Evaluation of Environmental Hazards at Sites with Contaminated Soil and Groundwater

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Outline

• Petroleum Target COPCs
• Environmental Hazard Evaluation (EHE)
  – Overview of Environmental Hazards
  – Environmental Screening Levels (ESLs)
  – Environmental Hazard Tables & Maps
  – Advanced evaluation of environmental hazards
• EHE Reports
• Environmental Hazard Management Plans
References:

*Evaluation of Environmental Hazards at Sites with Contaminated Soil and Groundwater, Pacific Basin Edition (Summer 2008, updated Oct 2008):*
http://hawaii.gov/health/environmental/hazard/pacificbasin.html

  • Similar guidance available from CalEPA and Hawai‘i DOH;
  • Pacific Basin edition more closely follows USEPA guidance

Target Petroleum COPCs

- BTEX <15%
- *PAHs <1%
  (*naphthalenes)
- TPH 85%
- Gasoline
Target Petroleum COPCs

TPH >97%

BTEX <1%

*PAHs 2-3%

(*naphthalenes, methylnaphthalenes)

Diesel
Petroleum Target COPCs

**Gasolines**
- TPH, BTEX, naphthalene, additives (MTBE, TBA, ethanol, etc.)
- Soil gas: TPH, VOCs + methane

**Middle Distillates**
- TPH, BTEX, naphthalene, methylnaphthalenes
- Soil gas: same

**Residual Fuels**
- TPH, VOCs, PAHs (15), other
- Soil gas: same
Environmental Hazard Evaluation

- Site Investigation
- Environmental Hazard Evaluation
- Response Action

Advanced Evaluation of Targeted Hazards
Environmental Hazard Evaluation
- Something for Everyone -

• Chemistry: What is it?
• Geology: Where is it?
• Physics: Where is it going?
• Toxicology: What can it do to me?
• Combined: What are the concerns?
• Engineering: What can be done?
• Lawyers: Who’s going to pay for it?
Direct Exposure

Groundwater Flow

Prevailing Wind Direction

Leaching

Ecotoxicity

Gross Contamination

Free Product

Discharge to aquatic habitats

Dissolved plume

Stream

Drinking Water

Vapor Intrusion
Environmental Hazards

- **Terrestrial Habitats**
  - Gross Contamination
- **Aquatic Habitats**
  - Gross Contamination
  - Leaching
- **SOIL**
  - Human Health
  - Vapors Intrusion
  - Direct Exposure
- **SOIL GAS**
  - Vapors Intrusion
  - Drinking Water (toxicity)
- **GROUNDWATER**
  - Human Health
Benzene ESLs
Residential, exposed soils, over drinking water

Terrestrial Habitats
25 mg/kg

Gross Cont.
500 mg/kg

Human Health

SOIL

Leaching: 0.31 mg/kg

Aquatic Habitats
46 ug/L

Gross Cont.
170 ug/L

Human Health

GROUNDWATER

Vapors to IA
1,500 ug/L

Drinking Water
5.0 ug/L

0.25 ug/m³

INDOOR AIR

Vapors to IA
0.53 mg/kg

Direct Exposure
1.1 mg/kg

250 ug/m³

SOIL GAS
Tier 1 Environmental Screening Levels
"Risk" Drivers For Soil

Leaching (75%)

Direct Exposure

Vapor Intrusion

Other
Explosive hazards, nuisances, gross contamination, etc.
## Contaminant Group vs Primary Environmental Hazards

<table>
<thead>
<tr>
<th>Concern</th>
<th>Chemical Family</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaching</td>
<td>Light petroleum, solvents, pesticides, inorganic salts</td>
</tr>
<tr>
<td>*Direct Exposure</td>
<td>Carcinogen PAHs, PCBs, metals, etc.</td>
</tr>
<tr>
<td>Vapor Emissions</td>
<td>Carcinogenic VOCs</td>
</tr>
<tr>
<td>Terrestrial Ecotoxicity</td>
<td>Noncarcinogenic metals &amp; pesticides</td>
</tr>
<tr>
<td>Gross Contamination</td>
<td>Heavy TPH, noncarcinogenic metals &amp; solvents, phenols, etc.</td>
</tr>
</tbody>
</table>

*Ingestion and dermal absorption
Environmental Screening Levels (ESLs)

- ESLs for 150 common contaminants
- Soil, Groundwater, Surface Water; Soil Gas, Indoor Air
- No significant environmental hazards if concentration of contaminant is less than the ESL
- Volume 1: Tier 1 Final ESLs
- Volume 2: Detailed Screening levels
### ESL Lookup Tables

#### Soil and Groundwater Summary ESLs

<table>
<thead>
<tr>
<th>Ground-Water Use</th>
<th>Shallow Soil</th>
<th>Deep Soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>DW</td>
<td>TABLE A</td>
<td>TABLE C</td>
</tr>
<tr>
<td>Non DW</td>
<td>TABLE B</td>
<td>TABLE D</td>
</tr>
</tbody>
</table>

**Summary Tables:**
- Residential vs Commercial/Industrial Land use
- Table E: Indoor Air & Soil Gas
- Table F: Surface Water
- Detailed tables in Appendix 1
ESL Surfer

• Electronic lookup tables;
• Rapidly screen data and identify potential environmental hazards;
• Printable report summaries
Use of ESLs

• Screen out “low-risk” sites
• Use to complete investigations & delineate areas of potentially significant contamination
• Quickly identify potential environmental hazards
• Focus on advanced evaluation of tentatively identified hazards as needed
Contaminant Fate & Transport

Equilibrium Partitioning Factors:

\[ H' = \frac{\text{Vapor Conc.}}{\text{Dissolved Conc.}} \]

\[ K_d = \frac{\text{Sorbed Conc.}}{\text{Dissolved Conc.}} \]

Total Soil Conc. = Sorbed + Dissolved + Vapor + NAPL

Soil Properties: moisture, organic carbon, etc.
Tier 1 Contaminant Partitioning in Soil (based on default USEPA RSL soil type)

Sorbed  Vapor  Dissolved

Vinyl Chloride  BaP  Benzene  Perchlorate

Are VOCs & SVOCs really “volatile”?
Environmental Hazards

- Terrestrial Habitats
  - Gross Contamination
  - Human Health
  - Leaching

- Aquatic Habitats
  - Gross Contamination

- Soil
  - Vapors Intrusion
  - Direct Exposure

- Soil Gas

- Groundwater
  - Vapors Intrusion
  - Drinking Water (toxicity)
  - Human Health
### Direct Exposure

**“Dose Makes The Poison”**

<table>
<thead>
<tr>
<th>Chemical</th>
<th><em>Maximum Daily Dose (mg/day)</em></th>
<th>Chronic Health Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>10,000,000+ (a few gallons)</td>
<td>hyponatremia</td>
</tr>
<tr>
<td>Aspirin</td>
<td>&gt;100</td>
<td>G/I tract</td>
</tr>
<tr>
<td>PCBs</td>
<td>0.0002</td>
<td>Multiple</td>
</tr>
</tbody>
</table>

MTBE maximum daily dose = 24 ug/day  
Assumed water consumption = 2 L/day  
Drinking water action level = 12 ug/L  

*For example only*
## Direct Exposure
(assumed daily exposure)

<table>
<thead>
<tr>
<th>Media</th>
<th>Child Exposure</th>
<th>Adult Exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drinking Water</td>
<td>1 liter/day</td>
<td>2 liter/day</td>
</tr>
<tr>
<td>Air</td>
<td>10 m³/day</td>
<td>20 m³/day</td>
</tr>
<tr>
<td>Soil</td>
<td>200 mg/day</td>
<td>100 mg/day</td>
</tr>
</tbody>
</table>

*For example only*
Common Problems

• Key COPCs ignored (e.g., TPH)
• No Exposure = No Risk
  – Vapor emissions to outdoor air (e.g., benzene?)
  – Other environmental hazards?
  – Implied land use restrictions (caps, etc.)?
  – Long-term management requirements?
When Do You Need a Risk Assessor?

More Work (not less!)
• Keep track of the Big Picture & prepare EHE
• Help design site investigation (exposure areas)
• Evaluate current direct exposure hazards & complex mixture of contaminants
• Support alternative cleanup levels
• Evaluate dietary exposure
• Support litigation
• Explain health concerns to public
Tier 1 Direct Exposure Models

- Based on USEPA RSL models & assumptions
- Default cancer risk $10^{-6}$; noncancer HQ 0.2
- Target $10^{-5}$ risk used for widespread, urban contaminants (PAHs, PCBs, Technical Chlordane)
- Route-to-Route extrapolation used for VOCs that lack an IUR or RfC (problem with some RSLs)
- Test for bioaccessible arsenic if total As > 20mg/kg
- Traditional human health risk assessment required in rare cases

Refer to Volume 1 & Appendix 1 of EHE guidance for details
Tier 2 Soil Direct Exposure Model

Options:
• Exposure assumptions
• Target risk
• Thickness of contaminated soil

Tier 1 – Infinite source thickness
Tier 2 – Site specific thickness
Arsenic Bioaccessibility in Hawai‘i

Wood Treatment facility (7,720 mg/kg; 83% BA)

- Typical Fields
- Kea‘au Fields
- Golf Course
- Plantation Camp

Most fields

In vivo study

Total Arsenic (mg/kg)
Vapor Intrusion Hazards
(example PCE action levels)

- Indoor Air (0.33 ug/m³)
- Soil Gas (330 ug/m³)
- Soil 0.07 mg/kg
- Groundwater (140 ug/L)

Background 1+ ug/m³

Step 1

Step 2

Step 3

Residence
Common Vapor Intrusion Model Problems

• Assume wet, clayey soil directly under building slab
  – “Stops” vapor flow into building
  – More common: Dry, permeable, silty/sandy fill material
  – Allows moderate flow of vapors into building (default 5 L/minute per 100m² floor area)
Step 1. Compare PCE in groundwater to screening level for vapor intrusion.

**Groundwater VI Screening Level Exceeded**
Step 2. Collect soil gas data

Soil Gas Samples

for example only
Compare soil gas data to screening level for vapor intrusion.

Soil Gas Screening Level Exceeded

for example only
Step 3. Indoor Air Sampling (Caution!)

- Indoor sources of VOCs (e.g., petroleum & solvents)
- Indoor air data often inconclusive
- Avoid for petroleum unless soil gas data > 1,000 times typical levels in ambient air
- Avoid for HVOCs unless screening levels significantly exceeded
Leaching of Contaminants from Soil

1. Concentration in soil

2. Concentration in source leachate

3. Concentration in leachate at groundwater interface

4. Concentration in groundwater
Advanced Evaluation of Leaching Hazards

- Tier 1 leaching model over predicts contaminant mobility and concentration in leachate.
- Tier 1 leaching screening levels excessively stringent
- USEPA SPLP Batch Test Leaching Model more accurately estimates Kd and leaching hazards
Tier 1 Kds vs Batch Test Kds

**Default Kds**
- 1,000+ 
  - BaP (790) → Not Mobile
- 20 
- 10 
- 1
  - TPH-diesel (5) → Slight
  - Atrazine (0.23) 
  - Benzene (0.17) 
  - PCE (0.11) 
  - Perchlorate (0) → High

**Site-Specific Kds**
- Arsenic: 14,000+
- TPH-diesel (290?)
- Benzene (10)
- Atrazine (7)
- Perchlorate (4)

Much greater sorption of aged contaminants to soil than predicted.
Explosives Related Contaminants

AMINO,2- DINITROTOLUENE,3,6-
AMINO,4- DINITROTOLUENE,2,6-
CYCLO-1,3,5-TRIMETHYLENE-2,4,6-TRINITRAMINE (RDX)
DINITROBENZENE, 1,3-
DINITROTOLUENE, 2,4- (2,4-DNT)
DINITROTOLUENE, 2,6- (2,6-DNT)
NITROBENZENE
NITROGLYKERIN
NITROTOLUENE, 2-
NITROTOLUENE, 3-
NITROTOLUENE, 4-
PENTAERYTHRITOLTETRANITRATE (PETN)
TETRANITRO-1,3,5,7-TETRAAZOCYCLOOCTANE (HMX)
TRINITROPHENYLMETHYLNITRAMINE, 2,4,6- (TETRYL)
TRINITROTOLUENE, 1,3,5-
TRINITROTOLUENE, 2,4,6- (TNT)

Environmental Hazards almost always driven by potential leaching and groundwater contamination.
Common Problems

- Ignored
- Models underestimate permeability of clayey/silty intervals (longer travel time)
- Assumed biodegradation rates overestimate contaminant loss in leachate
- Impacts to groundwater underestimated

But:

- Models underestimate sorption to clays (Kd factor)
- Overestimate contaminant mobility and potential impacts to groundwater
Bad Kds…

- Excessively “low” soil leaching cleanup levels
- Pump & treat rebound forever
- Vastly underestimate contaminant mass in plume
Ecological Impacts

**Soil**
- Ontario MOE summary of ecotoxicity factors (limited contaminants)
- Site-specific study if important habitat

**Groundwater (discharges to aquatic habitats)**
- Promulgated aquatic toxicity standards
- Other published criteria and studies
- Groundwater should meet chronic surface water action levels at discharge point
Groundwater Discharges to Surface Water
Groundwater Discharges to Surface Water
(thermal image)
Groundwater Discharges to Surface Water

Freshwater Springs
Along Shoreline
Common Problems

- Ignored
- Not a source of drinking water = no risk
- Models overestimate dilution in hypothetical mixing zone prior to discharge
Advanced Evaluation of Groundwater Discharge Hazards

• Groundwater monitoring (best)
• Increased monitoring in buffer zones adjacent to habitats (e.g., 150m)
• Modeling (to guide remediation and monitoring program)
Gross Contamination Hazards

- Odors & nuisance
- Explosive vapors
- Potentially mobile free product
- Interference with future development
- General resource degradation
Drinking Water Gross Contamination (Secondary MCLs)

Final drinking water action levels for many nonchlorinated chemicals with low toxicity based on taste & odor concerns.
## Tentatively Identified Hazards – Next Steps

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Next Steps</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Direct Exposure:</strong></td>
<td>Talk to a risk assessor</td>
</tr>
<tr>
<td><strong>Total Arsenic &gt;20 mg/kg:</strong></td>
<td>Test for bioaccessible As</td>
</tr>
<tr>
<td><strong>Vapor Intrusion:</strong></td>
<td>Collect soil gas samples</td>
</tr>
<tr>
<td><strong>Leaching:</strong></td>
<td>Run SPLP batch tests</td>
</tr>
<tr>
<td><strong>Discharges to aquatic habitats:</strong></td>
<td>Monitor groundwater &amp; storm sewers</td>
</tr>
<tr>
<td><strong>Gross Contamination:</strong></td>
<td>Field check</td>
</tr>
</tbody>
</table>
Site-Specific Conceptual Site Models

Potential Exposure Pathways
- Ingestion
- Inhalation (vapors & dust)
- Dermal absorption

Exposed soil?

Leaching?

Groundwater Impacted?

Discharges to aquatic habitats?

Vapors intruding buildings?

Wells Impacted?
EHE Report

- Site Background
- Summary of investigations
- Comparison of site data to action levels
- EHE: Identification of potential hazards
- Advanced evaluation of targeted hazards
- Conclusions & Recommendations
  - Summarize findings
  - Addition site investigation?
  - Advanced evaluation of targeted hazards?
  - Prepare remedial action plan?
  - Prepare EHMP?
  - No further action required?
Environmental Hazard Management Plans

• Same information as in EHE
• Soil & groundwater management plan
• Discuss need for caps, etc.
• Includes surveyed, to-scale maps of affected areas
• Discuss need for deed restriction (or include in appendix)
• Discuss need to include in budget and SOPs for future development & maintenance, etc.
### Environmental Hazard Tables
- **Soil**

<table>
<thead>
<tr>
<th>COPC</th>
<th>DE</th>
<th>VI</th>
<th>LCH</th>
<th>GC</th>
<th>ECO</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPHg</td>
<td>Yes</td>
<td>?</td>
<td>Yes</td>
<td>Yes</td>
<td>na</td>
</tr>
<tr>
<td>Benzene</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>na</td>
</tr>
<tr>
<td>Xylenes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>na</td>
</tr>
<tr>
<td>Lead</td>
<td>Yes</td>
<td>na</td>
<td>²No</td>
<td>No</td>
<td>na</td>
</tr>
</tbody>
</table>

1. Collect soil gas.
2. Based on batch test Kd results

Representative concentration of COPC exceeds screening level for noted environmental hazard.
### Environmental Hazard Tables

#### - Groundwater -

<table>
<thead>
<tr>
<th>COPC</th>
<th>DW (tox)</th>
<th>VI</th>
<th>GC</th>
<th>ECO</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPHg</td>
<td>Yes</td>
<td>1?</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Benzene</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
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1. Collect soil gas.

Representative concentration of COPC exceeds screening level for noted environmental hazard
Environmental Hazard Maps

- Simple summary of contamination
- Prioritize resources for cleanup
- Use for long-term management of sites
Environmental Hazard Maps
ConocoPhillips Site, Honolulu
Soil Gross Contamination Hazards

ESI, Honolulu
Soil Direct Exposure Hazards

ESI, Honolulu
Groundwater Discharge to Surface Water Hazards

ESI, Honolulu
Vapor Intrusion Hazards (soil data)

ESI, Honolulu
Vapor Intrusion Hazards (groundwater data)

ESI, Honolulu
Vapor Intrusion Hazards (soil gas data)

ESI, Honolulu
Target Soil Treatment Areas

Objective
Remove primary vapor sources

ESI, Honolulu
Isorisk Environmental Hazard Maps (Soil Direct Exposure)

Cumulative Cancer Risk $>10^{-4}$

Noncancer HI $>1.0$

Cumulative Cancer Risk $>10^{-5}$

Westin Environmental, Honolulu
Isorisk Environmental Hazard Maps (Vapor Intrusion)

Cumulative Cancer Risk >10^-5
Cumulative Cancer Risk >10^-6

Westin Environmental, Honolulu
Summary of Environmental Investigations

Step 1: Identify contaminants of potential concern (Phase I study).

Step 2: Review potential environmental hazards associated with COPCs.

Step 3: Establish Site Investigation Objectives (SIOs).

Step 4: Establish decision units and sample collection strategy.

Step 5: Collect and analyze samples.

Step 5: Evaluate presence or absence of hazards.

Step 6: Provide recommendations for further actions.