Case Study: Use of Refrigerated Condensation for SVE Off-Gas Treatment of Chlorinated Solvents
Sanjay Vancheeswaran and Alistair Montgomery, CH2M Hill, John Scott, Boeing, and Lowell G. Kessel and Carol D. Winell, GEO Inc.

The Challenge
Treatment of soil vapors from either soil vapor extraction (SVE) or multiphase extraction (MPE) remedial systems at sites with high concentrations and/or NAPL level of recalcitrant or petroleum compounds has been a serious challenge. This is because many conventional soil vapor treatment technologies including granular activated carbon (GAC) and thermal oxidation are either technically inefficient/cost-prohibitive (a general concern for GAC) or not acceptable due to potential adverse effects/dioxins emissions (a general concern for thermal oxidation systems). Of particular challenge to the off-gas treatment selection processes are the potential variety of chemical constituents and concentrations changing over time.

Off-Gas Treatment Solution
The C3 Technology has proven to be an excellent alternative off-gas treatment technology which can overcome the aforementioned challenges. The C3 Technology is also modular and fully scalable to meet various application.

Three Phased Approach to Soil Vapor Extraction
Phase I Mass Removal / Recovery Approach: Refrigerated condensation Condition: High VOC concentrations
Phase II Longer Term Venting Approach: Activated Carbon Condition: Asymptotic Influent VOC concentrations below 200 ppmV
Phase III Rebound Testing Approach: Activated Carbon Condition: VOC concentrations below 50 ppmV

Case Study Site Description
Southern California Former Industrial Facility

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Max VOC Concentrations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trichloroethene</td>
<td>8,100</td>
</tr>
<tr>
<td>Methylene Chloride</td>
<td>4,700</td>
</tr>
<tr>
<td>cis-1,2 Dichloroethene</td>
<td>83</td>
</tr>
<tr>
<td>Toluene</td>
<td>33</td>
</tr>
<tr>
<td>Tetrachloroethylene</td>
<td>100</td>
</tr>
<tr>
<td>Isopropanol</td>
<td>1,100</td>
</tr>
</tbody>
</table>

Phase I Results of Soil Vapor Extraction Remediation
- 18 Shallow Extraction Wells
- 18 Deep Extraction Wells
- 400 ACFM system
- 2 years operation
- Max System VOC Concentration of 8,714 ppmV
- Total Mass Recovered of greater than 83,000 pounds

Site Conditions
Site located in Los Angeles basin. Site lithology from ground surface to 90 feet below ground surface (ft bgs) is silt and clay with intercalated sand layers and lenses. Groundwater present at 35 ft bgs.

Phased Approach to Soil Vapor Extraction Mass Removal
The three phased approach to soil vapor extraction off-gas treatment technology selection results in lower cost and reduced time.

The multiple decision criteria model is based on lifecycle economic factors influenced by the currently available technology operation performance, efficiency and cost as they relate to the site conditions including, the geology and contaminant chemistry.

The graphs shown to the right illustrate the difference in operational performance in a cost per pound vs. influent vapor concentration calibrated to total life cycle cost of operation for one year with respect to three technologies evaluated during the feasibility process prior to technology selection, including activated carbon, thermal oxidation, and refrigerated condensation (C3-Technology).

What is C3 Technology?
The C3 Technology (Patent Pending) developed by GEO, Inc. is a combination of cryogenic, compression, and condensation (C3) with a proprietary regenerative adsorption technology that efficiently recovers volatile organic compounds (VOCs) from the off-gas vapor stream of soil vapor extraction (SVE) or multi-phase extraction (MPE) systems. The chemical is recovered as a non-aqueous phase liquid (NAPL) that is temporarily containerized in appropriate vessels for off-site recycling, re-use or fuel blending incineration. Generally, greater than 99.8% of the VOCs are recovered from the vapor stream. Depending on the contaminant and state or local agency permits requirements and guidance, final effluent may be polished with granular activated carbon (GAC).

Process Description
- Soil vapor or mixture of vapor and water is drawn from the subsurface through extraction wells by a positive displacement blower and through an air-water separator where entrained liquids are separated.
- Process air is then delivered to a compressor where it is compressed to approximately 150 pounds per square inch (psi) before entering an air-cooled after-cooler.
- Condensed water vapor is removed from the vapor stream during compression and at the air-cooled after-cooler as it is cooled to ambient temperature.
- From the air-cooled after-cooler, the vapor stream is further cooled to approximately -40°F in the cryogenic stage refrigerated heat exchangers, where the majority of the chemical constituents are condensed and separated from the chilled vapor stream.
- The chilled vapor stream is then sent to a regenerative adsorber, which removes any residual chemical constituents and directs it back to the inlet stream at the air-water separator.
- Condensed liquids are securely drummed and transported off-site or treated on-site and discharged in accordance with all local and federal regulatory requirements.