Chemical exposure via inhalation of soil derived dust
Modelling versus measurement
• The problem

• Assessing exposure via dust inhalation
  – Modelling
  – Measurement

• Conclusions
The problem

• Dust inhalation is one of the modelled pathways in CLEA

• Exposure via dust inhalation is generally small relative to ingestion of soil + household dust
  – e.g. CLEA residential land-use, $A_D E_{dust} = 0.3\%~ A_D E_{ingest}$

• As a result, dust inhalation is only important when:
  – Inhalation toxicity $>>$ oral toxicity; or
  – Dust inhalation is the only active pathway
<table>
<thead>
<tr>
<th>Dust important?</th>
<th>HCV&lt;sub&gt;oral&lt;/sub&gt; ug.kg&lt;sup&gt;-1&lt;/sup&gt;.d&lt;sup&gt;-1&lt;/sup&gt;</th>
<th>HCV&lt;sub&gt;inhal&lt;/sub&gt; ug.kg&lt;sup&gt;-1&lt;/sup&gt;.d&lt;sup&gt;-1&lt;/sup&gt;</th>
<th>Ratio (inhal/oral)</th>
<th>Assessment Criteria mg.kg&lt;sup&gt;-1&lt;/sup&gt;</th>
<th>SGV or GAC mg.kg&lt;sup&gt;-1&lt;/sup&gt;</th>
<th>Basis</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Oral</td>
<td>Inhal</td>
<td></td>
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<tr>
<td>✗</td>
<td>Arsenic 0.3</td>
<td>0.002</td>
<td>150</td>
<td>32</td>
<td>85</td>
<td>32</td>
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<td>✗</td>
<td>Cadmium 0.36</td>
<td>0.0014</td>
<td>257</td>
<td>11</td>
<td>185</td>
<td>10</td>
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<tr>
<td>✗</td>
<td>2-Chloro naphthalene 80</td>
<td>0.286</td>
<td>280</td>
<td>1300</td>
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<td>22</td>
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<tr>
<td>✓</td>
<td>Benzo[a]pyrene 0.02</td>
<td>0.00007</td>
<td>286</td>
<td>1.5</td>
<td>2.9</td>
<td>1</td>
</tr>
<tr>
<td>✗</td>
<td>Copper 160</td>
<td>0.286</td>
<td>559</td>
<td>2660</td>
<td>10400</td>
<td>2330</td>
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<td>Chromium (III) 150</td>
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<td>19500</td>
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<td>2000</td>
<td>531</td>
<td>127</td>
<td>130</td>
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<tr>
<td>✓</td>
<td>Chromium (VI) 1</td>
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<td>10000</td>
<td>12.4</td>
<td>4.3</td>
<td>4.3</td>
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<tr>
<td>✓</td>
<td>Asbestos ?</td>
<td>??</td>
<td>&gt;1000?</td>
<td></td>
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</table>
How do we assess dust exposure?

- Most dust > PM10 caught in trachea + ingested
- Particles in PM10 or PM2.5 range are able to reach lungs
- Smaller particles penetrate further, have longer residence times + therefore present greater risk

Exposure = Respiration rate \times [PM10] \times \text{Conc. of contaminant on PM10}

Measure or Model
Modelling
CLEA model

- Different equations for exposure (mg.d\(^{-1}\)) for outdoor + indoor inhalation:

\[
IR_{out} = C_s \left( \frac{1}{PEF} \right) V_{inh} \left( \frac{T_{out}}{24} \right)
\]

PM10 outdoors arising from soil (0.425 \(\text{ug.m}^{-3}\), residential)

\[
IR_{in} = \left[ C_s \left( \frac{1}{PEF} \right) + C_s \cdot TF \cdot DL \right] V_{inh} \left( \frac{T_{in}}{24} \right)
\]

Contaminant concentration in PM10 indoors

PM10 indoors (50 \(\text{ug.m}^{-3}\), residential)
Inhalation of dust outdoors

• 1/PEF (i.e. PM10 from soils) calculated using Cowherd’s model + air dispersion model

\[
\frac{1}{\text{PEF}} = \frac{J_w}{Q/C_{wind}}
\]

• \( J_w = \) PM10 emission flux (g.m\(^{-2}\).s\(^{-1}\)) estimated using Cowherd

\[
J_w = (1-V)\left(\frac{u}{u_t}\right)^3 \cdot F(x)
\]

(1-V) = fraction of site with bare soil
u = average windspeed at 10m height
\( u_t \) = threshold windspeed at 10m height
F(x) = empirical factor based on u:\( u_t \)

• \( J_w = 1 \times 10^{-6} \) g.m\(^{-2}\).s\(^{-1}\) for residential land-use
Inhalation of dust outdoors

• Q/C = dispersion factor estimated using US EPA AERMOD PRIME

• PM10 increases with increasing area

• Are predicted PM10 concs realistic?
  - Predicted PM10 for > 1 ha bare earth site ≈ 40 ug.m⁻³

• Are predicted contam concs in air realistic?
  - Predicted air conc of As using this PM10 & 20mg.kg⁻¹ in soil = 0.8 ng.m⁻³
  - UK average air conc As for rural areas = 1 to 4 ng.m⁻³

• But note: uncertainties in Cowherd model are HUGE!
Inhalation of dust indoors

• What is indoor dust composed of?
  – Many things, e.g. soil particles, hair, skin, fibres, pollen, dust mites, soot, ash, animal fur and dander, food, building components
  – PM10 < 10% by mass of typical house dust collected in hoover bag?
  – Composition is highly variable between houses

• Contaminants in house dust
  – Tracked back soil/dirt
  – Outdoor air
  – Internal sources
Estimation of exposure – indoor dust inhalation

• Indoor air PM10 = dust loading factor (DL)
  – Range of values reported by Oomen + Litzen, 2004 = 12.6 to 157 ug.m⁻³
  – Highest value occurred for a school
  – WHO (1989) give range of 20 to 60 ug.m⁻³
  – CLEA assumes 50 ug.m⁻³ for UK houses – is this reasonable?

• Concentration of contamination in PM10 = Cs x TF
  – TF = transport factor and should be contaminant specific
  – Default value = 0.5, i.e. concentration of contaminant in PM10 = half the concentration in soil
- Trowbridge & Burmaster (1997)
  - found reasonable correlation between conservative tracer components in garden soil + indoor dust
  - Mean TF = 0.43
- But, TF varies for many contaminants and can exceed 1 due to enrichment
  - Pb can be up to 3?
  - PAHs?

Measurement
• Preliminary research on dust exposure in UK:
  – Amateur research on my house in 2009
    • Comparison of PAH concentrations in house dust + garden soil
    • Measuring PM10 indoors
  – Current research by Dr Chris Collins, University of Reading
    • Comparison of PAH concentrations in house dust + garden/allotment soils
    • Measuring PM10 indoors
    • Measuring PAH concentrations in suspended dust
Measuring PM10

- Air pump with filter sent to lab for gravimetric analysis (≈ £10/sample)
- Infrared refractive sampling e.g. Casella DustPro monitor (≈ £2500)
- Laser photometry e.g. Turnkey Instruments Osiris (≈ £6000)
- Real-time gravimetric analysis e.g. Thermo Partisol 2025 (≈ £16000)
Chemical analysis of suspended dust

• University of Reading using passive sampling technique developed by Abdallah & Harrad (2010)
  – Polyurethane foam disk for assessing vapour phase PAHs
  – Glass fibre filter for assessing particulate sorbed PAHs

PM10 indoors – my house – DustPro results

- PM10 indoors measured using Casella DustPro= 30 to 40 ug/m³
PM10 indoors – my house – Osiris results

- PM10 = 8 to 97 ug.m⁻³
- PM2.5 = 4 to 24 ug.m⁻³
- Average PM10 = 15 ug.m⁻³
- Average PM2.5 = 6 ug.m⁻³
Soil to dust transport factor – my house

- What proportion of PM10 is likely to be from garden soil?
- 2 lines of evidence:
  - PAH analysis of dust from hoover bag vs soil analysis
    - Average [BaP] in surface soil = 1.2 mg/kg
    - [BaP] in dust = 1.0 mg/kg
    - PAH profile in dust similar to garden soil
  - SOM analysis of dust from hoover bag vs soil analysis
    - Average SOM in surface soil = 13%
    - SOM in dust = 32%
    - If we assume that dust composed of soil (13% SOM) + skin/food (100% SOM), TF = 0.8 – higher than CLEA generic assumption!
University of Reading study

- Sampled and analysed soils from garden + allotment (0.5 miles from house) for PAHs
- Sampled and analysed house dust from hoover bag for PAHs
- Indoor air PM10 monitoring using Osiris
- Passive suspended dust sampling for PAHs
University of Reading results

- Very similar PAH profiles between garden soil, allotments soil + house dust
- Awaiting PM10 + passive sampler results
Conclusions

- Dust inhalation indoors is a key pathway for BaP, Ni, Cr(VI) and asbestos.
- Key uncertainties:
  - PM10 – Highly variable – need long-term monitoring in occupied buildings to determine.
  - Transport factor - Varies significantly from site to site + contaminant to contaminant.
- Hoover bag analysis helps check on TF but may not be valid for respirable particles.
- Further research required to ascertain if there is a correlation between concentrations in soil + respirable dust (especially for PAHs + asbestos).
- Why is $HCV_{\text{inhal}} \ll HCV_{\text{oral}}$ for BaP, Ni + Cr(VI)?

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