Evaluation of the Petroleum Vapor Intrusion Risk of Ethylene Dibromide (EDB) and 1,2 Dichloroethane (1,2 DCA)

RemTech

2017
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Background
Petroleum Vapour Intrusion

A subset of Vapour Intrusion, from
› Light nonaqueous phase liquids (LNAPL) source
› PHC contaminated soil and
› PHC contaminated groundwater

Migration is often limited by microorganisms that are normally presented in soil, which is different than
› Radon and
› Chlorinated solvents vapour
Occurrence of Petroleum Vapor Intrusion

- Documented occurrences of PVI intrusions are rare
- Assessment largely driven by vapour modelling that does not consider biodegradation (J-E model)

© EPA
PVI screening distance
PVI Screening Distance – Vertical

Figure 6. Vertical Separation Distances Between Source Of PHC Contaminants And Hypothetical Receptor: (a) Dissolved Source, (b) LNAPL Source.

Figures © EPA
PVI Screening Distance – Lateral

Figure 5. Lateral Separation Distance Between Source Of PHC Contamination And Hypothetical Receptor

Figures © EPA
PVI-Screen Distance – Precluding Factors

› Influence of methanogenesis on oxygen demand - higher ethanol blends of gasoline
› Effect of extensive high organic matter soils (e.g. peat) with potentially high natural oxygen demand
› Reduce oxygen flux caused by certain geological conditions (which are not favorite aerobic microorganisms)
› Fractured rock
› Non UST sites (refinery, terminals) and
› Leaded gasoline sites
Lead Scavengers
Use

- EDB = lead additive; soil fumigant
- 1,2 DCA = lead active; commercial chemical/solvent, paints, etc.

### Chemical Properties

<table>
<thead>
<tr>
<th>Compound</th>
<th>Henry’s Low Constant</th>
<th>Vapor Pressure (mm Hg)</th>
<th>Effective Solubility-Gasoline&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Effective Air-phase Saturation (ug/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDB</td>
<td>0.027</td>
<td>11</td>
<td>1,900</td>
<td>51</td>
</tr>
<tr>
<td>1,2DCA</td>
<td>0.048</td>
<td>79</td>
<td>3,700</td>
<td>178</td>
</tr>
<tr>
<td>Benzene</td>
<td>0.23</td>
<td>95</td>
<td>15,000</td>
<td>3,450</td>
</tr>
</tbody>
</table>

<sup>a</sup> - Falta, 2004. *Ethylene Dibromide and 1,2-Dichloroethane Contamination from Leaded Gasoline Releases, Ground Water Management - Petroleum Hydrocarbons and Organic Chemicals in Ground Water: Prevention, Assessment, and Remediation Conference*, pp. 252-260
Background: Biodegradation

Fate and Transport (in subsurface)

› Aerobic biodegradation
  › EDB: $t_{1/2} = \text{days} - \text{weeks}$
  › 1,2 DCA: $t_{1/2} = \text{days} - > \text{several months}$

› Anaerobic:
  › EDB: $t_{1/2} = \text{months}$
  › 1,2 DCA: $t_{1/2} = \text{months} - \text{years}; \text{sulfate, methanogenic conditions only}$

Co-metabolic biodegradation demonstrated (methane), yet biodegradation may be slowed in the field by the presence of other hydrocarbons.
Background: Analytical Methods

<table>
<thead>
<tr>
<th>Method</th>
<th>1,2 DCA</th>
<th>EDB</th>
<th>Screening Level&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1, 2 DCA</td>
</tr>
<tr>
<td>Groundwater (µg/L)</td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>8260B</td>
<td>3</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>8011</td>
<td>0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil Vapour (µg/m³)</td>
<td></td>
<td></td>
<td>0.4</td>
</tr>
<tr>
<td>8260B</td>
<td>100</td>
<td>200</td>
<td>0.4</td>
</tr>
<tr>
<td>TO 15</td>
<td>4-8</td>
<td>7.5-15</td>
<td>0.4</td>
</tr>
<tr>
<td>TO-15 (sim)</td>
<td>0.2</td>
<td>0.4</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> - contaminated site regulation, British Columbia Ministry of Environment 2014
Background: Occurrence (EDB United States)

The distribution of EDB in the sites included in the OUST State Survey is similar to the distribution in South Carolina.

<table>
<thead>
<tr>
<th>Maximum Concentration at Site</th>
<th>South Carolina (Falta data)</th>
<th>OUST State Survey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above 100 μg/L</td>
<td>7%</td>
<td>6%</td>
</tr>
<tr>
<td>Above 50 μg/L</td>
<td>11%</td>
<td>10%</td>
</tr>
<tr>
<td>Above 1 μg/L</td>
<td>35%</td>
<td>25%</td>
</tr>
<tr>
<td>Above 0.05 μg/L</td>
<td>50%</td>
<td>42%</td>
</tr>
</tbody>
</table>

Percent of Sites
Background: Occurrence in the US

Figure 5: % Sites with EDB

Figure 6: % Sites with 1,2 DCA

# of states monitoring for lead scavengers

Background: Risk (EDB) © EPA
Our Study
Background/Initiative

› New methodology developed for PVI site screening
› Method based on use of vertical screening distances
› Method incorporated into ITRC, US EPA OUST, and California Low Threat Tank Closure Policy
› Historical leaded gasoline releases defined as “precluding factor” in US EPA OUST & ITRC guidance
Objectives

› Assess PVI risk
› Develop risk-based exclusion distance criteria for use in PVI assessments at petroleum-hydrocarbon release sites based on sound science
## Empirical Databases

<table>
<thead>
<tr>
<th>SNC-Lavalin 139 UST sites – Western Canada</th>
<th>Sites</th>
<th>% of database</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pb scavengers in groundwater (analyzed)</td>
<td>66</td>
<td>47</td>
</tr>
<tr>
<td>Pb scavengers &gt; DLs in groundwater</td>
<td>7</td>
<td>5*</td>
</tr>
<tr>
<td>EDB = 0.5 μg/L; 1,2-DCA = 0.5 μg/L</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Geotracker Database

<table>
<thead>
<tr>
<th>Area Name (25)</th>
<th>#Total Sites (extracted)</th>
<th>GW L.S. analyzed</th>
<th>Soil Gas L.S. Analyzed</th>
<th>Both</th>
<th>Paired points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alameda</td>
<td>767</td>
<td>109</td>
<td>51</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Butte</td>
<td>102</td>
<td>6</td>
<td>3</td>
<td>1</td>
<td>0</td>
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<tr>
<td>Contra Costa</td>
<td>277</td>
<td>48</td>
<td>29</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>Orange</td>
<td>796</td>
<td>796</td>
<td>156</td>
<td>156</td>
<td>36</td>
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<tr>
<td>Riverside</td>
<td>351</td>
<td>352</td>
<td>65</td>
<td>65</td>
<td>0</td>
</tr>
<tr>
<td>SanLuisObispo</td>
<td>158</td>
<td>158</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Fresno</td>
<td>209</td>
<td>209</td>
<td>14</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>Salano</td>
<td>750</td>
<td>686</td>
<td>62</td>
<td>51</td>
<td>0</td>
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<tr>
<td>SantaCruz</td>
<td>173</td>
<td>173</td>
<td>18</td>
<td>18</td>
<td>0</td>
</tr>
<tr>
<td>Shasta</td>
<td>40</td>
<td>32</td>
<td>2</td>
<td>1</td>
<td>0</td>
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<tr>
<td>Sutter</td>
<td>42</td>
<td>37</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Tuolumne</td>
<td>43</td>
<td>38</td>
<td>8</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Kings</td>
<td>49</td>
<td>36</td>
<td>12</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Lake</td>
<td>46</td>
<td>28</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Los Angeles</td>
<td>2,161</td>
<td>255</td>
<td>114</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>Mariposa</td>
<td>22</td>
<td>12</td>
<td>2</td>
<td>2</td>
<td>0</td>
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<tr>
<td>Merced</td>
<td>150</td>
<td>150</td>
<td>33</td>
<td>33</td>
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<tr>
<td>Napa</td>
<td>115</td>
<td>115</td>
<td>8</td>
<td>8</td>
<td>0</td>
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<tr>
<td>Sacramento</td>
<td>395</td>
<td>40</td>
<td>34</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>SanBernardino</td>
<td>211</td>
<td>27</td>
<td>11</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>SanDiego</td>
<td>1,000</td>
<td>170</td>
<td>68</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>SantaBarbara</td>
<td>352</td>
<td>88</td>
<td>10</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Sonoma</td>
<td>457</td>
<td>81</td>
<td>15</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Ventura</td>
<td>390</td>
<td>59</td>
<td>10</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Yuba</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>9,056</strong></td>
<td><strong>3,705</strong></td>
<td><strong>733</strong></td>
<td><strong>423</strong></td>
<td><strong>43</strong></td>
</tr>
</tbody>
</table>
Database Development: General Elements

- Groundwater and soil gas concentrations
- Soil gas sampling method (vapor probe, monitoring well head space)
- Soil type (presence of fractured rock)
- Surface cover (asphalt, open, building)
- Source type (LNAPL, dissolved)
- Water-table elevation
- Facility type (UST, industrial)
- Sampling dates
- Presence of fractured rock (excluded)
- Vertical separation distances
- Lateral offset (source, monitoring well)
- Method (detection limits)
- Site operational history (releas pre-1986, operation pre-1986)
- QA/QC (including leak testing, no on-going remediation, GW well screened across water table)
Evaluation of the Petroleum Vapor Intrusion Risk of Ethylene Dibromide (EDB) and 1,2 Dichloroethane (1,2 DCA), RemTech 2017

1,2 DCA: All Data

- 10 ft from waste oil tank
- MW Headspace - LNAPL
- 5 ft from waste oil tank
- Source soil (railroad siding)

Graph showing soil gas concentration in different distances above the source.

Bar chart showing the percentage of samples with 1,2 DCA concentration in groundwater.
1,2 DCA: Paired Data

**PAIRED DATA**

- < 30 days between sample events
- < 30 ft between sample locations
- vapour probe only
- > 10 ft from source areas (waste-oil tanks)

![Graph showing 1,2 DCA concentration in groundwater (µg/L)]
1,2 DCA: Paired Data

![Graph showing the relationship between groundwater concentration and soil-gas concentration for 1,2 DCA, with data points indicating detection and non-detection of soil-gas. The graph includes a predicted soil-gas concentration based on equilibrium partitioning.]
EDB: All Sites with Historical Use of Leaded Gasoline

[Graphs showing EDB concentrations in soil gas (µg/m³) versus distance above source-water table (m) for EDB (LNAPL) and EDB (DISSOLVED-PHASE).]

Evaluation of the Petroleum Vapor Intrusion Risk of Ethylene Dibromide (EDB) and 1,2 Dichloroethane (1,2 DCA), RemTech 2017
EDB: Paired Data

- **GROUNDWATER CONCENTRATION (μg/L)**
- **SOIL-GAS CONCENTRATION - LOWERMOST PROBE (μg/m³)**

- **Non Detect (13 Samples)**

- Predicted soil-gas concentration based on equilibrium partitioning

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Conclusions

› Inability to assess screening distances
  › Lots of ND data (method DLs and RLs above soil-gas screening levels, especially for EDB)
  › Few representative soil-gas/groundwater data pairs

› Empirical data indicate limited PVI risk
  › Aerobic biodegradation – rates similar to benzene
  › Volatility – lack of occurrence in groundwater
  › Results consistent with empirical studies (limited detections of hydrocarbons in soil-gas above dissolved-phase sources)
Acknowledgements

Matthew Lahvis, Ph.D.,
Team Lead Soil and Groundwater
(Shell Projects and Technology US)

Janice Paslawski, Ph.D., P.Eng.
Director, Risk Assessment Centre of Excellence
(SNC-Lavalin)
Values that guide us

Our values keep us anchored and on track. They speak to how we run our business, how we express ourselves as a group, and how we engage with our stakeholders and inspire their trust.

Teamwork & excellence
We’re innovative, collaborative, competent and visionary.

Customer focus
Our business exists to serve and add long-term value to our customers’ organizations.

Strong investor return
We seek to reward our investors’ trust by delivering competitive returns.

Health & safety, security and environment
We have a responsibility to protect everyone who comes into contact with our organization.

Ethics & compliance
We’re committed to making ethical decisions.

Respect
We consistently demonstrate respect for all our stakeholders.