Survey on bioaccessibility implementation
Author:
Agnieszka Latawiec

Co-authors:
Peter Simmons, Brian Reid

University of East Anglia, School of Environmental Sciences, NR4 7TJ, Norwich, United Kingdom

Collaborators:
Newcastle City Council and all the Local Authorities that kindly participated in the survey

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Further information available from:
Agnieszka Latawiec
a.latawiec@uea.ac.uk
alatawiec@gmail.com

The views reported in this document are not necessarily those of the authors.
Executive summary

This report details the results of a questionnaire- and interview-based survey of Local Authority Officers in England and Wales. This survey was designed to:

- Explore views on the use of bioaccessibility within contaminated land management.
- Identify current constraints in bioaccessibility implementation.
- Identify areas in which academic research could contribute towards a better understanding and further utilization of bioaccessibility.
- Investigate the extent of use of bioremediation to regenerate PAH-contaminated land.
- Identify which guidelines are commonly used to assess land contaminated with polycyclic aromatic hydrocarbons (PAHs).

Responses were received from 151 Local Authorities, which correspond to 40.3% of all English and Welsh Local Authorities. The results from the questionnaire were complemented by 17 personal or telephone interviews. The most significant findings include:

- The majority of participants (70.2%) perceived bioaccessibility as a useful tool that facilitates contaminated land management.
- Whilst necessity to access more information regarding bioaccessibility was indicated by 76.8% of participants, a need for more research for under-investigated contaminants, such as benzo(a)pyrene was emphasised.
- Lack of statutory guidance was indicated as the main factor hampering application of bioaccessibility data (78.2%).
- CLEA has been indicated by 93.6% of respondents as the most commonly used model for PAH-contaminated land assessment.
- ‘Never’ was the most common (44.4%) answer to the question regarding the frequency of bioremediation use in order to clean-up PAH-contaminated land.

The results of this study have been used to inform Local Authorities, Environment Agency, Department for Environment, Food and Rural Affairs and the research community (further journal articles are in preparation) about the Officers’ views on bioaccessibility application and the real-world circumstances regarding the use of bioaccessibility.
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1. Introduction

Sustainable, proportionate and risk based-approach to contaminated land management pervades contaminated land regimes throughout the world (Rothstein et al., 2006). While this approach stipulates national and international priorities, its practical implementation in the United Kingdom (UK) is reliant upon Local Authorities.

Principles of contaminant sequestration within a heterogeneous soil matrix, whereby a proportion of the total contaminant present is not readily accessible for transformations (Alexander, 2000), have led to formulations of bioaccessibility concepts. On the account of risk-based contaminated land assessment, these concepts have been perceived as a pragmatic decision-support tool that facilitates a more accurate land evaluation, whereby only the ‘accessible’ fraction may present a risk. In the UK, bioaccessibility has been recognized as a decision-support tool yet its incorporation into contaminated land decision-making is not statutorily defined.

Research on bioaccessibility in the context of contaminated land management has attracted both substantial academic (Ruby et al., 1996; Ehlers and Luthy, 2003; Pu et al, 2004; van de Wiele et al., 2004; Palumbo-Roe et al., 2005; Juhasz et al., 2007; Laird et al., 2007; Intawongse and Dean, 2008; Ollson et al., 2009) and regulatory attention (RIVM, 2006; EA, 2007; Saikat et al., 2007; US EPA, 2007). With respect to human health risk assessment, the ‘bioaccessible fraction’ is defined as the fraction of a substance that is released from the soil, during such processes as digestion into solution making it available for absorption (measured in vitro), whilst ‘bioavailability’ relates to the fraction that reaches the blood system via the gastrointestinal tract (EA, 2002). Bioavailability testing involves in vivo models, which raises ethical issues and is too time-consuming and costly to be routinely incorporated into site-specific risk assessments. In vitro approaches to estimating the bioaccessible fraction, as a surrogate for bioavailability, have therefore been investigated for more than 10 years (Ruby et al., 1996; Saikat et al., 2007).

Risk-based approaches advocate that only the fraction of contaminant that reaches the central blood circulation may exert adverse effects on human health (RIVM, 2006). Therefore, information on contaminant bioavailability and bioaccessibility can promote a more proportionate and cost-effective assessment of contaminated land. Indeed, it has been demonstrated that the use of bioaccessibility data prevented unnecessary (and unsustainable) remediation, avoided public anxiety and land blight (Nathanail and Smith, 2007; Naidu et al., 2008).

Along with the acceptance of the rationale behind the concept of bioaccessibility and its favourable reception by land owners and developers, ambiguity associated with the practical application of bioaccessibility data remains. Issues that are the subject of on-going discussions in relation to the implementation of bioaccessibility include: variability in results obtained from different laboratories on the same sample, lack of a standard method and scarcity of evidence that methods are being correlated with appropriate and robust bioavailability data to address population variability (EA, 2007), and the embedding of bioaccessibility within regulatory frameworks (EA, 2006; Latawiec et al., 2009).

In this study we (i) investigate the extent to which scientific research on bioaccessibility has been accepted by Local Authority decision-makers and incorporated into contaminated land assessment practice, (ii) identify current limitations in implementing
bioaccessibility, (iii) explore trade-offs to bioaccessibility adoption along with the current and potential role of bioaccessibility in contaminated land management (‘do we need bioaccessibility?’) and (iv) identify areas in which academic research could contribute to a better understanding and further utilization of bioaccessibility.

Commonly used guidelines to evaluate PAH-contaminated land are also presented and the frequency of bioremediation used to clean-up PAH-contaminated land is discussed.
2. Research design

In England and Wales Local Authorities are the primary regulators for contaminated land assessment (Defra, 2006). This study targeted therefore Local Authority Contaminated Land Officers or their equivalents, such as Environmental Health Officers, Planning Officers or Environmental Protection Officer. The invitation to participate in the survey along with a link to an online questionnaire (Appendix A) was sent twice, in August and September 2008, via the Chartered Institute of Environmental Health to its members in 300 Local Authorities in England and Wales. A list of Local Authority contacts with responsibility for contaminated land in all 375 district and unitary Local Authorities in England and Wales (EA, 2006) was subsequently obtained from the Environment Agency. In order to increase the survey coverage and maximize the number of responses, the invitation was sent again in November to all of the contacts on this list. In each mailing, Officers were invited to respond either online, by e-mail, fax, post or over the telephone. It should be noted that a small number of these Local Authorities was not successfully reached (approximately 20). Responses were received from 143 Local Authorities in addition to the 8 Local Authorities that participated in the pilot study conducted in May and June 2008. 143 responses were received from English Local Authorities and 8 from Wales. The proportion of returns corresponded to 40.3 % of all Local Authorities in England and Wales. Although it is possible that there was a self-selection bias towards individuals with greater interest in bioaccessibility, the response rate makes the findings applicable to, at least, 40.3 % of regulators. In addition, responses were received from both rural and urban regions of England (Defra, 2008). Of 117 respondents from England that provided the name of their Local Authority, 44% of the responses were received from urban Local Authorities (major urban, large urban and other urban), whereas 56% of Local Authorities from rural regions responded.

The questionnaire consisted of 14 questions and covered topics relating to contaminated land management in the Local Authority’s jurisdiction area. The questionnaire was developed on the basis of issues identified from the literature review (e.g. EA, 2002; Ehlers and Luthy, 2003; EA, 2006; BGS, 2007) and preliminary interviews with the Officers. Questions focused more specifically on land contaminated with PAHs, including guidelines used for PAH-contaminated land assessment (Question 3) and bioremediation of PAH-contaminated land (Question 4). Three questions (Question 5, 6 and 7) related to the use of bioaccessibility for contaminated land decision-support. Although the questionnaire was anonymous, the respondents were asked to provide background information including the name of their Local Authority, the number of persons in their contaminated land team, the length of time they have worked with contaminated land and the range of tasks they are involved in on a day-to-day basis. Here, all results are reported and the findings of a subset of results relating specifically to the use of bioaccessibility and constraints associated with the implementation of bioaccessibility are discussed. The Officers’ perspective on the use of bioaccessibility (Question 5) was rated on a 5-point Likert scale (strongly agree, agree, neither agree nor disagree, disagree, strongly disagree) with an additional ‘don’t know’ option. Question relating to constraints upon barriers to the implementation of bioaccessibility and a question relating to bioavailability and bioaccessibility definitions allowed respondents to choose more than one answer: the sum of the results for these questions therefore exceeds 100%. Each question was accompanied by a free text space for respondents to make additional comments. All comments are attached in the Appendix B. The names of the
Local Authorities or any facts that might have led to their identification were removed from the text.

In order to complement the data generated by the questionnaire-based survey and aid the interpretation of the results, the questionnaire was triangulated with semi-structured personal and telephone interviews (after Arksey and Knight, 2007). 17 interviews were conducted in February and March 2009 with survey respondents who had indicated that they were willing to be approached for more information. The interviews lasted from 25 to 45 minutes of conversation. Each interview focused on 3 key questions regarding 1) the use of bioaccessibility in the area of the Local Authority, 2) guidance on bioaccessibility and uncertainties associated with bioaccessibility, and 3) need for bioaccessibility data. These questions were further explored by using additional probe questions to achieve greater elaboration and clarifications of the answers given.

SPSS 16.0 for Windows was used for statistical processing of the questionnaire data. Descriptive results are presented as percentage of responses to each question (not necessarily of total number of participants). Results were considered significant at the 95% confidence level (p < 0.05). ArcGIS was used to analyze the spatial distribution of the questionnaire responses and to classify the English Local Authorities according to the Department for Environment, Food and Rural Affairs’ rural/urban classification scheme (Defra, 2008). To honour assurances of confidentiality given to respondents the spatial analysis is not presented here and the generic results have been used only to support the interpretation of the survey findings.
3. Results and discussion

The use of bioaccessibility

Question - Please indicate to what extent you agree with each of the following statements relating to contaminated land. Rate on a scale of 1-5 (1 strongly agree, 2 agree, 3 neither agree nor disagree, 4 disagree, 5 strongly disagree)

Table 1. Collation of Officers’ views on bioaccessibility.

<table>
<thead>
<tr>
<th>Statements</th>
<th>1 – strongly agree</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5 – strongly disagree</th>
<th>Don’t know</th>
<th>Response count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioavailability/bioaccessibility testing is a useful tool that facilitates</td>
<td>24.2% (30)</td>
<td>46.0% (57)</td>
<td>21.8% (27)</td>
<td>1.6% (2)</td>
<td>0.8% (1)</td>
<td>5.6% (7)</td>
<td>124</td>
</tr>
<tr>
<td>contaminated land management</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total contaminant concentration is a better guide for decision-making than</td>
<td>4.0% (5)</td>
<td>15.3% (19)</td>
<td>43.5% (54)</td>
<td>21.8% (27)</td>
<td>7.3% (9)</td>
<td>8.1% (10)</td>
<td>124</td>
</tr>
<tr>
<td>bioavailability/bioaccessibility data</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Information on benzo(a)pyrene bioavailability/bioaccessibility is needed to</td>
<td>23.4% (29)</td>
<td>41.9% (52)</td>
<td>19.4% (24)</td>
<td>7.3% (9)</td>
<td>0.8% (1)</td>
<td>7.3% (9)</td>
<td>124</td>
</tr>
<tr>
<td>support our decision-making</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Information on PAHs bioavailability/bioaccessibility to microorganisms can</td>
<td>15.4% (19)</td>
<td>38.2% (47)</td>
<td>22.0% (27)</td>
<td>0.8% (1)</td>
<td>0.8% (1)</td>
<td>22.8% (28)</td>
<td>123</td>
</tr>
<tr>
<td>determine suitability of bioremediation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use of contaminant bioavailability/bioaccessibility data leads to more</td>
<td>15.4% (19)</td>
<td>38.2% (47)</td>
<td>30.9% (38)</td>
<td>1.6% (2)</td>
<td>0.8% (1)</td>
<td>13.0% (16)</td>
<td>123</td>
</tr>
<tr>
<td>cost-effective site management</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>We would need more information on bioavailability/bioaccessibility before</td>
<td>26.4% (33)</td>
<td>50.4% (63)</td>
<td>13.6% (17)</td>
<td>8.8% (11)</td>
<td>0.0% (0)</td>
<td>0.8% (1)</td>
<td>125</td>
</tr>
<tr>
<td>deciding if it could help us within risk assessments</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The majority of respondents (70.2%) either strongly agreed or agreed that ‘bioavailability/bioaccessibility testing is a useful tool that facilitates contaminated land management’ (Table 1). Only 2.4% (corresponding to 3 respondents) either disagreed or strongly disagreed with the statement. The rest of the respondents neither agreed nor disagreed or indicated ‘don’t know’ option (corresponding to 21.8% and 5.6%, respectively). It is noteworthy that all respondents that selected the latter options also neither agreed nor disagreed or selected the ‘don’t know’ option with respect to other questions within the questionnaire.
In many areas throughout England and Wales there are naturally occurring contaminants at levels exceeding guideline values. It is virtually impossible to remediate an entire Local Authority’s jurisdiction area and/or preclude development on the basis of natural abundance of contaminants. The interviews found that bioaccessibility testing has therefore been perceived as a pragmatic, *ad hoc* decision-support tool when dealing, in particular, with naturally occurring contaminants. It was also indicated by 8 out of the 17 interviewees that bioaccessibility data was being applied to so-called ‘grey-zone’ concentrations where the exceedance of the guideline value is not substantial. It has been recognized that measuring bioaccessibility is impractical where the exceedance of the guidelines value is significant, whereby the use of bioaccessibility data would not affect the final designation of the land as contaminated.

The majority (79.4%) of respondents that selected ‘neither agree nor disagree’ and ‘don’t know’ option in answer to the question about the usefulness of bioaccessibility also strongly agreed or agreed that more information on bioavailability and bioaccessibility was needed. Participants more familiar with bioaccessibility commented that whilst greater access to information is needed generally, from their perspective as Local Authority regulators new research is critical only for some contaminants, such as PAHs (preferably in mixtures).

It has been also previously demonstrated that bioaccessibility data can lead to more cost-effective land management (Nathanail and Smith, 2007). Respondents who considered bioaccessibility to be a useful tool were also more likely to view it as leading to more cost-effective management of contaminated land (Figure 1).

![Figure 1. Percent of respondents indicating usefulness of bioaccessibility vs. cost-effectiveness of bioaccessibility.](image-url)
Information on contaminant bioaccessibility brings additional advantages when considering large, open-space areas where a significant amount of soil would have to be removed and/or remediated. Indeed, it was confirmed during the interviews with Officers from urban areas that bioaccessibility data might not be beneficial to smaller contaminated sites (such as gardens attached to houses), where the cost of bioaccessibility testing might surpass the cost of breaking the significant pollutant linkage (e.g. by capping). Some Officers in areas where naturally elevated contaminants have been identified acknowledged their regular use of bioaccessibility data. They perceived the use of bioaccessibility criteria as the only option to prevent remediation of entire Local Authority areas and to allow development.

Seven interviewees pointed to a prevailing concern among some Officers about overestimation of risks when applying current guideline values. The following comment, taken from one of the questionnaire, illustrates a view that was recurrently expressed:

‘I am firmly of the opinion that our perception of risk is far greater than the actual or true risk posed in many contamination assessments. It is recognized that non consideration of what is and what is not both bioavailable and accessible can lead to gross overestimation. This can result in a number of negative impacts both financially and in terms of human health risk assessment. PAH’s B(a)P and Arsenic are the immediate areas most often quoted and referenced in the debate’ (Questionnaire, 2008)

From the interviews it also appeared that bioaccessibility could be used not only with respect to (mostly naturally occurring) arsenic and heavy metals but also to other contaminants, both from natural and anthropogenic sources. For example, 65.3% of respondents either strongly agreed or agreed that information on bioaccessibility of benzo(a)pyrene (B(a)P), an organic contaminant that belongs to PAHs, is needed. It was elucidated during the interviews that organic contaminants have been perceived as under-researched (see also Rivett et al., 2002) and there was a held view among respondents that it is impractical to remediate the land where contamination would inevitably re-appear on account of elevated ambient concentrations from anthropogenic sources. Indeed, ubiquity of organic contaminants, as a consequence of pervasive and trans-boundary contamination from combustion of organic materials from both anthropogenic sources (fossil fuels) and natural processes (e.g. forest fires), has been previously demonstrated (Bamforth and Singleton, 2005).

‘There is no soil guideline value for PAHs/BaP in the UK. We have a TOX report from which the derived SGV is is around 1mg/kg for BaP, this is pretty much the same as the CIEH/LQM GAC. These values are usually well below the background concentrations in urban areas (...) The GAC is a considered to be the highest 'safe' value, what we do not have is knowledge of what value might cause 'harm' of 'significant possibility of harm'. Also lacking is data on land uses other than residential gardens and allotments e.g public open space.’ (Questionnaire, 2008)

Views on bioaccessibility did not appear to be influenced by the type of area covered by the Authority: statistical analysis of responses to the survey questions found
no significant difference between Officers in rural and in urban Authorities in England (Table 2). Similarly, cross-tabulation against other variables such as number of persons in contaminated land team, years of experience with contaminated land or the tasks Officers were involved in revealed no statistically significant differences (p > 0.05). It was therefore inferred that complex site-by-site circumstances, due, for instance, to naturally occurring elevated levels of contaminants or increased ambient anthropogenic concentrations and hence the necessity of a subsidiary decision-making tool, are the most likely factors driving the extent of familiarity with and acceptance of bioaccessibility.

Table 2. Percent of responses from rural and urban areas cross-tabulated with the statement relating to the usefulness of bioaccessibility and the information on benzo(a)pyrene. P-value established on the basis of Pearson Chi-Square test.

<table>
<thead>
<tr>
<th>Bioaccessibility is a useful tool</th>
<th>Rural</th>
<th>Urban</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly agree</td>
<td>23.7</td>
<td>27.1</td>
<td>0.82</td>
</tr>
<tr>
<td>Agree</td>
<td>44.1</td>
<td>52.1</td>
<td></td>
</tr>
<tr>
<td>Neither agree nor disagree</td>
<td>23.7</td>
<td>12.5</td>
<td></td>
</tr>
<tr>
<td>Disagree</td>
<td>1.7</td>
<td>2.1</td>
<td></td>
</tr>
<tr>
<td>Strongly disagree</td>
<td>0</td>
<td>2.1</td>
<td></td>
</tr>
<tr>
<td>Don’t know</td>
<td>6.8</td>
<td>4.2</td>
<td></td>
</tr>
<tr>
<td>Information on benzo(a)pyrene needed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strongly agree</td>
<td>25.4</td>
<td>25</td>
<td>0.14</td>
</tr>
<tr>
<td>Agree</td>
<td>45.8</td>
<td>39.6</td>
<td></td>
</tr>
<tr>
<td>Neither agree nor disagree</td>
<td>13.5</td>
<td>22.9</td>
<td></td>
</tr>
<tr>
<td>Disagree</td>
<td>8.5</td>
<td>4.2</td>
<td></td>
</tr>
<tr>
<td>Strongly disagree</td>
<td>0</td>
<td>2.1</td>
<td></td>
</tr>
<tr>
<td>Don’t know</td>
<td>6.7</td>
<td>6.2</td>
<td></td>
</tr>
</tbody>
</table>
Bioaccessibility and bioremediation

The bioaccessibility concept has been recognized not only from a human health perspective but also in terms of ecological risk assessment (Ollson et al., 2009) and in the context of applicability of bioremediation techniques (Diplock et al., 2009). Bioremediation is believed to be the most sustainable of all remediation approaches (van Dillewijn et al, 2009), whereas the ability of microorganisms to successfully biodegrade PAHs (especially low molecular weight PAHs) is well documented (Cerniglia, 1992; Bamforth and Singleton, 2005). It is noteworthy that Local Authorities are primarily involved in human health risk assessments. 53.6% of the respondents strongly agreed or agreed that ‘Information on PAHs bioavailability/bioaccessibility to microorganisms can determine suitability of remediation’ (Table 1). Also, 50.7% of the respondents indicated that bioremediation has been used in their area while 44.4% indicated that it has ‘never’ been used (Table 3). Of the respondents reporting the use of bioremediation in their areas, 40.8% reported it has been ‘rarely’ used (< 10% of sites under remediation), 8.5% answered it has been used ‘sometimes’ (10-30% of remediated sites), whilst only 1.4% has applied it ‘often’ (i.e. to more than 30% of sites under remediation).

Table 3. How often has bioremediation been used to clean-up PAH-contaminated land in your area?

<table>
<thead>
<tr>
<th></th>
<th>never (&lt;10% of sites under remediation)</th>
<th>rarely (10-30% of sites under remediation)</th>
<th>sometimes (&gt;30% of sites under remediation)</th>
<th>don’t know</th>
<th>Response Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>frequency</td>
<td>44.4% (63)</td>
<td>40.8% (58)</td>
<td>8.5% (12)</td>
<td>1.4% (2)</td>
<td>4.9% (7)</td>
</tr>
</tbody>
</table>

Common opinion among participants was that bioremediation can lead to a more cost-effective and more sustainable remediation (avoiding the ‘dig and dump’ approach). Yet, time and space constraints, uncertainty associated with residual levels and/or an inability to reduce contamination to the guideline value levels were the main factors perceived as limitations to the adoption of bioremediation. It was also suggested that the current financial crisis may slow down development and encourage developers to undertake more cost-effective albeit less time-efficient bioremediation.
What are the limitations to the implementation of bioaccessibility data?

Question - Which, if any, of the following factors hamper the application of bioavailability/bioaccessibility data in your area? (Please choose as many as relevant)

![Figure 2. Factors hampering the use of bioaccessibility data. Bars represent percent of responses to each option.](image)

In a survey of English and Welsh Local Authorities carried out in early 2005 by the Environment Agency the principal reason given by survey participants for not accepting bioaccessibility assessments was that there was no guidance published by the Environment Agency on the use of bioaccessibility (EA, 2006). In our survey, lack of statutory guidance was indicated as the main reason hampering the use of bioaccessibility (78% of participants; Figure 2). Officers who were interviewed emphasized that not necessarily statutory but that guidance from an authoritative body, such as the Environment Agency, is needed. Recurring opinion of the Officers within the survey was ‘conservatism of contaminated land assessment criteria’ regardless of substantial research in the field of bioaccessibility, both on national and international level; an observation congruent with some authors (BGS, 2007).

Other reasons indicated as limitations to bioaccessibility application that emerged from the questionnaire included: uncertainty associated with bioavailability/bioaccessibility data (71%), insufficient financial resources available to carry out testing (41.1%), failings in risk assessment reports (34.7%) and a lack of time to analyse the data (19.4%). It was also clear from the interviews that there was an implicit expectation that the guidance would dispel the uncertainties by establishing a standard methodology.
It was further apparent from the interviews that respondents who were more comfortable with using bioaccessibility data adopted strategies for dealing with the uncertainties. These included: incorporating a ‘worst-case’ scenario (the largest bioaccessibility value); carrying out extra sampling to verify whether data variability was due to heterogeneity of the site or the performance of the method; incorporating information about method robustness from an authoritative source such as the British Geological Survey (BGS); recommendation of a single test throughout all sites (e.g. Physiologically Based Extraction Test for arsenic) to assure consistency across the jurisdiction area; considering trends in data; and looking at vegetable uptake and; considering the use of the site.
Bioavailability and bioaccessibility definitions

Question - Do you make any distinction between the terms bioavailability and bioaccessibility? (Please choose as many as relevant)

![Figure 3. Percent of respondents relating to bioavailability and bioaccessibility terminology.](image)

It is noteworthy, that respondents who were more confused by the terminology of bioavailability and bioaccessibility were as concerned with the lack of guidance as with uncertainties. Respondents who indicated confusion with terminology indicated the lack of statutory guidance (71.7%) to be as important a limitation as uncertainty associated with bioaccessibility data (69.6%). Respondents who were familiar with terminological differences indicated the lack of statutory guidance (81.1%) to be the principal limitation, although not necessarily prevention, to the use of bioaccessibility.
**PAH-contaminated land**

Question - Please estimate how many sites are officially designated as contaminated in your area.

Question - Of these sites, what proportion is contaminated with polycyclic aromatic hydrocarbons (PAHs; e.g. benzo(a)pyrene)?

These questions were designed to quantify sites contaminated with PAH within England and Wales. Due to inconsistencies within data these questions are not interpreted within this report.

Question - Which guidelines would you accept within risk assessments of sites contaminated with PAHs? (Please choose as many as relevant)

![Figure 4. Guidelines used for PAH-contaminated land decision-making.](image)

Most common comments on the use of the guidelines within risk assessments of sites contaminated with PAHs included:

‘Site specific criteria will be accepted where derived from robust, justifiable and relevant risk assessment models which have been adapted to be in line with UK policy.’

‘There is no clear guidance at present on what values to use. LAs are at present basically in a position where we been asked to calculate values for each site with little guidance from DEFRA. This lack of guidance also has implications for our PPS23 work.’
‘I have accepted Site Specific Assessment Criteria for PAH based on Toxicity Equivalent factors as this seems a logical approach. I would also accept generic values derived by large consultancies such as Hydrock, Hyder, Atkins, WSP etc so long as the figures were derived using accepted models (e.g. CLEA, SNIFFER), and do not differ too greatly from those derived by LQM GAC or other transparent approaches. Consultancies seem to favour SNIFFER, though RBCA is increasingly popular for commercial sites (…).’
4. Conclusions and recommendations

‘I think bioaccessibility is useful but there is no certainty of its use in this field [contaminated land] and lack of guidance and information to either support or disagree with using bioaccessibility. If we use it there is no government body to back us up and support us and if we don’t use it, what else do we use?’ (Questionnaire, 2008)

As corroborated by the interviews, the above statement epitomises the opinion of a number of decision-makers throughout England and Wales. Indeed, only 4.8% of the respondents indicated that they use bioaccessibility data confidently (Figure 2). Given the ubiquity of natural contamination and prevalent elevated ambient concentrations of anthropogenic contaminants there is an uncontested need to equip decision-makers with appropriate management tools. At the moment, for problematic site-specific risk assessments, bioaccessibility data is perceived as the way forward.

As bioaccessibility is already in use there is, firstly, an urgent need for straightforward, void of scientific jargon guidance to standardise the application of bioaccessibility data throughout the country and to uniform criteria for development. Secondly, more information, training and availability of successful case studies, together with greater access to research articles are needed to instil confidence in the use of bioaccessibility data. Indeed, 76.8% of the respondents either strongly agreed or agreed that more information was needed. Whilst there is a need for a standard test for arsenic and metals quoted as extensively investigated, there is also a need for a framework for PAH risk assessment and more research on PAH bioaccessibility. Finally, bringing the knowledge and opinion of Local Authorities into policy-making and into academia, whilst making academic research more available to decision- and policy-makers, can trigger more relevant academic research on the one side, and facilitate more appropriate decision-making on the other.

The concepts underpinning the use of bioaccessibility constitute a contaminant behaviour paradigm and it is now widely recognized that the risk from contaminants in the soil arises not from the mere presence of the contaminant of concern but from the ‘significant possibility of significant harm’ that the contaminant poses to environmental receptors. Bioaccessibility embedded within a risk-based approach that provides flexible frameworks and intrinsically stimulates scientific advances to improve accuracy of risk assessments can create strong epistemic and pragmatic circumstances for driving progress in contaminated land risk assessment. For a risk-based system to operate, policy-maker, risk assessor and researcher must however effectively communicate.

Statutory requirements for the management of contaminated land incorporate qualitative caveats regarding the stringency with which authorities should apply them, stipulating that their application should not entail excessive cost or conflict with ‘overriding public interests’ (Pollard et al., 2004). In this context bioaccessibility offers a decision-support tool. Evaluation of bioaccessibility is however not meant to replace other approaches but to assist decision-makers in situations where alternative solutions are limited.
Uncertainties associated with bioaccessibility along with a lack of robust *in vivo* bioavailability data have been reported as the main limitations to bioaccessibility acceptance by policy-makers (EA, 2002; Interviews, 2009). As uncertainties suggest the need for more research on the one hand and incorporation of already published research into policy-consideration on the other, the latter limitation could appear to be a ‘dead-end’ statement given its immanent contradiction with respect to animal testing policy (BGS, 2007).

Decision-makers managing land contamination face an array of complex issues and pressures associated with public and financial liability, with the management of different regulatory interfaces, with interpretation of sophisticated analytical data and risk assessment reports, with evaluation of the relative capabilities of remediation technologies and with the maintenance of public confidence in remediation projects. In the face of these challenges and of economic and environmental pressures, it has been indicated by survey participants that consideration of bioaccessibility can aid decision-making, refine risk assessments and may facilitate sustainable land management.

However, this study indicates that unless a greater commitment is made with respect to developing a standardised perspective on bioaccessibility and securing it within a framework from an authoritative source, the confidence of local regulators in the use of this tool will be undermined and progress in integrating it into contaminated land decision-making will continue to be hampered.
Summary

Most significant findings of this survey include:

- Bioaccessibility is a useful tool that facilitates contaminated land management. 70.2% of the questionnaire participants either strongly agreed or agreed with this statement.
- 65.3% of respondents expressed the need for information on benzo(a)pyrene bioavailability/bioaccessibility to support decision-making on contaminated land.
- Lack of statutory guidance on the use of bioaccessibility was indicated as the main factor hampering the use of bioaccessibility. This was indicated by 78.2% of participants.
- 15 out of 17 interviewees were ‘ready to accept bioaccessibility’, which corroborated findings of the questionnaire.
- There is an outspoken need to equip regulators with decision-support tools especially in the context of elevated natural and ambient contaminants concentrations.
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