requirements and

anticipated costs, these technologies were not considered appropriate for the site. Rather, an innovative technology, Forager™ Sponge treatment material was identified as being the most appropriate and cost effective for the site. The Forager™ Sponge material is designed to remove heavy metals through a process of selective affinity. The results of the bench-scale testing, performed at the site, indicated that the Forager™ Sponge Technology was capable of providing cadmium removal efficiencies of 65 percent to 100 percent.

After identifying the treatment technology, potential discharge locations were evaluated. The alternatives included discharging the water to an existing stream on-site or re-injecting it to the groundwater. Based on permitting requirements and the time constraints of the client, re-injection of the treated water under a permit-by-rule was identified as the most expeditious discharge alternative. Based on the hydrogeologic conditions of the site this approach not only provided a readily available and technically sound discharge location, but also created a recycling process that promoted the flushing of contaminants from the source area.

During the pilot remediation test, approximately 1,728,000 gallons of groundwater were recovered and treated with the Forager™ Sponge material. This corresponded to the removal of approximately 70 pore-volumes of water from the primary source of contamination. At the completion of the test, the concentrations were well below the GWQS.

Following the pilot remediation test, quarterly groundwater monitoring was performed in this area for a period of one year to confirm the effectiveness of the remediation activities. The results of the quarterly monitoring confirmed that the concentrations of cadmium remained below the GWQS and that no further remediation was necessary. Accordingly, the NJDEP issued an Unrestricted Use/No Further Action letter for the site.

INTRODUCTION

The facility was located in a predominantly residential area of Morris County, New Jersey and occupied approximately 15.5 acres. The site included two environmentally sensitive areas consisting of a pond classified as State Open Water and a low-lying area, which was designated as freshwater wetlands. The groundwater beneath the site and surrounding residential properties was used for potable water supply. Sanitary wastes were treated on-site in septic systems and drywells. Previously, industrial wastes were discharged to these subsurface systems and an on-site lagoon.

The site was vacant, undeveloped land prior to the 1930's. Operations began in the 1930's and included manufacturing electronic assemblies for the radio broadcast, telecommunications, and test/measurement industries. From approximately 1968 to 1980, operations included printed circuit board manufacturing and assembly; metal finishing operations; printing and silk screening.

The facility was located on valley-fill material comprised of Wisconsin Age stratified glacial drift. The valley-fill was primarily composed of sands, silty sands, and gravelly sands. Above the stratified drift, a thin (approximately 1-foot) soil horizon had developed. The basement rock

below these unconsolidated materials was undifferentiated Precambrian age gneiss. In the cadmium-impacted area, a gravel layer was present approximately 5 to 7 feet below grade. The water table ranged between 5 and 9 feet below grade across the site.

The groundwater flow direction was determined to be in a south-southeast direction across the site towards the open waters and wetlands area. The sandy aquifer supported a very small hydraulic gradient (approximately 0.001) across the site. Topographically, the northern part of the site was slightly elevated (approximately 5 feet) relative to the southern part of the site. The slope towards the southern part of the site locally caused surface runoff to flow towards the open waters. However, the sandy soils allowed direct infiltration of rainfall into the vadose zone during typical rainfall events.

INVESTIGATION

Remedial investigation activities were initiated at the site in the fall of 1992 pursuant to New Jersey's Environmental Cleanup Responsibility Act (ECRA), the predecessor to ISRA. Comprehensive soil and groundwater investigation activities were performed in several areas of concern from 1992 to 2000. In addition, underground storage tank removals and soil remediation were completed at the property.

The investigation of the septic systems identified cadmium-impacted groundwater in one area. However, the evaluation of the soil in this area identified concentrations below the NJDEP soil cleanup criteria, indicating the impacts were the result of past discharges to the septic system. The cadmium in the groundwater was subsequently evaluated and delineated using monitoring wells, groundwater probes and temporary well points. Sampling and analysis of filtered and unfiltered samples from the wells confirmed that cadmium was present in dissolved phase concentrations at levels above the GWQS. The concentrations of cadmium ranged from 14 to 58 parts per billion (ppb), which exceeded the GWQS of 4 ppb. The sampling indicated that the impacted groundwater was localized to the former septic system area. Due to its proximity to residential properties, its relationship with the community, and on-site use of groundwater as a potable water supply, the facility's objective was to quickly and efficiently remediate the groundwater to New Jersey's GWQS, rather than consider natural attenuation under a groundwater Classification Exception Area. Therefore, a remedial alternative analysis was initiated to identify a cost effective and technically feasible solution to the problem.

REMEDIAL ALTERNATIVES ANALYSIS

A remedial alternatives analysis was completed to identify and evaluate technologies for addressing the concentrations of cadmium in the groundwater. The technologies identified were primarily ex-situ physical and chemical treatment alternatives, such as ion exchange and precipitation. The technologies were reviewed relative to cost effectiveness and ease of installation and operation. To meet the client's objectives, the system had to be installed in a relatively short time frame, be cost effective, occupy a small foot print, not interfere with manufacturing operations and require minimal maintenance.

Ion exchange has been widely used to address metals in liquid waste streams. However, these methods typically are very expensive. Physical and chemical treatment methods such as precipitation generally require high maintenance and also are expensive to install. Given the site-specific characteristics and anticipated costs, these technologies were not considered appropriate for the site. A review of innovative technologies identified Forager™ Sponge as a potential technology for the site.

INNOVATIVE TECHNOLOGY

The Forager™ Sponge Technology was evaluated and selected as the most appropriate and technically feasible remedial alternative for the site. The Forager™ Sponge utilizes an open-celled cellulose material that incorporates a chelating polymer to selectively remove metals from an aqueous waste stream. This technology is applicable to waste streams containing metals concentrations in the parts per billion (ppb) to the parts per million (ppm) ranges. The influent waste stream at the site was expected to contain on average 35 ppb of cadmium. Prior studies at other sites indicated that a cadmium removal efficiency of 80 percent or higher could be achieved utilizing this technology.

Several advantages of the sponge material were identified. The first was its open-celled nature that allows relatively high flow rates; the second was cost-effectiveness; and the third was the material's low affinity for sodium, potassium, and calcium, three common naturally occurring groundwater ions that can interfere with the effectiveness of typical ion exchange systems for treating specific priority pollutant metals. The selective affinity of the polymer enables the Forager™ Sponge to bind toxic heavy metals over benign monovalent and divalent cations such as calcium, magnesium, potassium and sodium. In addition, prior studies have shown that the sponge material is effective over a wide range of pH. The pH at the site was determined to range from 4 to 5 standard units. Another advantage was that a simple treatment system could be designed and installed similar to a typical carbon adsorption system. Based on the results of the remedial analysis, a bench-scale test was designed and conducted to evaluate the effectiveness of the Forager™ Sponge material for treating the cadmium impacted groundwater at the site.

Subsequent to identifying the treatment technology, potential discharge locations were evaluated. The alternatives included discharging the water to an existing stream on-site or re-injecting it to the groundwater. Based on permitting requirements and the time constraints of the client, re-injection of the treated water to the existing septic system under a permit-by-rule was identified as the most expeditious discharge alternative. This approach not only provided a readily available and technically sound discharge location, but also created a recycling process that promoted the flushing of contaminants from the source area.

The design plans for the site were to use the Forager™ Sponge in a groundwater recovery and treatment scenario whereby groundwater would be pumped from a recovery well at a rate of 10 gallons per minute (gpm). The recovered groundwater would then be filtered through two 55-gallon drums packed with Sponge material. The effluent would be monitored to ensure that sufficient removal of cadmium was being achieved, and the water would be recharged through the existing septic system. The physical constraints at the site dictated that only a small shed, 8-foot by 12-foot, could be used to house the treatment equipment in the vicinity of the impacted

area. To determine the design parameters and ensure the removal efficiencies of the Forager™ Sponge, bench scale testing was performed prior to the design and installation of the equipment for the pilot study.

BENCH SCALE TESTING

As part of the evaluation of remedial alternatives, bench scale tests were performed on the groundwater to determine the effectiveness of removing cadmium using the Forager™ Sponge treatment material. Two bench scale tests were conducted.

The first test included an evaluation of the Forager™ Sponge material using a pre-assembled test unit supplied by the manufacturer. The test unit was constructed of a 3-foot long, 3-inch diameter PVC tube containing shredded Forager™ Sponge material. Sample ports were located on the inlet and outlet of the test unit. To evaluate the removal effectiveness of the material, groundwater was recovered from a contaminated monitoring well at the site at approximately 0.5 gpm and pumped through the test unit. Samples were collected from before and after the treatment material and analyzed for cadmium to evaluate the removal effectiveness.

The small test unit was operated for approximately 5 hours during which 150 gallons of groundwater were treated with the Forager™ Sponge material. Samples were collected from the inlet and the outlet of the test unit. The concentrations of cadmium in the groundwater entering the test units ranged from 0.0064 ppm to 0.0084 ppm. The discharge concentrations of cadmium for the small test unit varied from undetected to 0.001 ppm.

In addition to the initial test, a second, larger-scale test was performed to evaluate the removal effectiveness of the sponge material in its normal configuration, which consists of small cubes roughly the size of sugar cubes. To perform the test, a 10-foot long section of 4-inch PVC unit pipe was filled with cubes of Forager™ Sponge material. The 10-foot test unit contained four sample ports along the length of the pipe. As in the initial test, groundwater was recovered from a contaminated on-site monitoring well and pumped through the unit at a rate of approximately 1.5 gpm. Samples were collected from the sample ports and analyzed to evaluate the removal efficiency of the Forager™ Sponge material.

The second bench scale test was operated for approximately 5 hours, during which 600 gallons of groundwater were removed and treated. Samples were collected from the inlet and outlet of the unit as well as along the length of the treatment material. Samples were collected at one, three, and five hours after initiating the test. The concentrations of cadmium steadily decreased as it passed through the treatment material.

Both bench-scale tests indicated a decrease in the concentration of cadmium in groundwater as it moved through the test units. The small unit removed a greater percentage than the larger one due to the greater surface area of the treatment material combined with the lower flow rate. The removal efficiencies for the small test unit varied from 87% to 100%. For the larger unit containing the cube material, the removal efficiencies ranged from 64% to 79%. Based on the test results, it was determined that the cubed treatment media had sufficient removal efficiency to

warrant further evaluation. Therefore, additional pilot testing on a larger scale was proposed to the NJDEP and performed at the site using a permit-by-rule.

PILOT TREATMENT STUDY

To conduct a more thorough evaluation of the effectiveness of the Forager™ Sponge technology and initiate remediation activities, a pilot remediation test was implemented at the site. The test consisted of two phases, an initial 90-day period and a follow-up 30-day extension that was approved and implemented 3 months after the completion of the initial phase. A review of the data from the initial phase indicated that the pilot test, with some expansion, would be sufficient to remediate the groundwater at the site. Therefore, during the time period between the phases, additional monitoring wells were installed within the contaminated area to provide more withdrawal and monitoring points for the purpose of evaluating water levels and cadmium concentrations. To meet the time constraints of the project, both phases of the pilot test were performed under a permit-by-rule issued by the NJDEP.

The objectives of the pilot test were to evaluate the effectiveness of the treatment material in removing cadmium from the groundwater, to evaluate the area of influence that would develop around the groundwater withdrawal points, and potentially to remediate the groundwater sufficiently such that no further action would be required. The pilot remediation test was designed to pump groundwater from the contaminated monitoring wells at a rate of 10 gpm, treat it with the Forager™ Sponge material and discharge it to the former septic system.

The groundwater was recovered from the contaminated monitoring wells using a centrifugal pump and pumped through two 55-gallon drums of Forager™ Sponge material. The drums of Forager™ Sponge were constructed similar to carbon adsorption units, and operated in series and parallel during the pilot test. The groundwater was subsequently passed through a drum of marble chips to passively raise the pH, which was typically between 4 and 5. After treatment, the water was re-injected in the former septic system.

The 10-gpm pilot system was installed in a storage shed located in the immediate area of groundwater contamination. During the test, approximately 1,728,000 gallons of groundwater were recovered and treated with the Forager™ Sponge material. This corresponds to the removal of approximately 70 pore-volumes of water from the immediate vicinity of the contaminated wells (20-foot radius). The cadmium concentrations in the effluent from the treatment system ranged from 1.03 to 2.08 ppb. During the test, three drums of Forager Sponge were used, and only one drum was depleted. The drums of spent material subsequently were disposed off site.

The groundwater concentrations during the delineation sampling ranged from 14 to 58 ppb. Groundwater sampling conducted during the pilot remediation test indicated a decrease in cadmium concentrations in the wells. At the completion of the test, the concentrations in the monitoring wells were well below New Jersey's GWQS. Quarterly monitoring performed for one year following the test identified residual concentrations ranging from 0.66 ppb to 3.76 ppb, corresponding to an overall reduction of 73 to 99% in the concentration of cadmium in the groundwater.

The pilot remediation test confirmed that the Forager™ Sponge Technology is effective in removing low concentrations of cadmium from groundwater.

Following the pilot remediation test and quarterly groundwater monitoring, which confirmed that the concentrations of cadmium remained below the GWQS, no further remediation was necessary. Based on the post remediation monitoring results, the NJDEP issued an Unrestricted Use/No Further Action letter for the site.

CONCLUSIONS

During the pilot remediation test, approximately 1,728,000 gallons of groundwater were recovered and treated with the Forager™ Sponge material. Following the pilot remediation test, quarterly groundwater monitoring was performed in this area for a period of one year to confirm the effectiveness of the remediation activities. The results of the quarterly monitoring confirmed that the concentrations of cadmium remained below the GWQS and that no further remediation was necessary. Based on these results, the NJDEP issued an Unrestricted Use/No Further Action letter for the site.

The results of the pilot test indicate that the Forager™ Sponge Technology is a simple and cost effective method for remediating groundwater contaminated with heavy metals. The design, installation and operation of a system are not complex. The systems are similar to the installation and operation of carbon adsorption units. Minimal maintenance is necessary during the operation of the system and the Sponge material is effective in removing specific heavy metals present in groundwater. Due to the selective nature of the removal process, common naturally occurring groundwater ions such as sodium, potassium, and calcium, do not interfere with the effectiveness of the treatment process. In addition, the open-celled nature of the material allows relatively high flow rates.

The applicability of such a system is site specific and requires evaluation on a case-by-case basis. The effectiveness of the sponge material depends on the type and concentrations of metals present, and the design of a system must take into account concentrations, anticipated flow rates and contact time. Based on information provided in the EPA Superfund Innovative Technology Evaluation (SITE) Program, the Forager Sponge Technology is able to achieve significant reductions in lead, cadmium, chromium and copper at concentrations ranging from 500 to 900 ppb in liquid waste streams. The results of the pilot test indicate that the Forager™ Sponge Technology is a viable metals removal technology and should be considered in a remedial alternatives analysis for addressing groundwater impacted with metals.