Towards a unified approach for the determination of the bioaccessibility of organic pollutants

Chris Collins
Bioaccessibility and bioavailability

- **Bioaccessibility**: Maximal amount of contaminant that is released from soil into gastrointestinal fluid
  - *In vitro studies*: CHEAP

- **Bioavailability**: Fraction contaminant absorbed by systemic circulation
  - *In vivo studies (pigs, monkey)*: EXPENSIVE
Why do we do bioaccessibility tests?

**The Telegraph**

**Allotments really are good for your health**

Keeping an allotment really is good for your health, the first study to directly has found.

*By Stephen Adams, Medical Correspondent*

8:30AM GMT 23 Nov 2010

1,576 followers

1 Comment

Dutch researchers have found that allotment keepers in their 60s tend to be significantly healthier than their more sedentary neighbours.

While plenty of anecdotal evidence exists to suggest growing one’s own fruit and vegetables protects against ill-health, no one had carried out such a direct comparison before.

**Free up green-belt land for new housing, says Policy Exchange**

Thinktank set up by new planning minister, Nick Boles, argues that releasing 2% of land would create extra 8m homes

Nicholas Watt, chief political correspondent
guardian.co.uk, Thursday 13 September 2012 07.00 BST
Jump to comments (…)

Nick Boles was appointed as planning minister in last week’s reshuffle. Photograph: Christopher Thomond for the Guardian

Green-belt land in England should be freed up for new housing.
Why do we do bioaccessibility tests?

- Fine tune risk assessments of human exposure, particularly when soil concentration close to guidance value.
- Reliance on total contaminant soil concentrations is likely to over-estimate risks, resulting in unnecessary determinations and remediation.
- Ingestion dose for critical pathway in many scenarios e.g. new housing, urban agriculture.
Where are we now?

- ‘…. part of body of evidence….’  
  EA, England and Wales

- Flanders bioaccessibility HHRA for PAH

- ‘Careful use of oral bioaccessibility data in DQRAs can help clarify risks and has been supported by CLRs but its limitations and uncertainties must be recognised.’  
  CIEH

- But generally applied for toxic elements. Even then regulatory guidance not complete.
What factors determine an acceptable test?

**BARGE (Bioaccessibility Research Group in Europe)**

- It should be physiologically based, mimicking the human GI physico-chemical environment in the stomach and small intestine (colon).
- It should represent a conservative case;
- There should be one set of conditions for all potentially harmful elements (PHE) being studied;
- It must be demonstrated that the test is a good analogue of in vivo conditions
- The test must be able to produce repeatable and reproducible results within and between testing laboratories.
Idealised physiologically based extraction test system

Mouth
- pH 6.5
- 5 min

Stomach
- pH 2.5
- 1 hr

Small intestine
- pH 7
- 4 hr

Colon
- pH 6.5
- 16 hr
<table>
<thead>
<tr>
<th>Model</th>
<th>Researchers</th>
<th>Compartments</th>
<th>Dietary status</th>
<th>Bile salts (g l(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOREhST</td>
<td>Cave et al</td>
<td>Saliva, stomach, SI</td>
<td>Fed</td>
<td>1.1</td>
</tr>
<tr>
<td>SHIME (dynamic)</td>
<td>Cave et al</td>
<td>Stomach, SI, colon</td>
<td>Fed</td>
<td>2.5</td>
</tr>
<tr>
<td>CEPBET</td>
<td>Tilston et al</td>
<td>Stomach, SI, colon</td>
<td>Fed</td>
<td>1.75</td>
</tr>
<tr>
<td>PBET</td>
<td>Yu et al.</td>
<td>Saliva, stomach, SI</td>
<td>Un fed</td>
<td>0.9</td>
</tr>
<tr>
<td>PBET</td>
<td>Wang et al.</td>
<td>Stomach, SI</td>
<td>Un fed</td>
<td>2.5</td>
</tr>
</tbody>
</table>
Importance of the colon

Tilston et al (2011) EST 45:5301-5308
Influence of bile salts


Liquid to solid ratio and other test components e.g. proteins also have an impact.
Fed state required

House Dust  Reference material SRM 2585 and CE-

Bioaccessibility (%)
Do we need ‘sinks’

James et al (2011) EST 45:4586-4593


ICCE, Oslo 2017
In vivo


James et al (2011) EST 45:4586-4593
Variability reported

Variability reported

Repeatability vs Reproducibility

Soil concentration (mg/kg)

\[ o \rightarrow \text{between lab} \]
\[ + \rightarrow \text{within lab} \]

%RSD

NIST
As: 626, Cd: 22, Pb: 5532
SGV (UK)
As: 32, Cd: 10, Pb: 450

Wragg et al. (2011) Sci. Total Env. 409, 4016-4030

ICCE, Oslo 2017
Recommended test format

Add 1 g sample matrix maintain liquid to solid ratio 100:1 \(^1\)

Use material sieved to <150 μm \(^2\)

- **Stomach**
  - pH 2.5
  - 1 hr \(^3\)
  - Add stomach medium (pepsin, NaCl, HCl). \(^4\)
  - Food components \(^4\)

- **Small intestine**
  - pH 7
  - 4 hr
  - Add bile, pancreatin, adjust pH
  - Food components

- **Colon\(^5\)**
  - pH 6.5
  - 16 hr
  - Sample centrifuged, and supernatant taken for analysis/colon medium added to soil pellet.

Matrix of interest e.g. soil, dust, food

Sink e.g. silicone, TENAX

Dialysis membrane
Here’s something we prepared earlier.........
## Conclusions

<table>
<thead>
<tr>
<th>Requirements of bioaccessibility test</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>It should be physiologically based, mimicking the human GI physicochemical environment in the stomach and small intestine (colon).</td>
<td>Yes</td>
</tr>
<tr>
<td>It should represent a conservative case.</td>
<td>Partial yes – not known for sure, but with addition of food, high levels of bile salts and sinks researchers are striving for this.</td>
</tr>
<tr>
<td>There should be one set of conditions for all potentially harmful elements (PHE) being studied.</td>
<td>Yes – no one is suggesting different systems for different pollutants.</td>
</tr>
<tr>
<td>It must be demonstrated that the test is a good analogue of in vivo conditions.</td>
<td>Partial yes – trends are the same between tests, but agreement could be better.</td>
</tr>
<tr>
<td>The test must be able to produce repeatable and reproducible results within and between testing laboratories.</td>
<td>Partial yes – not really known for organics but experience with PTEs would suggest repeatability is good, but reproducibility needs to improve especially at relevant concentrations.</td>
</tr>
</tbody>
</table>
Future needs

• We have made significant progress supported by knowledge from measurements for toxic elements

• Inter-laboratory comparisons required
  – Isolate reproducibility and repeatability
  – Appropriate soils and standards
  – High quality SOPs – video
  – Independent lab analysis

• In-vivo experiments

• End points – parent compounds/metabolites
Thanks

Funders

Researchers

• Emma Tilston
• Mark Craggs
• Katerina Kademoglou
• Sonia Garcia-Alcega
• Stephen Lowe
• Phillip Mayer
• Varvara Gouliarmou
• Monica Mosquera-Vasquez

ICCE, Oslo 2017
What controls bioaccessibility
Influence of matrix - carbon

SS = standard sediment
CL = clay
ST = soot

Chai et al. (2008). Chemosphere 72, 432-441.

Influence of matrix - source

Household dusts

- BDE 47
- BDE 99
- BDE 183
- BDE 209

Bioaccessibility (%)

house1, house2, house3, house4
Influence of matrix – food type

% bound

- Control
- Carrot root
- Celery
- Green bean
- Soybean
- Tomato

ICCE, Oslo 2017
Influence of chemical - Kow

Bioaccessibility (%) vs. Log $K_{OW}$

- TCEP
- TDCPP
- TEHP
- TTP
- BDE 99
- BDE 47
- BDE 183
- BDE 209

$R^2 = 0.6902$
Aging

Average Pesticide Concentration (ng/g DW)

- SI
- Colon
- Residual

DALA

0 3 7 14 21

ICCE, Oslo 2017
In vivo

Soils were spiked with phenanthrene


No linear relationship OC and clay