Interim Guidance for Evaluating Human Health Risks Associated with Direct Exposure to Contaminated Sediments at Federal Contaminated Sites in Canada

Elliot Sigal, Chris Bacigalupo and Adam Safruk
Intrinsik Environmental Sciences Inc.

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• A health-based environmental guideline is:
  • A chemical concentration in a specific environmental medium, at or below which, no appreciable human health risk is expected under the conditions for which the guideline was derived (CCME, 2006)

• Human health-based guidelines typically consider:
  • Daily intake from other sources to ensure total exposure (from all potential sources) does not exceed the TDI; and,
  • Background concentrations within the medium of interest to ensure effects-based values are not set below background or practical quantitation limits.

Screening for Chemicals of Potential Concern (COPCs) often involves a comparison between:

A chemical concentration measured in a given environmental medium (e.g., soil, water, air)

AND

A chemical- and media-specific effects-based guideline (e.g., a human health-based soil quality guideline - HHSQG)
Currently, neither Health Canada nor the CCME have endorsed universal human health-based screening or assessment guidelines for sediment contaminated sites;

There are currently no federal human health-based environmental quality guidelines for sediment in Canada (HHSedQGs);

Available sediment quality guidelines (CCME) are protective of ecological endpoints only (EcoSedQGs);

How does one identify COPCs and, if necessary, evaluate human health risks at sediment contaminated sites?
Objectives

• Derive human health-based sediment quality guidelines (HHSedQGs) based on recommendations from Golder (2010) and Health Canada (2010);
• Conduct a Screening Criteria Evaluation - compare the newly developed HHSedQGs with existing soil (HHSQG) and sediment (EcoSeQG) guidelines;

  • Provide recommendations concerning interim screening guidelines for use at sediment contaminated sites;
  • Provide interim guidance concerning the assessment of exposure and risk to COPCs in sediment via ingestion and dermal contact.
Previous Work

- This work builds on the following:
  - Golder Associates (2010):
  - Health Canada (2010):
  - Federal Contaminated Site Risk Assessment Guidance Manuals (Parts I through III)
Definition of Sediment

“Material, such as sand or mud, suspended in or settling to the bottom of a liquid. Sediment input to a body of water comes from natural sources, such as erosion of soils and weathering of rock, or as a result of anthropogenic activities, such as forest or agricultural practices, or construction activities.” (ASWG, 2009)¹

¹Aquatic Sites Working Group sub-committee of the Federal Contaminated Sites Management Working Group
Sediment Contaminated Sites

The interim sediment screening guidelines discussed herein would apply to the following areas:

– Tidal zones
– Non-tidal water bodies
– Ephemeral streams and wetlands
Derivation of HHsedQGs

With the exception of:

1. The use of sediment-specific loading factors provided by Shoaf et al., 2005;
2. The amount of exposed skin assumed to come into contact with sediment; and,
3. Background concentrations in sediments (when available)

HHsedQGs were derived using the same exposure parameters, TRVs, and EDIs as those used to derive the CCME HHSQGs

Derivation of HHSedQGs

Exposure scenarios were based on recommendations provided by Golder (2010) and Health Canada (2010) and included:

1. Recreational Scenario – High Contact (beach activities)
   – Option 1 - arms, hands, legs, and feet
   – Option 2 – whole body exposure

2. Recreational Scenario – Low Contact (water based activities); and,

3. Commercial/Industrial Scenario
Derivation of HHSedQGs

• Exposure Pathways Considered:
  – incidental ingestion of sediment; and,
  – direct dermal contact with sediment

• Exposure Pathways Excluded:
  – inhalation of particulates (e.g., wind entrained sediments);
  – inhalation of sediment-borne volatiles;
  – dermal exposure to suspended sediments in water; and,
  – consumption of fish and shellfish
Derivation of HHSedQGs

• Derivation of HHSedQGs followed the principles used by Health Canada to develop guidelines for other environmental media

• Guideline for protection of human health = (Target Risk Level)/(Predicted Exposure)

• Target Risk Level:
  • Incremental Lifetime Cancer Risk (ILCR) of $1 \times 10^{-5}$ for carcinogens; and,
  • Hazard Quotient (HQ) of 0.2 or one fifth of the TRV, for non-carcinogens
Derivation of HHSedQGs

\[ HHSedQG = \frac{(TDI - EDI) \times SAF \times BW}{\left[(AF_G \times SIR) + (AF_S \times SDCR)\right] \times ET} + BSC \]

Where:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>TDI</td>
<td>Tolerable daily intake</td>
<td>mg/kg/day</td>
</tr>
<tr>
<td>EDI</td>
<td>Estimated daily intake</td>
<td>mg/kg/day</td>
</tr>
<tr>
<td>SAF</td>
<td>Sediment allocation factor</td>
<td>unitless</td>
</tr>
<tr>
<td>AF_G</td>
<td>Relative absorption factor for gut</td>
<td>unitless</td>
</tr>
<tr>
<td>SIR</td>
<td>Sediment ingestion rate</td>
<td>kg/d</td>
</tr>
<tr>
<td>AF_S</td>
<td>Relative absorption factor for skin</td>
<td>unitless</td>
</tr>
<tr>
<td>SDCR</td>
<td>Sediment dermal contact rate</td>
<td>kg/d</td>
</tr>
<tr>
<td>ET</td>
<td>Exposure term</td>
<td>unitless</td>
</tr>
<tr>
<td>BSC</td>
<td>Background sediment concentration</td>
<td>mg/kg</td>
</tr>
</tbody>
</table>
Derivation of HHSedQGs

\[ SDCR = (SA_H \times DL_H + SA_f \times DL_f + SA_L \times DL_L + SA_A \times DL_A + SA_{HT} \times DL_{HT}) \times EF \]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Units</th>
<th>Toddler High Contact – Option II</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA_H</td>
<td>Surface area of hands</td>
<td>m²</td>
<td>4.30E-02</td>
<td>HC PQRA (2009)</td>
</tr>
<tr>
<td>SA_F</td>
<td>Surface area of feet</td>
<td>m²</td>
<td>4.30E-02</td>
<td>O’Connor (1997)</td>
</tr>
<tr>
<td>SA_L</td>
<td>Surface area of legs (upper and lower)</td>
<td>m²</td>
<td>1.69E-01</td>
<td>HC PQRA (2009)</td>
</tr>
<tr>
<td>SA_A</td>
<td>Surface area of arms (upper and lower)</td>
<td>m²</td>
<td>8.90E-02</td>
<td>HC PQRA (2009)</td>
</tr>
<tr>
<td>SA_{HT}</td>
<td>Surface area of head and torso</td>
<td>m²</td>
<td>2.69E-01</td>
<td>HC PQRA (2009)</td>
</tr>
<tr>
<td>DL_H</td>
<td>Dermal loading of sediment to hands</td>
<td>kg/m²-event</td>
<td>4.90E-03</td>
<td>Shoaf (2005); Golder (2010)</td>
</tr>
<tr>
<td>DL_F</td>
<td>Dermal loading of sediment to feet</td>
<td>kg/m²-event</td>
<td>2.10E-01</td>
<td>Shoaf (2005); Golder (2010)</td>
</tr>
<tr>
<td>DL_L</td>
<td>Dermal loading of sediment to legs</td>
<td>kg/m²-event</td>
<td>7.00E-03</td>
<td>Shoaf (2005); Golder (2010)</td>
</tr>
<tr>
<td>DL_A</td>
<td>Dermal loading of sediment to arms</td>
<td>kg/m²-event</td>
<td>1.70E-03</td>
<td>Shoaf (2005); Golder (2010)</td>
</tr>
<tr>
<td>DL_{HT}</td>
<td>Dermal loading of sediment to head and torso</td>
<td>kg/m²-event</td>
<td>4.35E-03</td>
<td>Shoaf (2005); Golder (2010)</td>
</tr>
<tr>
<td>EF</td>
<td>Exposure Frequency</td>
<td>events/d</td>
<td>1.00E+00</td>
<td>CCME (2006)</td>
</tr>
</tbody>
</table>
# Dermal Contact Rates

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Sediment$^1$</th>
<th>Soil$^1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$DL_H$</td>
<td>Dermal loading of sediment to hands</td>
<td>4.90E-03</td>
<td>1.00E-04</td>
</tr>
<tr>
<td>$DL_F$</td>
<td>Dermal loading of sediment to feet</td>
<td>2.10E-01</td>
<td></td>
</tr>
<tr>
<td>$DL_L$</td>
<td>Dermal loading of sediment to legs</td>
<td>7.00E-03</td>
<td>1.00E-05</td>
</tr>
<tr>
<td>$DL_A$</td>
<td>Dermal loading of sediment to arms</td>
<td>1.70E-03</td>
<td></td>
</tr>
<tr>
<td>$DL_{HT}$</td>
<td>Dermal loading of sediment to head and torso</td>
<td>4.35E-03</td>
<td></td>
</tr>
</tbody>
</table>

units kg/m$^2$-event

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Sediment - Option II (whole body)$^1$</th>
<th>Soil$^1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$DCR_H$</td>
<td>Dermal Contact Rate - hand</td>
<td>2.11E-04</td>
<td>4.30E-06</td>
</tr>
<tr>
<td>$DCR_{OH}$</td>
<td>Dermal Contact Rate - other than hands</td>
<td>1.15E-02</td>
<td>2.58E-06</td>
</tr>
<tr>
<td>$DCR_{TOTAL}$</td>
<td>Total Dermal Contact Rate</td>
<td>1.17E-02</td>
<td>6.88E-06</td>
</tr>
</tbody>
</table>

units kg/d

1,700 fold difference
Sediment versus Soil

Sediment - Relative Contribution per Exposure Pathway

- Dermal Contact: 93.6%
- Sediment Ingestion: 6.4%

Soil - Relative Contribution per Exposure Pathway

- Dermal Contact: 0.90%
- Soil Ingestion: 99.10%

Outcome attributed to differences in:
1) dermal loading rates
2) area of exposed skin

All contributions were adjusted by the appropriate RAFs.
## Comparing Different Screening Guideline Options

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Lowest Effects based HHSedQC*</th>
<th>Lowest CCME Eco-SedQQ</th>
<th>Lowest CCME HHSQG</th>
<th>Background Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>21</td>
<td>5.9</td>
<td>31</td>
<td>20</td>
</tr>
<tr>
<td>Benzene</td>
<td>2.4</td>
<td>-</td>
<td>110</td>
<td>0</td>
</tr>
<tr>
<td>Cadmium</td>
<td>20</td>
<td>0.6</td>
<td>14</td>
<td>0.38</td>
</tr>
<tr>
<td>Lead</td>
<td>86</td>
<td>30.2</td>
<td>150</td>
<td>2</td>
</tr>
<tr>
<td>Hg (inorganic)</td>
<td>0.63</td>
<td>0.13</td>
<td>7</td>
<td>0.3</td>
</tr>
<tr>
<td>Chromium (total)</td>
<td>45</td>
<td>37.3</td>
<td>220</td>
<td>10</td>
</tr>
<tr>
<td>PAHs</td>
<td>0.11</td>
<td>0.032</td>
<td>5.3</td>
<td>0.03</td>
</tr>
<tr>
<td>TCE</td>
<td>6.9</td>
<td>-</td>
<td>28</td>
<td>0</td>
</tr>
<tr>
<td>Toluene</td>
<td>4,500</td>
<td>-</td>
<td>22,000</td>
<td>0</td>
</tr>
</tbody>
</table>

*Recreational – High Contact Option II*
Evaluating Options for Sediments Screening Criteria

- 5 of 19 HHSedQGs were lower than the corresponding residential HHSQGs;
- The HHSedQGs for cadmium, cyanide, and selenium were higher than the corresponding HHSQGs;
- All Eco-SedQGs were lower than the derived HHSedQG; and,
- The background approach could result in many chemicals having a greater than 50% chance of exceeding median background sediment concentrations.
Interim Recommendations

• The selection of COPCs at sediment contaminated sites could be facilitated through the use of the HHSedQGs developed using the Recreational - High Contact (Option II) Scenario;

• Depending on the COPC, consumption of fish/shellfish can be a significant source of exposure that has not been considered in the development of the interim HHSedQGs.
Guidance on Performing HHRA of Sediment Contaminated Sites

The same guiding principles and general approach used to conduct a HHRA for soil apply to sediment contaminated sites, with the exception of:

- The use of interim HHSedQG required for chemical selection purposes;
- The use of sediment-specific dermal loading rates;
- Assumptions surrounding the area of exposed skin available for contact with sediment;
Guidance on Performing HHRA of Sediment Contaminated Sites

• Time activity patterns – number of events per year an individual may be in contact with sediments; and,

• Indirect pathways (e.g., the consumption of fish/shellfish that may use contaminated sediment as habitat) should be considered on a chemical by chemical basis
Thank You

For further information, contact:

Elliot Sigal
Phone: (905) 364-7800 x222
esigal@intrinsik.com

or

Adam Safruk
Phone: (905) 364-7800 x208
asafruk@intrinsik.com

or

Chris Bacigalupo
Phone (519) 836-2363
cbacigalupo@intrinsik.com

www.intrinsik.com