TRICHLOROETHYLENE in Edible Fruit Growing Above Shallow Groundwater Plumes: field survey results

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TRICHLOROETHYLENE in edible fruit growing above shallow groundwater plumes: field survey results.

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- Tiffany Leo
- Clint Rogers
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HAFB history/overview

• Maintenance facility, active since the early 1940s
• Solvents releases investigated since 1976
• 6,670 acres on a plateau roughly 300 feet above the valley floor.
• Surrounded by the communities of South Weber, Riverdale, Sunset, Clearfield, Clinton, Roy and Layton.
• Adjacent land use is residential and mixed agricultural, commercial and residential.
Climate

- Temperate and semi-arid
- The frost-free growing season: May-September
- Average annual precipitation: 19.8 inches mainly in October-May
Hill Air Force Base Operable Unit Sites

- OU1
- OU2
- OU3
- OU4
- OU5
- OU6
- OU7
- OU8
- OU9
- OU10
- OU11

Legend:
- Soil contaminated below risk-based levels
- Soil contaminated above risk-based levels
- Extent of ground-water contamination
- Extent of LNAPL
- OU 2, 4, 5, 6, 8, 10, and 11 show TCE isoconcentration contour lines
  - 5-10
  - 10-100
  - 100-1,000
  - 1,000-10,000
  - >10,000
- OU 1 shows 1,1-DCE isoconcentration contour lines
  - 0-70
  - 70-1,000
  - >1,000
- OU 8
- 1,2-DCA plume
Fall 2001

- TCE identified in trees (cottonwood, willow) on base.
- Residents near base requested that samples of fruit and vegetables be analyzed for TCE.
- Locations chosen mainly on specific requests from landowners.
- 200+ samples collected (including replicates) from fruit trees (apple, peach, pear) and other vegetation (tomato, zucchini) above historical plume boundaries.
- Analysis by headspace gas chromatography with electron capture detection (GC/ECD) and GC/MS in SIM mode using procedure developed for tree cores
Backyard sampling
ECD chromatogram
TCE found in local fruit tree samples

by Charles Freeman
Environmental Public Affairs

Results from a recent Hill AFB sponsored study show traces of TCE (Trichloroethylene) in home-grown fruit from selected fruit trees sampled in Sunset and Clinton.

In August and September, Utah State University scientists - at Hill's request - sampled fruit trees and vegetable gardens for possible contamination and discovered small traces of the chemical in the fruit samples. Hill environmental officials believe this could be the first time TCE has ever been detected in homegrown fruits.

Hill officials did the study after they were approached by residents who attended environmental-sponsored InfoFairs held last fall in Sunset and Clinton. At that time, nine residents asked environmental personnel to sample their fruit trees and vegetable gardens for possible contamination.

Extremely low traces of TCE were found in trees belonging to seven of the nine residents. There was no detection of TCE in fruit at the property of the other two residents. In addition, the study showed no such contamination in vegetable gardens sampled in the same areas.

During the last few years community outreach efforts have been stepped up considerably by Hill's environmental staff. The InfoFairs provide an opportunity for people in the surrounding areas, impacted by the groundwater contamination, to get pertinent information on Hill's cleanup program.

TCE is a degreasing solvent commonly used at Hill AFB until the mid-1970s and is the most common groundwater contaminant at Hill. According to published information, TCE is suspected of causing cancer in animals, but its effects on humans, especially at low levels, isn't known.

“The sample results came as a complete surprise to us,” said Allan Dalpiaz, the base's director of Environmental Management. “When the first set of sampling results arrived in late August, our first inclination was that there was probably a mistake somewhere.” A second set of samples

How chemicals get into trees

Trees pump the most water during the spring and summer when the fruit is growing. Once the fruit has matured, the tree pumps less water. During winter, the tree pumps just enough water to stay alive.

Trees take up water where they can find it. Mature trees have roots that can reach down to the shallow groundwater. In contaminated areas, the lowest chemical concentrations are at the top of the shallow groundwater.

Shallow Groundwater

Chemicals in the groundwater are pumped up through the roots and into the leaves and fruit.
2001 Results Summary

• TCE found in fruit samples
  – < MDL (0.1) to 18 µg TCE/kg fresh wt.
• ECD results confirmed with GC/MS SIM
• TCE levels in the fruit were as high or higher than those in stem cores collected from the same tree.
• TCE concentrations and the frequency of detections in the fruit samples were generally higher in the August than in the September.
2002 Objectives

- Validate headspace/GC/MS SIM method for quantifying TCE in fruit tissue and establish method detection limits suitable for risk assessment.

- Collect and analyze field samples.

- Determine whether the detection of TCE in fruit in fall 2001 was an isolated incident.
Method validation study

• Fruit Type
  – Apple
  – Peach
  – Tomato
  – Carrot

• MDL
  – 0.05 $\mu$g/kg wet wt
2002 Field Sampling

Sample Types
- Fruits: apples and peaches
- Vegetables: tomatoes and carrots
- Tree cores (when permitted by the landowner)

Other considerations
- Availability of selected plant types
- GW TCE concentration and depth
- Resident willingness & previous year’s participation
2002 Sampling location map

HAFB

TCE Concentration (mg/L)

- 5-10
- 10-100
- 100-1,000
- 1,000-10,000
- > 10,000

Sampling area boundary
Sample collection and analysis
Headspace/GCMS Analysis

• Hewlett-Packard® 6890 GC/5973 MS in SIM mode.
  – Column: DB-624, 30 m x 0.25 mm, 1.4 μm
  – Carrier gas: He at 0.7 mL/min (3.52 psi);
  – Temperature program: 35 ºC for 2 min to 170 ºC at 30 ºC/min, then 170 to 230 ºC at 70 ºC/min. with a 1 min. hold 230 ºC
  – Split/splitless inlet vent flow 10.4 mL/min.; and split ratio was 15:1.

• Tekmar 7000HT Headspace Analyzer/Autosampler
  – Platen/sample temperature: 50 ºC,
  – Transfer line and sample loop temperatures: 180 ºC.
  – Sample equilibrium time: 10 min.
  – Headspace sample volume: 2 mL
QA/QC samples

- Minimum of one of each type for each sample location:
  - trip blank
  - spiked MMS
  - blank MMS
  - spiked fruit
  - “clean” fruit
Fall 2002 Results

• Over 400 samples were collected (including replicates) from six communities surrounding HAFB.
• No TCE was found in any of the fruit or vegetable samples above MDL (approximately 0.05-0.1 ug/kg fresh weight, depending on sample size)
• TCE was detected in several fruit tree core samples.
Fall 2003 objectives

• Focus on 5 sites
  – Shallow GW (5-7 ft bgs) low TCE (0.1-10 ppb)
  – Shallow GW high TCE (25-350 ppb)
  – Deep GW (10-20 ft bgs) low TCE
  – Deep GW high TCE
  – Shallow GW no TCE

• Limitations: Type and age of tree varied greatly
Fall 2003 Approach

• Samples collected at same 5 locations over entire growing season
  – Fruit (apples, peaches)
  – Cores
  – Stems
  – Groundwater
  – Soil gas
Fall 2003 Methods

• Locations
  – Same general areas as 2001-2002

• Fruit
  – Same method as 2002 (headspace/GC/MS)

• Groundwater
  – Headspace GC/MS

• Soil Gas
  – Hand-driven well points
  – Soil gas collected on Tenax traps
  – Traps analyzed by thermal desorption/GC/MS
2003 results

- TCE in found in three fruit samples
  - Walnut (green peel): 0.25 µg/kg wt weight
    - Groundwater 13 ppb, 10-12 ft bgs
    - Core concentration: 10 µg/kg
  - Apples 0.24, 35 µg/kg wt weight
    - Groundwater 350 ppb, 15-30 bgs
    - Core concentration: 100 µg/kg
- TCE found in same tree cores as 2001-02
Summary of 2001-2003 fruit results

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>2001 Total</th>
<th>2001 &quot;Hits&quot;</th>
<th>2002 Total</th>
<th>2001 &quot;Hits&quot;</th>
<th>2003 Total</th>
<th>2003 &quot;Hits&quot;</th>
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</thead>
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<tr>
<td>Fruit</td>
<td>134</td>
<td>12</td>
<td>87</td>
<td>0</td>
<td>172</td>
<td>3</td>
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<tr>
<td>Peel</td>
<td>0</td>
<td>0</td>
<td>42</td>
<td>0</td>
<td>31</td>
<td>0</td>
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<td>Core</td>
<td>45</td>
<td>15</td>
<td>26</td>
<td>7</td>
<td>207</td>
<td>119</td>
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<tr>
<td>Leaf</td>
<td>33</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>190</td>
<td>4</td>
</tr>
<tr>
<td>Twigs</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>177</td>
<td>51</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>216</strong></td>
<td><strong>27</strong></td>
<td><strong>155</strong></td>
<td><strong>7</strong></td>
<td><strong>777</strong></td>
<td><strong>177</strong></td>
</tr>
</tbody>
</table>
**Fruit Tree Physiology**

**Xylem** delivers water and nutrients from roots to leaves, stems, and fruit.
- High flow rates (10 cm/min).
- Unidirectional movement
- Backflow during times of high transpiration
- Lateral movement to phloem can occur
- Small contribution to fruit growth

**Phloem** transports photosynthates from leaves to fruits, stems, and roots
- Low flow rates (1 cm/min)
- Bidirectional movement
- Large contribution to fruit growth

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**Early Stages of Fruit Development**
- ~ Half phloem contribution
- ~ Half xylem contribution

**Later Stages of Fruit Development**
- ~ Large phloem contribution
- ~ Small xylem contribution
Modeling Plant Uptake of Organics (Trapp et al., 2003)

- Growth dilution
- Metabolism

Diagram:
- Leaves
- Fruit
- Stem
- Soil
- Soil water
- Roots
- Air
- Xylem
- Phloem
- TSCF
- RCF
- K_{LA}
- K_{d}
- K_{RA}

Processes:
- Metabolism
- Sorption

Connections:
- K_{d}
- RCF
- K_{RA}
Conclusions??
Potential factors impacting tree and fruit concentrations

Above ground variables:
- Tree type
- Tree age/size
- Irrigation patterns
- Time of season
- # of fruit

Below ground variables:
- TCE GW concentration
- Depth to GW
- TCE soil & soil gas conc
- Soil type
- Fraction of GW used