Human Risk assessment of Chlorinated hydrocarbons (DNAPLs) in contaminated groundwaters

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Introduction

- Industrial utilization since middle 20th century
  - Dry cleaning
  - Metal degreasing
  - Pharmaceutical production

- Soil and groundwater contaminants

- Exposed people
  - Workers (producer and user)
  - General population: Drinking water

→ Public Health issue
DNAPLs’ chemical properties

- Chlorinated hydrocarbons
- DNAPLs: Denser-than water No Aqueous-Phase Liquid

![Chemical structures of chlorinated hydrocarbons]

- Tetrachloroethene
- Trichloroethene
- cis 1,2 Dichloroethene
- trans 1,2 Dichloroethene
- Vinylchloride
- Tetrachloroethane
- 1,1,2 Trichloroethane
- 1,2 Dichloroethane
- Chloroethane
- Carbon tetrachloride
- Cloroform
- Dichloromethane
- Chloromethane
DNAPLs’ physical properties

- Denser than water
- Volatile
- Mobile in the soil
- Poorly soluble in water
- Form pools in soils and plumes in groundwater

ORICA – Cleaning groundwater project
Biodegradation

- Degradation by microorganism

- But possibility that daughter molecules are
  - more persistent in environment
  - more toxic

[Scheutz C and Al., 2011]
Human Toxicity

- High toxicity in low concentration

- Targets organs
  - Central Nervous System
  - Liver
  - Heart
  - Lung
  - Kidneys
  - Skin

- Toxicity Acute or Chronic

- Carcinogenicity (IARC classification)
  - Vinyl chloride: Group 1 → Angiosarcoma
Objectives

- To assess human risk of contaminated groundwater by Chlorinated Hydrocarbons with RBCA model.

- To verify the correct toxicological and exposure values to be used in the model.

- To establish representative exposure scenarios.
Methodology

- **RBCA: Risk Based Corrective Action**
  - Tool for determining the amount and urgency of action necessary regarding to the human health

- **Uses**
  - Identify exposure pathways and receptors at a site
  - Determine the level and urgency of response required at a site
  - Determine the level of surveillance appropriate for a site
  - Incorporate risk analysis into all phases of the corrective action process
Methodology

- Steps of the risk assessment with RBCA
  - Exposure assessment
    - Identification of source
    - Identification population exposed
    - Determination of the exposure scenario and pathway exposure
    - Exposure factors
    - Exposure dose
  - Toxicity assessment
    - For non-carcinogenic: Exposure dose without significant effect
      - According to the entrance way (dermal, oral, inhalation)
    - For carcinogenic: Slope Factor (SF)
      - According to the entrance way (dermal, oral, inhalation)
  - Risk Analysis
    - For non-carcinogenic: Hazard Ratio (HR) >1 = Risk
      \[
      HR = \frac{\text{Exposure Dose}}{\text{Exposure dose without significant effect}}
      \]
    - For carcinogenic: Exposure Calculated x SF > 10E-5 = Risk
  - Uncertainties
    - Values use

Booth P, 2011
Study area

- Tarragona, Spain
  - Industry
  - Pollution detected in 1996
  - CT and CF

- Groundwater characteristics polluted plume:
  - 4 m of thickness
  - 2 m big
  - 7.5 m : depth of water table
Scenarios

- Play with the different value of:
  - Toxicological parameters
  - Exposure parameters
    - According the ages
    - According the genders
    - According the life style
  - Soil parameters
    - pH
    - Concentration of Organic Carbon
  - Groundwater parameters
    - pH
    - Concentration of Organic Carbon
Results: Water pollution

Mean Groundwater concentrations used for the risk analyses (in μg L-1)

<table>
<thead>
<tr>
<th>Chloromethane</th>
<th>Chloroethene</th>
<th>Chloroethane</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT</td>
<td>CF</td>
<td>CM</td>
</tr>
<tr>
<td>164.08</td>
<td>103.71</td>
<td>1.96</td>
</tr>
</tbody>
</table>

Drinking water WHO guideline (in μg L-1) (WHO 2004)

<table>
<thead>
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</tr>
</thead>
<tbody>
<tr>
<td>CT</td>
<td>CF</td>
<td>CM</td>
</tr>
<tr>
<td>4</td>
<td>200</td>
<td>-</td>
</tr>
</tbody>
</table>

- CT and CF: majority compounds
- Carcinogenic compounds: no threshold
- CT and VC in excess according the guideline
Results: Risk assessment for Catalonia

Excess cancer risk and HR by exposition to the polluted groundwater for commercial and residential receptors

<table>
<thead>
<tr>
<th>Excess cancer risk: GW Expo</th>
<th>Study area</th>
<th>Acceptable value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Commercial</td>
<td>Res 1</td>
</tr>
<tr>
<td>Female</td>
<td>1.9E-04</td>
<td>7.4E-07</td>
</tr>
<tr>
<td>Male</td>
<td>1.9E-04</td>
<td>6.8E-07</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hazard ratio : GW</th>
<th>Study area</th>
<th>Acceptable value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Commercial</td>
<td>Res 1</td>
</tr>
<tr>
<td>Female</td>
<td>1.2</td>
<td>8.6E-03</td>
</tr>
<tr>
<td>Male</td>
<td>1.2</td>
<td>8.6E-03</td>
</tr>
</tbody>
</table>

- Excess risk of cancer and toxicological effect
  - Commercial receptors

- Acceptable risk:
  - Residential receptors

- Low variation between genders
Results: European exposure parameters

Excess cancer risk and HR by exposition to the polluted groundwater according different life style in European countries and USA for commercial receptors

### Excess Risk

<table>
<thead>
<tr>
<th>Countries</th>
<th>Female</th>
<th>Male</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC</td>
<td>0,0E+00</td>
<td>0,0E+00</td>
</tr>
<tr>
<td>USA</td>
<td>0,0E+00</td>
<td>0,0E+00</td>
</tr>
<tr>
<td>Germany</td>
<td>0,0E+00</td>
<td>0,0E+00</td>
</tr>
<tr>
<td>Uk</td>
<td>0,0E+00</td>
<td>0,0E+00</td>
</tr>
<tr>
<td>Italie</td>
<td>0,0E+00</td>
<td>0,0E+00</td>
</tr>
<tr>
<td>Ndl</td>
<td>0,0E+00</td>
<td>0,0E+00</td>
</tr>
<tr>
<td>France</td>
<td>0,0E+00</td>
<td>0,0E+00</td>
</tr>
<tr>
<td>Catalo</td>
<td>0,0E+00</td>
<td>0,0E+00</td>
</tr>
</tbody>
</table>

### HR

<table>
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<tr>
<th>Countries</th>
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<th>Male</th>
</tr>
</thead>
<tbody>
<tr>
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Results: European exposure parameters

Excess risk of cancer and HR by exposition to the polluted groundwater according different lifestyle in European countries and USA for residential receptors

Excess risk

HR
Conclusion

- Risk:
  - Excess risk: commercial receptor
  - Acceptable risk: receptors residential

- Variation of the risk with exposure factors
  - Excess risk: commercial receptor (BC, Cat, USA, UK female)
  - Acceptable risk: receptors residential + commercial receptors (NdI, Fr, It, Uk male)

- No risk variation with water and soil parameters

  → Carcinogenic compounds = Risk
  → But acceptable risk by exposure to polluted water after 500 m from the polluted site
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Thank you for your attention