ART IN-WELL AIR STRIPPING – AN INNOVATIVE TECHNOLOGY SUCCEEDS WHERE OTHER TECHNOLOGIES HAVE FAILED

Marco M Odah, Ph.D., P.E. Accelerated Remediation Technologies, LLC (913) 438-4384

modah@artinwell.com

ABSTRACT

Accelerated Remediation Technologies, LLC (ART) developed a proprietary, patented, effective remediation technology that is based on verified and established concepts. The ART technology combines *in situ* air stripping, air sparging, soil vapor extraction, enhanced bioremediation/oxidation and Dynamic Subsurface Circulation™ in an innovative wellhead system. The system is designed to accommodate a four-inch well and is cost effective when compared with other remediation technologies. The air-sparging component results in lifting the water table. This lifting of the water in the well causes a net reduction in head at the well location. Vacuum pressure (the vapor extraction component) is applied atop of the well point to extract vapor from the subsurface. The negative pressure from the vacuum extraction results in water suction that creates additional water lifting (mounding). A submersible pump is placed at the bottom of the well to recirculate water to the top for downward discharge through a spray head. The water cascades down the interior of the well similar to what occurs in an air-stripping tower. Enhanced stripping via air sparging near the bottom of the well occurs simultaneously. In essence, the well acts as a subsurface air-stripping tower. The pumped and stripped, highly oxygenated water flows down the well annulus and over the "mounded" water back into the aquifer, which creates a circulation zone around the well to further enhance cleanup.

The ART technology has been implemented at several sites nationwide including industrial laundry facilities, manufacturing plants, and service stations and has achieved significant reductions in contaminant concentrations. Specifically, a concentration of tetrachloroethene (PCE) decreased from 2,700 to 240 µg/L, or by an average of approximately 90% in 13 days. In less than three months, the concentrations dropped further to 79 µg/L, which is within the range of background levels. Other sites utilizing the technology have exhibited similar reduction trends in complex subsurface environments.

Numerous remediation technologies, such as pump-and-treat and air sparging, have demonstrated mixed results at reducing subsurface contamination. It is increasingly apparent that many of these generally accepted technologies reach contamination reduction asymptote before site cleanup levels are achieved. A remediation technology that can move these "stalled" sites to acceptable levels of remediation and achieve site closure, while embracing economic reality is necessary. Accelerated Remediation Technologies, LLC (ART) developed a robust, field-flexible technology that shows effective remediation of volatile organic compounds (VOC).

ART INTEGRATED REMEDIATION SYSTEM

ART has developed an innovative remediation technology that is based on well-proven and established concepts. The ART technology combines in-situ air stripping, air sparging, soil vapor

extraction, enhanced bioremediation/oxidation and Dynamic Subsurface Circulation™ in an innovative wellhead system. The system is designed to accommodate a four-inch well and is cost effective compared with other remedial alternatives. The schematics of a typical ART Well are demonstrated in Exhibit-1.

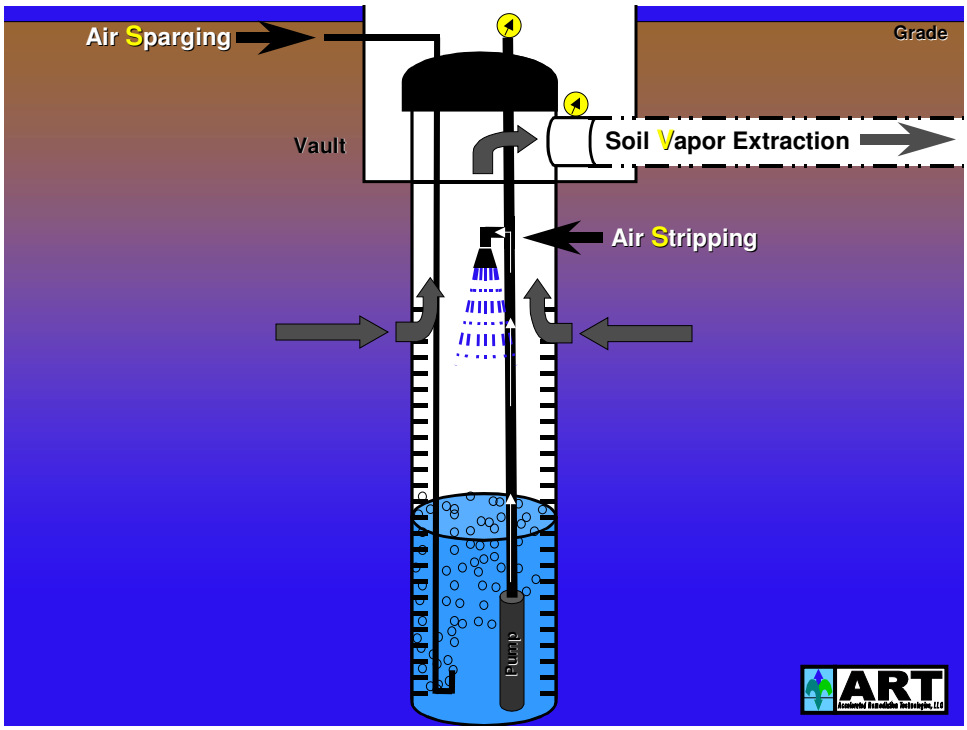

Exhibit-1 Typical ART well schematics

The air-sparging component results in lifting the water table. The lifting of the water in the well causes a net reduction in head at the well location, which results in water flowing toward the well. Vacuum pressure (the vapor extraction component) is applied at the well point to extract vapor from the subsurface. The negative pressure from vacuum extraction results in water suction that creates additional water lifting.

A submersible pump is placed at the bottom of the well to recirculate water to the top for downward discharge through a spray head. The water cascades down the interior of the well similar to what occurs in an air-stripping tower. Enhanced stripping via air sparging near the bottom of the well occurs simultaneously. In essence, the well will act as a subsurface air-stripping tower. In addition to the air stripping by the pumping/cascading, the treated highly oxygenated water flows down the well annulus and over the "mounded" water back in to the aquifer. This circulation zone surrounding the well further enhances cleanup. Radius of influence of up to ten times the water column in the ART remediation wells was achieved at sites where the ART technology was implemented. Multi-surface packing may be placed in a well to increase the effectiveness of air stripping; however, in most cases, in-well packing will probably not be necessary to achieve desired results. The effects of the synergistic forces in the subsurface in relation to the wellhead technology are shown in Exhibit-2.

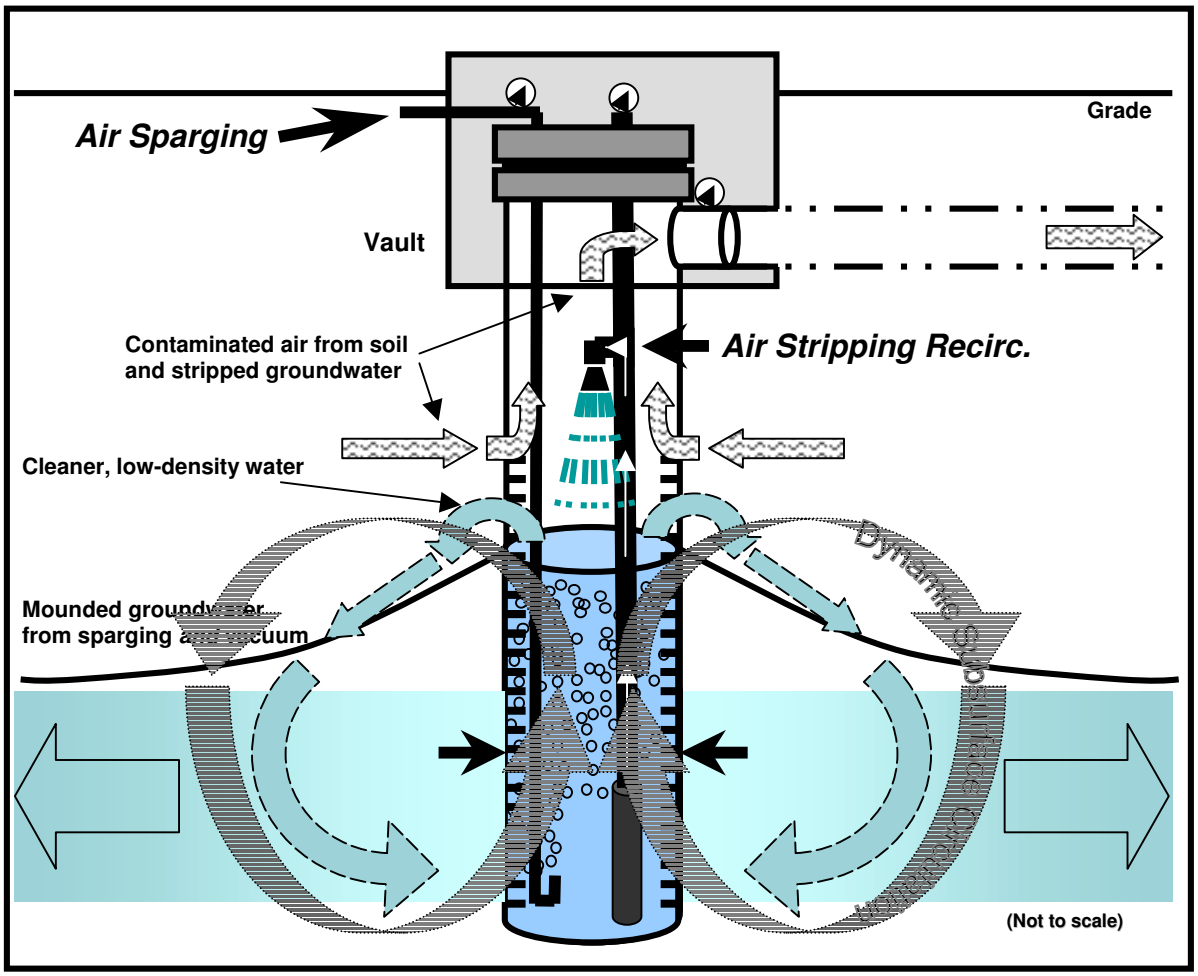

Exhibit-2 Synergistic subsurface effects of a typical ART well

In summary, contaminants are stripped from groundwater as a result of the combined effects of in-well air stripping and air sparging. The radius of treatment is created by a combination of (1) negative gradient as a result of air sparging, (2) additional, negative gradient resulting from the application of vacuum extraction, and (3) Dynamic Subsurface Circulation™ induced by a submersible pump and hydraulic mounding. All of these different components can be integrated and installed in a 4-inch groundwater well. Exhibit-3 is a photograph of a wellhead manhole component recently installed at a former California service station site.

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Exhibit-3 Photograph of an ART wellhead

Cost Comparison

Initial capital and installation costs of the ART technology are in the range of air sparging technology

alone, since the costs of added pump and in-well piping will be offset by the elimination of numerous, separate vapor extraction points and associated trenching and construction. However, the total project costs considering the significantly shorter project life of the ART technology is estimated to be less than 75 percent of air sparging costs. Costs savings are site dependant and may be calculated based on the project life reduction in years multiplied by yearly operation and maintenance costs. ART will be pleased to provide site-specific cost estimates.

Advantages

The ART technology is obviously a significant improvement to existing remedial alternatives. Based on several field implementations, this technology will expedite site closure for facilities where current remedial efforts have had limited success. Advantages of the ART technology include:

1. Single well, multiple technologies
2. Dynamic Subsurface Circulation(tm)
3. No injection, discharge fees
4. Groundwater, saturated zone and vadose zone remediation
5. Proven chlorinated remediation
6. No surface discharge, disposal
7. Jump-start stalled sites
8. Utilizes common 4" well configuration
9. Enhances bioremediation and oxidation of hydrocarbons/MTBE
10. Wells can be used to distribute amendments
11. Can retrofit to existing SVE/sparge systems
12. No complicated components
13. Relatively low installation and O&M costs
14. Low Risk
15. Makes sense

The speed of contaminant concentration reduction will be dependent on the subsurface hydraulic conductivity. Reduction is expected to be at a higher rate in higher permeability soils.

CASE STUDIES

The following two cases are presented to show the impressive effectiveness of the ART technology in treating soil and groundwater impacted by chlorinated hydrocarbons.

Industrial Laundry Facility

Remedial measures have been attempted at this site for many years. In-situ soil vapor extraction and

groundwater air sparging systems were installed at this site in 1995 to cleanup onsite soil and groundwater. In 2001, data indicated that elevated PCE concentrations remained suggesting that the remediation approach had become static.

An industrial laundry operations began at the site in the mid-1970s and included a solvent dry cleaning process that was used for several years. The topography of the site is relatively flat with a river located approximately 1,500 feet to the east. Subsurface soils at the site consist of fine sand mixed with silt, loam and organic sediments. Several soil borings and groundwater monitoring wells were installed at the site in 1994. PCE was detected at varying depths at several locations. The highest concentration of PCE in soils was 47,000 ug/kg and in groundwater was 20,000 ug/L, with the concentration fluctuating throughout the last seven years.

As a result of the impending sale of the site, the owner desired a remedial technology that would provide more effective results and reduce contamination at the site to acceptable levels in a shorter period of time. The owner selected the *ART* Integrated Remediation System, which was approved by their environmental consultant and the state regulatory agency.

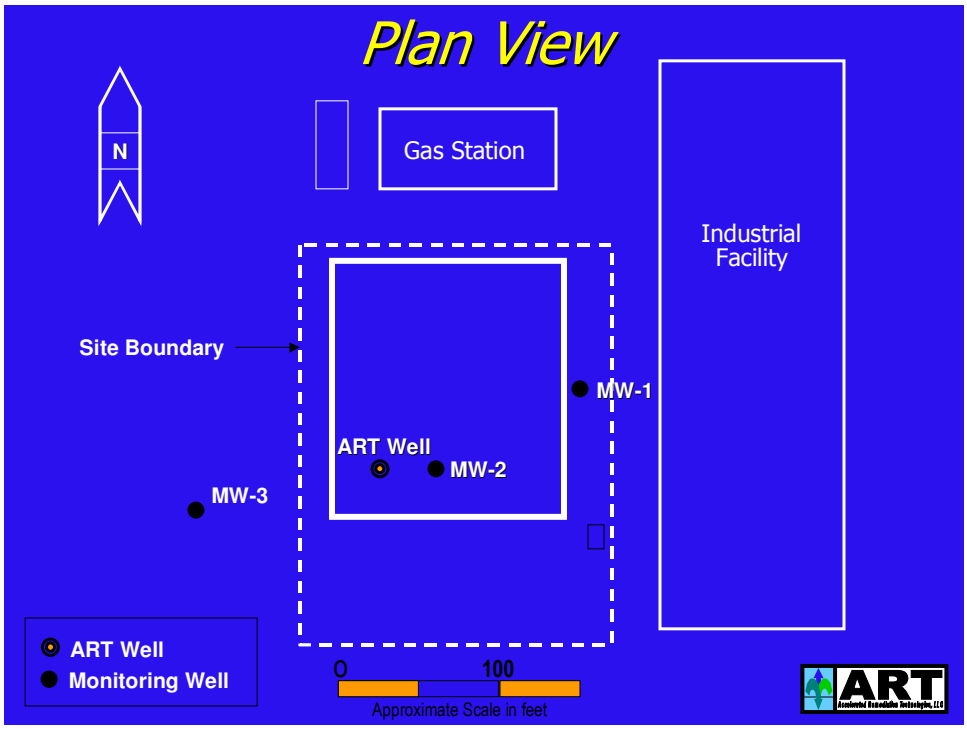

Exhibit-4 Site layout

In May 2001, an *ART* extraction well was installed approximately 18 feet upgradient of monitoring well MW-2 as shown in Exhibit-4. MW-2 was used as the main monitoring point to gage the effectiveness of the technology. Sampling data collected prior to the implementation of *ART* Integrated Remediation System alternative indicated that PCE and dissolved oxygen (DO) concentrations in groundwater were approximately 2,700 ug/L and 1.23 mg/L, respectively. MW-2 was sampled on May 29, 2001, thirteen days after the implementation of the *ART* system. Chemical

analysis indicated that PCE concentrations were reduced by approximately 90 percent to 240 ug/L. DO concentration increased from approximately 1.23 to 9.57 mg/L (near saturation).

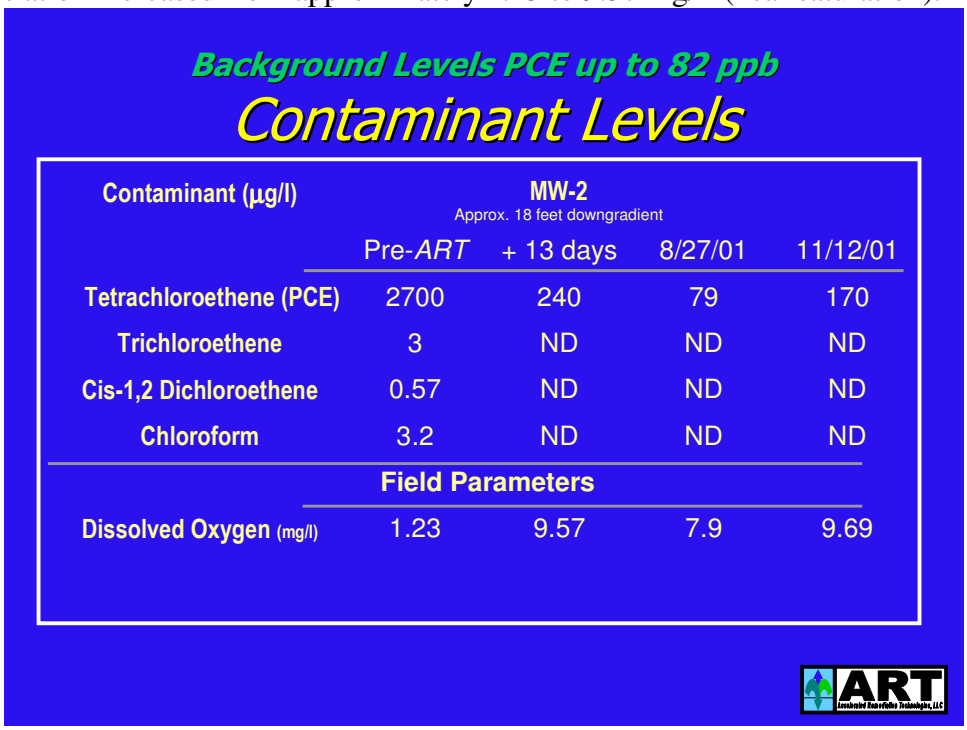

Exhibit-5 Groundwater sampling results

Additional groundwater sampling performed 70 days after the implementation of *ART* Integrated Remediation System determined that PCE concentrations decreased to 79 ug/L. The background concentrations of PCE in the area exist up to 84 ug/L. Groundwater sampling results are presented in Exhibit-5. The results indicate that the concentrations are within background levels. Minimal variations in PCE concentrations were encountered but were insignificant.

Manufacturing Facility

A 4-inch ART well was installed at a large industrial manufacturing facility with an extensive PCE plume. A soil vapor extraction well was retrofitted as a pilot project to assess the ART system's effectiveness. Multiple remediation techniques including SVE, air sparging, numerous anaerobic degradation compound injections, and pump and treat had been implemented over the last 10 years, costing millions of dollars.

The site is located on a geographic high. Soil types consist of silty and clayey sand with depth to groundwater approximately 30 feet below ground surface and a saturated thickness of about 3.5 feet with a steep hydraulic gradient. The PCE concentration levels exceeded 80,000 ug/L in groundwater in the source area.

The ART Technology was installed in an existing, 4-inch, source area well utilizing "plant air," existing SVE equipment, and piping in March 2002. Within two months, the ART Technology had

reduced contamination 30-85 percent in surrounding monitoring wells and achieved a radius of influence exceeding 50 feet based on DO and PCE concentration changes.

Conclusion

The case studies presented demonstrate that the ART Integrated Remediation System can be an effective alternative technology that is capable of stimulating site remediation and significantly reduce VOC contaminant concentrations over a relatively short period of time. The use of ART achieved more in a few weeks than other technologies achieved over a period of several years. Based on actual field implementations as discussed in the first case study, PCE concentration reduction achieved via the ART technology exceeded reduction achieved via air sparging alone over several years. The combined synergistic effects of the ART technology components have resulted in a very aggressive, effective and cost-efficient remedy.

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