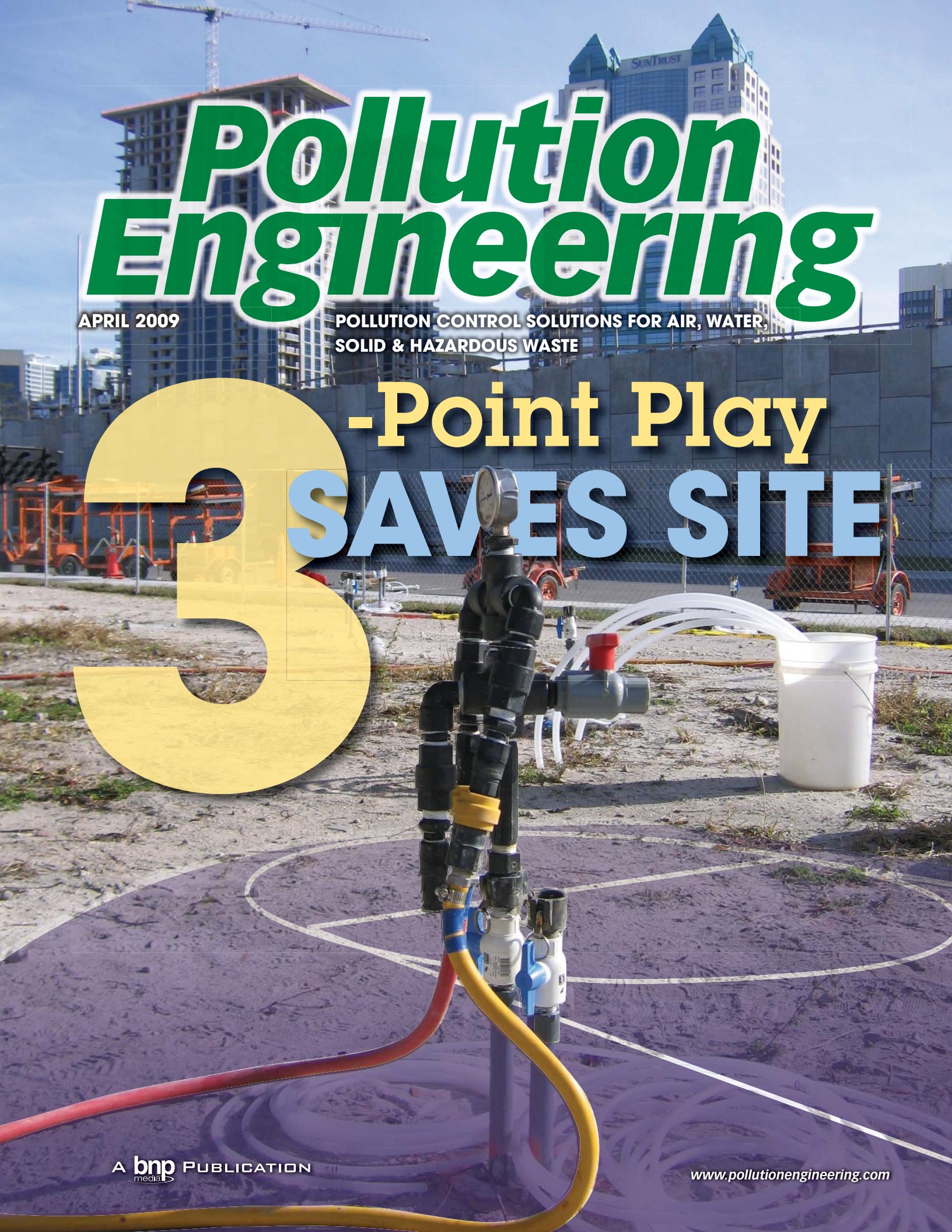

Pollution Engineering

APRIL 2009

POLLUTION CONTROL SOLUTIONS FOR AIR, WATER, SOLID & HAZARDOUS WASTE

3-Point Play SAVES SITE

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Remediation GOES FOR

Needing a cleanup win and up against the buzzer, a three-part plan using in-situ chemical oxidation was able to score a game-clinching groundwater cleanup.

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In 2007, the NBA's Orlando Magic and their host city unveiled the design for the Orlando Events Center as the professional basketball team's new downtown venue. Due diligence by the city identified a groundwater tetrachloroethene (PCE) plume with a source area located beneath the proposed arena footprint (see **Figure 1**).

The maximum PCE concentration found in the source area groundwater was 14,600 ug/L, which exceeded the Florida groundwater Cleanup Target Level (CTL) of 3 ug/L. Trichloroethene (TCE; maximum concentration of 57 ug/L) and cis-1,2-dichloroethene (DCE; maximum concentration of 98 ug/L) were also detected at concentrations exceeding their CTLs of 3 ug/L and 70 ug/L, respectively. Shallow soil (2 to 4 feet below grade) was also impacted in two discrete areas. The maximum soil PCE concentration was approximately 0.49 mg/kg, which exceeded the Florida soil CTL for leachability of 0.03 mg/kg.

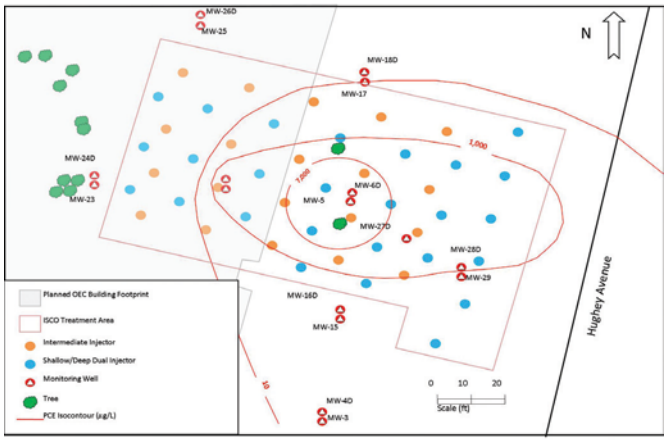


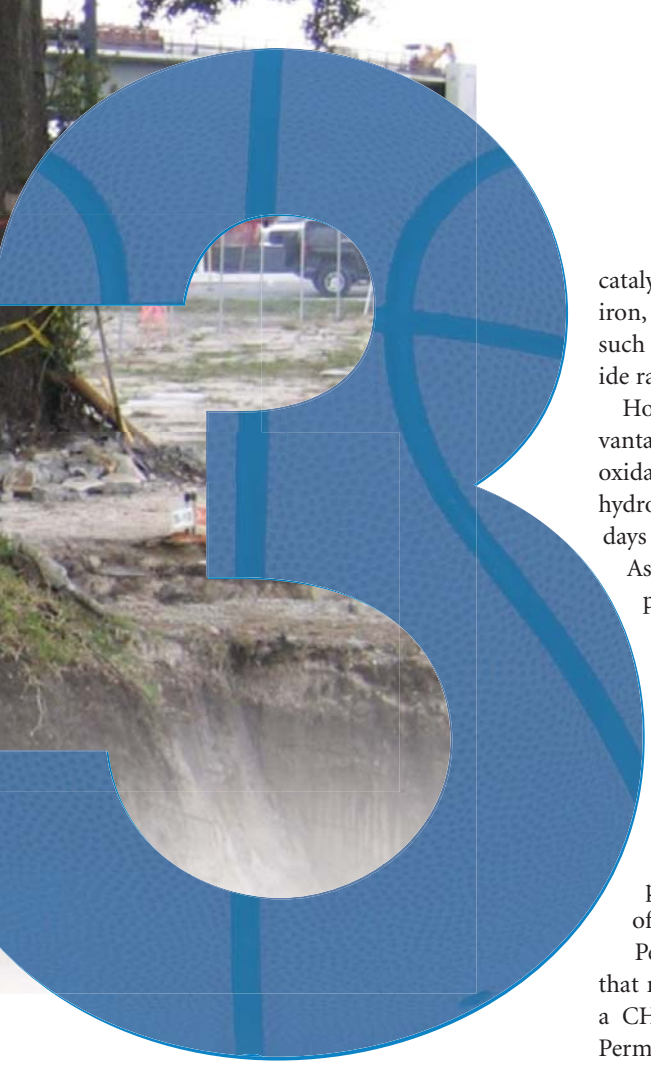
Figure1: The above drawing shows the location of the injection points, monitoring wells and other points of interest on the site.

The aquifer was primarily sand, with some finer-grained (silty sand) zones to a depth of approximately 40 feet below grade, underlain by a dense clay aquitard in the treatment area.

Drawing up the play

The city issued a request for proposal for a source area remedy with a fast-tracked, performance-based contract on Aug. 30, 2007. Construction was scheduled to begin in the late summer 2008, thus a very rapid and aggressive response was required to prevent any construction delay. Geo-Cleanse International Inc., Matawan, N.J., and Mactec Engineering and Consulting Inc., Newberry, Fla., agreed to partner for the project and developed a three-phase remediation plan.

The first phase consisted of in-situ chemical oxidation (ISCO) with catalyzed hydrogen peroxide (CHP) to target the concentrated source area. The second phase consisted of additional ISCO using sodium permanganate to target residual contaminants potentially remaining after the catalyzed peroxide application. The third phase consisted of removal with offsite disposal of impacted shallow soil.



Stacking the court

One of the novel components of the team's approach was the sequential application of different oxidants to achieve the CTLs. Plume management strategies typically employ ISCO in concert with other methods, such as engineered or natural bioremediation, extraction or air sparge/soil vapor extraction. However, most of these secondary technologies require longer periods of time to achieve cleanup goals (months or years). When time is a pressing issue, an alternative approach is to couple different ISCO technologies to more rapidly achieve low cleanup standards. Each general chemical compound such as catalyzed hydrogen peroxide (CHP), activated persulfate, or permanganate, has advantages and disadvantages. But in certain cases different oxidants can be applied together or in succession to rapidly reduce contaminant concentrations, as was shown in this application.

CHP includes a range of chemical reactions responsible for degradation of organic compounds such as PCE. When catalyzed by a transition metal such as iron, H_2O_2 generates powerful radicals such as the hydroxyl radical and superoxide radical.

However, the chemical also has disadvantages. One is the short lifetime of the oxidant in the subsurface. In most cases, hydrogen peroxide will persist for several days to perhaps a week in the subsurface. As a result, residual oxidant may not persist long enough to address contaminants slowly diffusing out of fine-grained (silt or clay) aquifer matrices, and the oxidant itself does not survive long enough to diffuse into those matrices. Long-term diffusion of contaminants from fine-grained aquifer matrices may pose a rebound problem, and prevent achievement or maintenance of the CTLs.

Permanganate exhibits characteristics that make it an excellent choice to follow a CHP treatment for PCE remediation. Permanganate is generally a less aggressive oxidant than CHP and not as efficient as CHP at rapidly destroying sorbed- or NAPL-phase contaminants. Permanganate is also a more costly oxidant than CHP in terms of cost per unit mass of contaminant destroyed. However, due to the slower reaction, permanganate has a much longer lifetime in the subsurface than CHP. Residual permanganate may last for months to address contaminants slowly diffusing from fine-grained matrices. Permanganate also diffuses directly into finer-grained aquifer matrices to directly attack those contaminants.

Executing the play

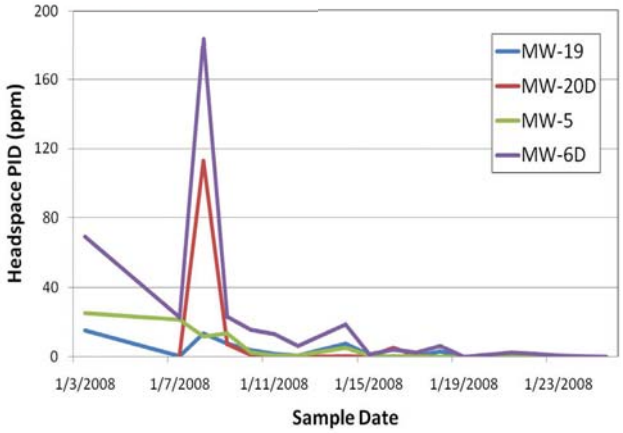
The design called for 72 injection wells installed across three depth intervals between approximately 10 to 40 feet below grade, in an 80-foot by 130-foot area (see Figure 1). Injector installation was conducted from Nov. 27 to Dec. 15, 2007. The injector seals were then allowed to cure for two weeks.

The first phase of remediation consisted of injecting 85,000 gallons of CHP solution over the period from Jan. 2 to 26, 2008. Measurements of volatile organic compounds (VOCs) in the headspace over groundwater samples, as taken with a photoionization detector (PID), provided a semi-quantitative measure of VOC concentration in the groundwater.

Figure 2 is a chart of the PID readings of groundwater samples from the four monitoring wells in the source area. The readings showed an initial spike in headspace PID measurements related to desorption of VOCs from the aquifer matrix, followed by subsequent destruction to non-detectable levels during the treatment. These data were used to determine when to cease CHP injection and confirm that the first treatment phase was complete.

One week was allowed for residual peroxide to degrade before beginning permanganate injection for the second phase. The same network of injection wells installed for the CHP injection was also utilized for the permanganate. This second phase of remediation consisted of injecting 21,000 gallons of 4-percent sodium permanganate solution over the period from Feb. 4 to 10, 2008. Field monitoring for sodium permanganate injection consisted of collecting groundwater samples for visual analysis to ensure uniform distribution of the permanganate. Permanganate (recognized by its characteristic purple color) was found throughout the treatment area following the injection. The post-injection groundwater monitoring period began after completion of the permanganate injection.

The third phase of remediation consisted of soil removal at two areas impacted with PCE. A total of 94 tons of soil was removed from Feb. 25 to 27, 2008. During the removal, a PVC pipe and apparent floor drain system were discovered (see **Figure 3**). The pipe was found to contain residual sludge and exhibited elevated PID readings, and was located directly over the groundwater source area, and thus was the presumed discharge source. The piping and associated bedding were also removed. The excavation was backfilled on March 7, 2008 after receipt of post-excavation sampling results.



The chart to the left is of readings from the four monitoring wells in the source area. The readings showed an initial spike in headspace PID measurements related to desorption of VOCs from the aquifer matrix, followed by subsequent destruction to non-detectable levels during the treatment.

Post-game wrap-up

The post-treatment performance sampling program consisted of three groundwater sampling events, conducted on Feb. 14, 2008 (four days after injection), April 23, 2008, and July 23, 2008, with a supplemental sampling event on Aug. 5, 2008. With one exception, the VOC concentrations in all five of the performance monitoring wells were reduced to below the CTLs.

The total VOC concentration (consisting of the summed PCE, TCE and DCE concentrations) is plotted in Figure 4 for the two monitoring wells exhibiting the highest pre-injection VOC concentrations. During the July 23 event, PCE was detected at 11 ug/L in MW-5 and was confirmed with a second analysis. MW-5 was a shallow well located adjacent to the soil removal area, thus the VOC detection was likely associated with the soil removal. Additional permanganate treatment was focused in the area of MW-5, and a confirmatory sample was collected on Aug. 5, 2008. All VOCs were below CTLs. The injection and monitoring wells were then abandoned in accordance with Florida regulations by Aug. 8, 2008.

Rarely can one single technology provide a complete remedy for a contaminated site. The combination of CHP with sodium permanganate provided a one-two ISCO punch to rapidly eliminate a concentrated PCE source area and reduce the dissolved concentrations below the regulatory standard.

Monitoring has also demonstrated that permanganate had diffused down gradient from the treatment area, providing additional benefit. The total time required from contract execution to injection well abandonment was 286 calendar days (about nine months). The field remediation component (drilling, injection and soil removal) required 101 calendar days, and the remainder was a regulatory review period and post-remediation monitoring. The total remediation cost (excluding post-remediation groundwater sampling conducted by another contractor) was $584,299. Construction was not delayed, and the opening horn of Magic basketball at the Orlando Events Center is moving ahead as planned for October 2010. ***PE***

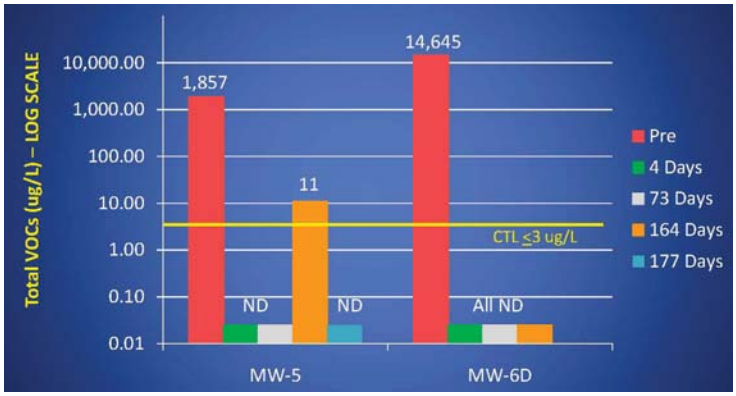


Figure 4 - Monitoring wells MW-5 and MW-6 exhibited the highest levels at the start of the project. The chart above shows the results after ISCO injections.

Figure 3 shows a floor drain system that was unearthed during excavation of 94 tons of soil. This was considered the source of the contamination.

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