Modelled Ecological No-Effect Soil Concentrations for Cattle, Sheep and Deer: Safe for Humans?

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Topics:

- **Toxicity Reference Value (TRV)** derivation
- Calculation of **Ecological No-Effect Soil Concentrations** (EcoNEC<sub>soil</sub>)
- Calculation of **Human Health No-Effect Soil Concentrations** (HHNEC<sub>soil</sub>)
- Conclusions and Applications
Background

- Consider...
  - In mining regions, soils can be naturally elevated in metals – exceed current standards
  - Remediated soils have to be “cleaned-up” – concentrations of metals and/or hydrocarbons have to be below a set standard

- Required: a set of guidelines for screening soils as hazardous or not for wildlife and domestic grazing receptors

- Dilemma: Currently there are no federal standards and few provincial standards (Alberta is the exception) for soil concentrations of metals or hydrocarbons in “Wildlands”
Background

- **Protection goals:**
  - Deer and other wildlife ungulates
  - Domestic ungulates (Cattle, Sheep)
  - Human consumers of deer, cattle and sheep
- **Developed Risk-Based Ecological No-Effect Soil Concentrations based on:**
  - Relevant Toxicity Data
  - Ungulate Biology
Definitions

• Toxicity reference value (TRV)
  • An exposure concentration or dose that is not expected to cause an unacceptable level of effect in receptor(s) exposed to the contaminant of potential concern.

• Ungulate
  • “hoofed animal”
  • Ungulates = Ruminants
Evaluation of ecotoxicology datasets

Toxicity Reference Values (TRV) derived

Determine oral exposure from soil
Determine oral exposure from dietary components
Determine daily oral dose in deer from exposure pathways

Food Ingestion Rate (FIR)

Maximum Allowable Soil ($C_{soil}$) Calculated:

$$C_{soil} = \frac{TRV}{FIR} \times (P_{ls} \times \frac{f_{ls}}{s}) + (\sum (P_{lx} \times BCF_{lx}) + (P_{ly} \times BCF_{ly} \ldots))$$
TRV derivation - Species Relatedness

Wildlife & Domestic Ungulates  Pigs (Order Artiodactyla)  Herbivores  All Mammals (Rodents)
TRV derivation – Selection Criteria

- Growth/development, reproduction or mortality endpoints
- No-observed adverse effects levels (NOAELs) selected
  - Conservative
  - Protective
- Effect Size of NOAEL selected
  - 10% or less
NOAEL and LOAEL Example

Control

10 mg/kg/day
No Observable Adverse Effect Level (NOAEL)

50 mg/kg/day
Low Observable Adverse Effect Level (LOAEL)

100 mg/kg/day
TRV derivation – Selection

Highest NOAEL TRV lower than

Lowest LOAEL

ENDPOINTS

Reproduction

Growth

Mortality

Dose (mg/kg/day)
Toxicity Reference Values (TRV) derived

Determine oral exposure from soil

Determine oral exposure from grasses

Determine daily oral dose in deer from exposure pathways

Maximum Allowable Soil (Cs) Calculated:

\[ Cs = \frac{TRV}{FIR \cdot (Ps \cdot f_s) + (Ps \cdot BCF)} \]

Hazard Quotient (HQ) = 1

Food Ingestion Rate (FIR)

Bioconcentration factor (BCF)

Bioavailable fraction (f_s) of metals (I) or hydrocarbons

Percent of soil in diet (Ps)

Percent of grasses in diet (Pg)

Exposure of ecotoxicology datasets

Evaluation of ecotoxicology datasets
Calculate Oral Exposure

<table>
<thead>
<tr>
<th></th>
<th>Deer</th>
<th>Cattle</th>
<th>Sheep</th>
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</thead>
<tbody>
<tr>
<td><strong>Food Ingestion Rate</strong></td>
<td>0.035 mg/kg/d</td>
<td>0.029 mg/kg/d</td>
<td>0.023 mg/kg/d</td>
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<tr>
<td><strong>Percent grass in</strong></td>
<td>9%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td><strong>diet ($P_g$)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Incidental Soil</strong></td>
<td>2%</td>
<td>18%</td>
<td>30%</td>
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<tr>
<td><strong>Ingestion ($P_s$)</strong></td>
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- Concentration of contaminant in grass relative to concentration in soil = Bioconcentration Factor (BCF)
  - $\frac{[\text{grass}]}{[\text{soil}]}$
- Availability of contaminant in soil = $f_s$

$$FIR^*((P_s f_s) + (P_g BCF))$$
Risk-based No-Effect Soil Concentrations

Standards developed for 19 metals and 17 hydrocarbons
Above – representative metals and PAHs
Safe for Humans?

Calculate exposure from eating meat

Pathway exposure factor

Human intake of meat

Proportion of meat in diet

Site Use Factor

Assume = 1

Biotransfer Factor – ungulate diet to meat

Dietary uptake from soil
- $P_s$ – incidental soil ingestion
- $f_s$ – bioavailability in soil

Dietary uptake from grass
- $BCF$ – bioconcentration factor
- $P_g$ – proportion of grass in diet
- $f_g$ – bioavailability in grass

$F_{dm} = (I_{dm} \cdot P_{dm}) \cdot (SUId \cdot [(P_s \cdot f_s) + (BCF_g \cdot P_g \cdot f_g)]) \cdot B_{dm}$

From MacKone and Ryan, 1989
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Average consumption rate - First Nations wild game consumers
Richardson, 1997

Average consumption rate of meat and eggs - Canadian general public
Richardson, 1997

Conservative assumption

Proportions of beef and "other" (assumed 100% lamb)
### Oral Exposure

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#### Chemical-specific parameters

$$F_{dm} = (I_m * P_m) * (SUF * [(P_s * f_s) + (BCF_g * P_g * f_g)]) * B_m$$
No-Effect Soil Concentration for Humans

\[ Hazard \ Quotient \ (HQ) = 1 \]

\[ = HHNEC_{soil} \times (I_{m} \times P_{m}) \times (SUF \times [(P_{s} \times f_{s}) + (BCF_{g} \times P_{g} \times f_{g})] \times B_{m}) / Human \ Health \ TRV \]

\[ HHNEC_{soil} = Human \ Health \ TRV / (I_{m} \times P_{m}) \times (SUF \times [(P_{s} \times f_{s}) + (BCF_{g} \times P_{g} \times f_{g})] \times B_{m}) \]
Risk-based No-Effect Soil Concentrations

- Deer - EcoNECsoil
- Cattle - HHChsoil
- Deer - HHChsoil
- Sheep - EcoNECsoil
- Sheep - HHChsoil

Bar chart showing concentrations for various elements and species.
Change Site-Use Factor (SUF)

- Restrict or limit cattle/sheep from grazing on contaminated soil
- Minimize spread area of remediated soil relative to a deer’s home range/seasonal use to limit contact

\[ HHC_{\text{soil}} = \frac{\text{Human Health TRV}}{(I_{\text{m}} \times P_{\text{m}}) \times (SUF \times [(P_{\text{s}} \times f_{\text{s}}) + (BCF_{\text{g}} \times P_{\text{g}})]}} \]
Conclusions

• Goal: Develop soil concentration guidelines that are protective of grazing wildlife and domestic ungulates
• Conservative assumptions → Protective guidelines
Conclusions

- Goal: Develop soil concentration guidelines that are protective for humans consuming ungulate meat
  - More conservative than EcoNEC_{soil}
- Can be refined
  - Proportion of diet
  - Site Use Factor
  - Use to set consumptive limits
Soil Management

• Useful as a Management tool
  • Soil “clean-up” guidelines/ Screening guidelines
  • Select guidelines for use based on management goals
    • Will consumption of ungulate grazers be an issue?
    • Is the meat consumed “sole sourced” from the contaminated area?