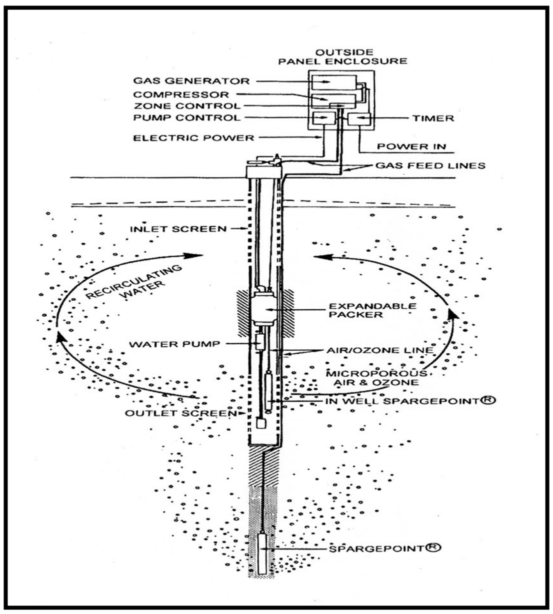
Ozone Sparging and Recirculation
Comparison of Design Approaches for Two Site Remediations

Steven D. Schroeder, P.E.
(RMT, Inc.)

Abstract: Ozone sparging and recirculation is a new technology being applied to remediate organic constituents in groundwater. The process, developed by KV Associates, Inc. (KVA), combines in-situ oxidation with in-well recirculation of groundwater. The KVA C-Sparger™ system sparges ozone at two separate depth intervals, and the in-well groundwater pump distributes the oxidant and creates mixing zones within the aquifer (Figure 1). The design approaches for two site remediations using KVA's C-Sparge™ process are presented for comparison. Initial field performance results are also presented, as available. The two sites vary in both their constituent distribution and performance goals, resulting in different design approaches. The design flexibility afforded by the KVA process allows designers to match the in-situ processes to site-specific conditions.

Figure 1 – Typical Ozone-Sparge Well (Type A)



Process Overview: The ozone-sparging process involves the injection of air-encapsulated ozone into groundwater, to provide *in-situ* treatment. The sparging apparatus is designed to produce "micro-bubbles" sized at 0.05 mm (0.002 inches). This small air bubble size provides a high surface area to volume ratio to maximize treatment efficiency, and also allows the air/ozone gas to readily flow between soil pore spaces to attack the target compounds in groundwater (1).

Ozone-sparging has been proven to be effective for remediation of halogenated volatile organic compounds (HVOCs). The oxidation mechanism provides rapid conversion of HVOCs to carbon dioxide and dilute hydrochloric acid, with no organic intermediates created. Batch testing has shown half-lives in the range of 20 to 60 days for various HVOCs (2).

The technology retains a high degree of flexibility. The two separate sparge zones can target different vertical levels of the aquifer, and the sequential timing of the different processes can be adjusted to meet site conditions. The recirculation patterns can be created in a “top to bottom” or “bottom to top” direction. In-well components are portable, and can be moved from one location to another as the remediation proceeds.

Case Studies: Two site designs for field-scale testing and full-scale remediation were completed using the ozone-sparging process. Both sites were subjected to a detailed remedial-options analysis which showed ozone-sparging to be the most cost-effective technology for remediation, based on Net Present Worth cost analysis.

Case Study #1:
The first case study site has groundwater impacted by trichloroethene (TCE) and 1,2-dichlorothene (DCE), with maximum total HVOC concentrations of 4 to 5 milligrams per liter (mg/L). Site geology consists of 50 feet (ft) of silty sands overlying bedrock. Approximately 97% of the HVOC mass are within the lower 10-ft of the overlying sands, and are the primary target zone for remediation. Remedial objectives are to reduce HVOC concentrations to at, or near, maximum contaminant levels (MCLs).

The design of the ozone-sparging system focuses on treatment of the lower portion of the sand aquifer. Sparge-recirculation wells (SP’s) are designed with a lower sparger placed at the top of bedrock (48 to 50-ft below grade [blg]), an upper sparger/circulation pump discharge at 40 to 42-ft blg, and circulation pump inlet at 33 to 35-ft blg. This orientation of sparge and recirculation is termed a “Type A” design, and was evaluated in field-tests using two SP wells located 30-ft apart.

Performance results of the two-well system indicate a significant reduction in HVOC concentrations has been achieved over the initial 9 weeks of operation (Figure 2).

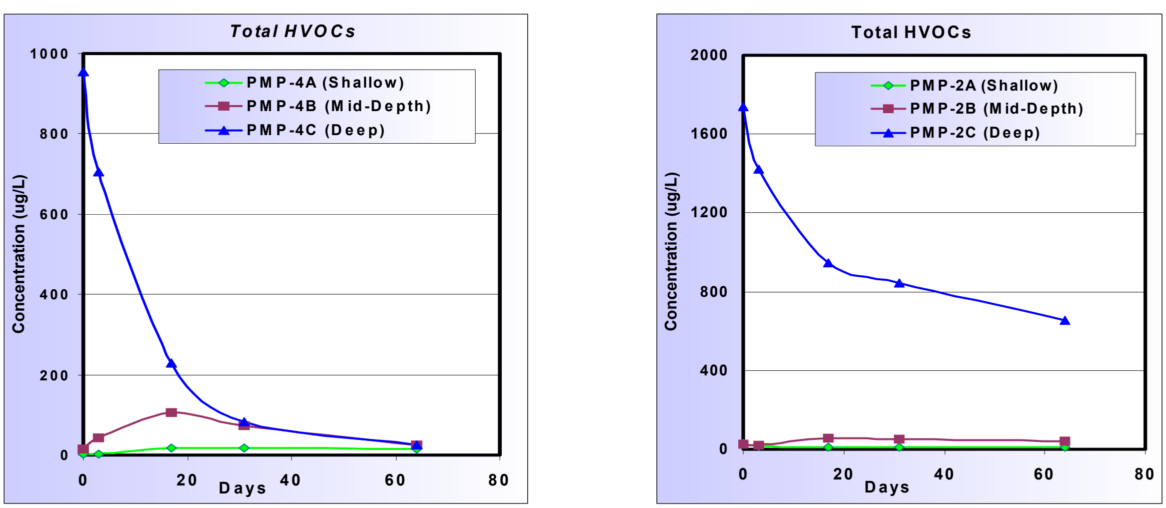


Figure 2 – Field Test Performance Results

Data show HVOC reductions of 30% to greater than 90% over the lower portion of the aquifer. A net reduction of over 50% of the HVOC mass over the entire study area was achieved. A short-term rise in HVOC concentrations was observed in mid-depth and shallow monitoring points. However, the magnitude of these concentration increases were small, and rising trends had stabilized or been reversed after 9 weeks.

Case Study #2:
In the second case study, site impacts in groundwater from TCE, DCE, and various forms of chlorinated benzenes are present. The aquifer consists of silty sands overlying bedrock, with HVOC impacts to depths of 50 to 70-ft blg present in the sand aquifer. HVOCs are distributed relatively evenly over the entire vertical profile of the silty-sand aquifer. Total HVOC concentrations exceeding 20 mg/L are present over a wide area, with maximum total HVOC levels exceeding 50 mg/L. The objective of the remedial design is to reduce the mass of HVOCs as a source control measure for groundwater.

In contrast to the previous case study, where remediation of the lower portion of the aquifer was dominant, a series of ozone-sparge and recirculation wells are designed in this case to remediate groundwater over the entire vertical depth of the aquifer. To accomplish this, ozone-sparge wells are designed so adjacent wells establish alternating recirculation patterns in the aquifer (Type A and Type B designs). The design depths for ozone-sparging and recirculation are also varied for the differing well types. These features are designed to maximize the distribution of ozone throughout the entire vertical profile of the aquifer.

A 4 sparge-well system has been designed for field-testing. Performance results are not yet available.

Use of Field-Testing for Full-Scale Design: The performance data from field-scale tests will be used to refine the design of full-scale systems based on site-specific criteria. The relationship between the magnitude of HVOC reduction achieved versus distance from an ozone-sparge well provides a basis for sparge well spacing, for full-scale. Evaluation of HVOC reduction over time provides information from which the duration of the remediation can be gauged. This information allows engineers to select from alternative designs, and achieve a cost-effective balance between the number of ozone-sparge wells and the time necessary to reach cleanup objectives.

References:
(1) Kerfoot, W.B. “Slantwell Sparging.” K-V Associates, Inc. Technical Publication # 101. Presented at Tenth Annual Conference on Contaminated Soils, Amherst, Massachusetts, October 23-25, 1995.

(2) Kerfoot, W.B. “Ozone Supersparging for Chlorinated and Fluorinated HVOC Removal.” K-V Associates, Inc. Technical Publication # 116. Presented at Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, California, May 22-25, 2000.