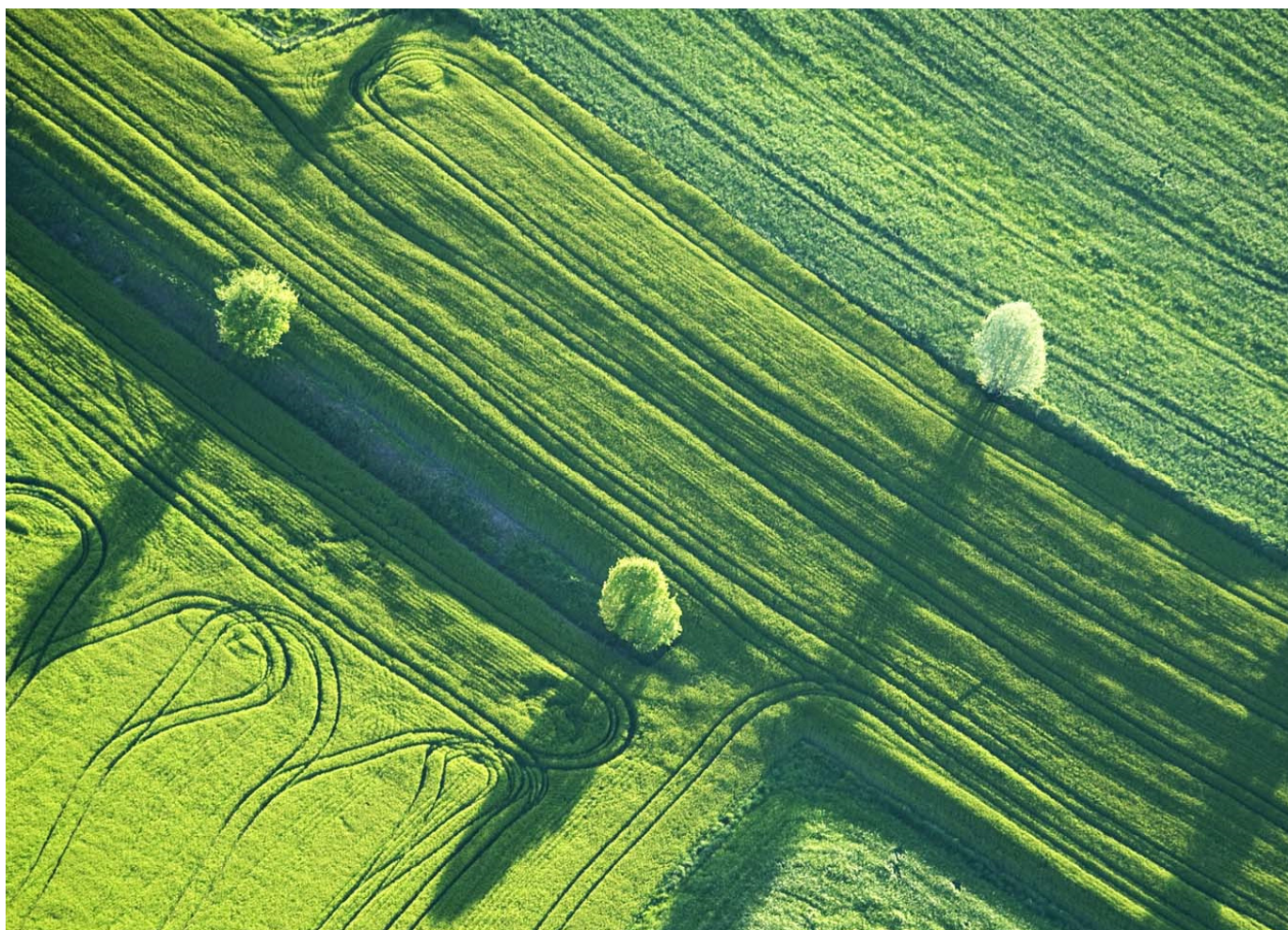




Six Town Housing

Traveller Site (Fernhill Caravan Park), Bury

Soil assessment –DQRA

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This work has been undertaken in accordance with the quality management system of RSK Environment Ltd.

CONTENTS

1	INTRODUCTION.....	3
1.1	Background.....	3
1.1.1	Legislative background.....	3
1.1.2	Investigations undertaken to date.....	6
1.2	Aim and objectives.....	7
1.3	Scope.....	7
1.4	Existing reports.....	7
1.5	Limitations.....	7
2	THE SITE.....	8
2.1	Site location, surrounding area and description.....	8
2.2	Ground conditions.....	8
2.2.1	Soil mounds.....	8
2.2.2	Landscaped areas (including plots).....	8
2.3	Contaminant concentrations.....	9
2.3.1	Summary statistics.....	10
2.4	Data gaps and uncertainty.....	11
3	BACKGROUND TO HUMAN HEALTH RISK ASSESSMENT.....	13
3.1	The UK approach to human health risk assessment.....	13
3.2	UK Model – CLEA 1.071.....	14
3.3	Generic assessment criteria.....	14
3.3.1	Category 4 screening levels.....	15
3.4	Benzo(a)pyrene as a surrogate marker.....	15
3.5	Site-specific assessment criteria.....	16
4	CONCEPTUAL MODEL.....	18
4.1	Sources.....	18
4.1.1	PAH in soil.....	18
4.1.2	PAH toxicity.....	19
4.2	Receptors.....	19
4.3	Pathways.....	19
4.4	Potentially complete linkages.....	20
4.5	Data gaps, uncertainties and assumptions.....	20
5	GENERATION OF A SITE SPECIFIC ASSESSMENT CRITERIA.....	21
5.1	Benzo(a)pyrene as a surrogate marker.....	21
5.2	Critical Receptor.....	23
5.3	Exposure frequency.....	23
5.4	Soil to dust transport factor.....	23
5.5	Dust loading factor.....	24
5.6	Soil and dust ingestion rate.....	24
5.6.1	Amendment 1 – child receptor.....	25
5.6.2	Amendment 2 – child receptor.....	25

5.7	Dermal contact.....	26
5.8	Physical parameters	27
5.9	Toxicological parameters	27
5.9.1	Benzo(a)pyrene as a surrogate marker	27
5.9.2	Low level of toxicological concern	27
5.9.3	Bioavailability and bioaccessibility	29
5.10	Model selection	30
5.11	Assessment criteria selection	30
6	SITE SPECIFIC RISK ASSESSMENT	32
6.1	Derivations of site-specific assessment criteria	32
6.2	Linkages for assessment	33
6.3	Assessment of benzo(a)pyrene concentrations – perimeter soil mounds	34
6.3.1	Exposure scenario 1 – child receptor AC1-AC6	34
6.3.2	Exposure scenario 2 - child receptor AC1-AC6	35
6.3.3	Exposure scenario 3 – child receptor AC1-AC6	35
6.3.4	Summary.....	36
6.4	Assessment of benzo(a)pyrene concentrations – plots/landscaped areas	36
6.4.1	Plot 10 (HP17)	36
6.4.2	Plot 13 (HP17)	36
6.4.3	Plot 15 (HP14)	37
6.4.4	Landscaping along roadways (HP16)	37
6.5	Sensitivity analysis	37
7	CONCLUSIONS AND RECOMMENDATIONS	38
8	REFERENCES.....	40

TABLES

Table 1: Soil exceedances above RSK GAC for a residential with home-grown produce land use – perimeter soil screening mounds.....	9
Table 2: Soil exceedances above RSK GAC for a residential with home-grown produce land use – plots/landscaped areas.....	10
Table 3: Summary statistics (RSK) – benzo(a)pyrene – perimeter soil mounds.....	11
Table 4: Site specific assessment criteria and top three relative pathway contributions to total exposure (%)	33

APPENDICES

Appendix A	Service constraints
Appendix B	Surrogate marker assessment tables
Appendix C	CLEA model runs

1 INTRODUCTION

RSK Environment Limited (RSK) was commissioned by Six Town Housing to carry out a detailed quantitative risk assessment (DQRA), of the land at the existing Fernhill Caravan Park, Every Street, Bury. Fernhill Caravan Park is herein after referred to as 'the site'.

The current report follows on from a generic quantitative risk assessment (GQRA; See RSK report Ref. 11151 R01), which took a precautionary approach to the risk assessment of soil-borne contaminants present within perimeter soil mounds, within landscaped areas adjacent to roadways and in certain residents plots. Where a generic approach to risk assessment is not appropriate to the proposed land use, as the underlying generic assumptions are not met, or generic assessment criteria (GAC) are exceeded at the site, a DQRA may be required to further understand potential risks to human health.

The current DQRA has therefore been undertaken to support an understanding of the potential risks due to exceedances of the GAC and to understand if intervention is warranted under Part 2A of the Environmental Protection Act 1990, or whether further investigation and associated risk assessment is required.

This report is subject to the RSK service constraints given in Appendix A.

1.1 Background

1.1.1 Legislative background

There are two regimes that are relevant to the current site and the approach taken to understand if soil-borne contaminants at the site may pose a potential risk to human health. These are discussed in detail in subsequent sections.

The planning regime deals with future developments and considers suitability of land that is subject to a change of use (requiring planning permission) to ensure the land is suitable for the intended use based on current knowledge. In contrast Part 2A of the Environmental Protection Act 1990 deals with the legacy of our industrial history or past activities at a site and considers if the land poses a significant risk to receptors.

The terminology used within the contaminated land regime and the planning system are very different, and have very different aims in terms of assessing potential risk to human health. Part 2A is focused on demonstrating a significant possibility of significant harm (i.e. unacceptable risk) and the planning system is focused on demonstrating that land (following remediation if required) is "safe", suitable for use and not capable of being determined as contaminated land under Part 2A. Consequently the level of risk associated with determining land as contaminated will be significantly higher than the

level of risk considered to be acceptable for future developments. This leaves many existing sites, or developments, where intervention is not required as the land is considered not to be posing a significant risk to human health, but if that land was to be redeveloped under the planning regime remediation would be required.

1.1.1.1 Town and Country Planning

The planning regime (Town and Country Planning Act 1990) provides for certain matters, including land contamination, to be considered and dealt with during redevelopment of land through the planning process. This regime is supported by the National Planning Policy Framework (NPPF; MHCLG, 2018). Paragraph 178 of the NPP states that:

“Planning policies and decisions should ensure that:

a site is suitable for its proposed use taking account of ground conditions and any risks arising from land instability and contamination.”

Consequently at the time of a developer making a planning application to redevelop land, they are required to ensure the land is suitable for the intended future use (e.g. a residential land use, a park, an industrial estate etc.). However, suitability is dependent on scientific knowledge at that time in relation to potential risks to human health (or controlled waters). The planning regime takes a precautionary approach to potential risks to receptors, and therefore is not necessarily the same approach to take when considering potential risks to human health (or controlled waters) of existing land uses which were granted planning permission many years previously. Existing land can be considered in the context of current criteria for suitability under the planning regime, as has been undertaken in the GQRA presented in RSK report Ref, 11151 R01. If there are exceedances of GAC used in such an assessment this does not automatically mean that the land is unsuitable for its current / existing use, rather it means that further assessment may be required to more fully understand if there are potential risks to receptors.

The 2012 Statutory Guidance for Part 2A (see below) explicitly states GAC are cautious estimates of concentrations of contaminants in soil at which there is considered to be no or minimal risk to health and are “*..designed to estimate levels of contamination at which risks are likely to be negligible or minimal and far from posing a significant possibility of significant harm to human health.*”.

1.1.1.2 Part 2A of the Environmental Protection Act 1990

Part 2A of the Environmental Protection Act 1990 came into force in England in April 2000. The regime places a duty on local authorities, as the primary regulators, to identify (normally through an intrusive investigation of that land) and secure the remediation of contaminated land in their respective areas. It was introduced to provide an improved system for the identification and remediation of land where historical contamination is causing unacceptable risks to human health or the wider environment, assessed in the

context of the current use and circumstances of the land. Therefore this regime considers existing land uses. A detailed understanding of Part 2A is provided by the Defra Statutory Guidance on Part 2A (Defra, 2012).

The definition of contaminated land under Section 78A(2) of Part 2A, with respect to human health is:

“any land which appears to the LOCAL AUTHORITY in whose area it is situated to be in such a condition, by reason of substances in, on or under the land, that –

“(a) SIGNIFICANT HARM is being caused or there is a SIGNIFICANT POSSIBILITY of such harm being caused.”

The contaminated land regime under Part 2A is a risk based approach to the identification and remediation of existing developed land where contamination, in the context of human health, poses an unacceptable risk (significant harm) to health or poses a significant possibility of significant harm (SPOSH).

A description of significant harm in relation to human health (death, disease, serious injury, genetic mutation, birth defects or the impairment of reproductive functions) is set out in Section 4 of the Defra Statutory Guidance on Part 2A (Defra, 2012). Unacceptable risk, unacceptable intake or unacceptable exposure is not defined in the legislation or Statutory Guidance and there are no generic soil assessment criteria for assessing unacceptable risk. Such assessment criteria to evaluate the potential for SPOSH at a site, and to be used within a risk assessment under Part 2A, therefore need to be derived on a case by case basis.

What constitutes significant harm or unacceptable risk is not a purely scientific assessment and will to a certain extent have to incorporate value or societal judgements. In the absence of guidance, approaches to whether potential receptors will be exposed to sufficient levels of a contaminant to cause SPOSH will vary between sites, local authorities and environmental consultants.

The 2012 Statutory Guidance presents a four category system for considering land under Part 2A:

Category 1 (contaminated land): Human health cases are those where the authority considers there is an unacceptably high probability supported by robust science based evidence that significant harm would occur if not action is taken to stop it. Land deemed as category 1 includes land where the authority is aware that similar land, situations or similar degrees of exposure via any medium are known or suspected on the basis of robust evidence to have caused such harm before in the UK or where the authority considers significant harm may already have been caused and an unacceptable risk exists that it may occur again.

Categories 2 and 3: For human health cases the authority should consider the broad objectives of the regime and government policy, the authority's assessment of the possibility of significant harm including the likelihood of such harm, estimated impact, timescale and uncertainty. Where the authority cannot make a decision the likely direct

and indirect health benefits and impacts of regulatory intervention should be considered. If it is not clear the net benefits outweigh the impact of remediation land should be placed into category 3. If after the impacts and benefits are considered the authority is still undecided land should be placed into category 3.

Land should be placed into category 2 (contaminated land) if the authority concludes there is a strong case for considering risks from land are of sufficient concern that the land poses a significant possibility of significant harm, i.e. land where there is little or no direct evidence that similar land, situations or levels of exposure have caused harm before, but nonetheless the authority considers on the basis of the available evidence including expert opinion there is a strong case for taking action under Part 2A on a precautionary basis.

Land should be placed into category 3 (not contaminated land) if the strong case does not exist and therefore the legal test for significant possibility of significant harm is not met. This may include land where the risks are not low, but the authority considers intervention under Part 2A is not warranted.

Category 4 (not contaminated land): Human health cases are those where the local authority considers that land does not pose a significant possibility of significant harm owing to no risk or a low level of risk. This classification can occur at any stage during risk assessment and include land where no relevant contaminant linkage is identified, land where only normal levels of contaminants exist, land excluded since contaminant concentrations are below generic assessment criteria or where estimated levels of exposure from soil are likely to form only a small proportion of what a receptor may be exposed to.

Land redeveloped, or remediated, through the planning regime would be expected to fall within Category 4.

1.1.2 Investigations undertaken to date

This report should be read in conjunction with RSK report Ref. 11151 R01, where the investigations undertaken to date (RSK and Tergeo) are detailed. The investigations focused on the perimeter soil mounds, landscaped areas adjacent to internal road ways and within three plots (Plot 10, 15 and 17).

Four potential contaminant linkages were identified at the site and evaluated as part of a GQRA by RSK. The conclusions of the report were that two linkages relating to soil borne contaminants (excluding asbestos) required further risk assessment. The two linkages specifically related, following the GQRA, to polycyclic aromatic hydrocarbons (PAHs) which exceeded the conservative GAC used in the GQRA. The four PAHs of interest are benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene and dibenzo(a,h)anthracene, all of which are genotoxic.

1.2 Aim and objectives

The aim of the proposed work is to complete a DQRA in relation to the presence of soil-borne PAHs at the site and the current receptors at the site.

The key objectives are to:

- Use the Category 4 Screening Level (C4SL) for benzo(a)pyrene as a surrogate marker for the genotoxic PAH (all reported exceedances in the generic quantitative risk assessment were for genotoxic PAH)
- Review available literature in relation to exposure parameters to refine the existing C4SL for benzo(a)pyrene to remove conservatism
- Review available toxicological data (as appropriate to the risk assessment) to refine the existing C4SL for benzo(a)pyrene, if required
- Derive a site specific assessment criteria (SSAC), or a range of SSAC, against which to evaluate if there is likely to be a significant possibility of significant harm (SPOSH)

1.3 Scope

The scope of the DQRA and layout of this report has been designed with consideration of CLR11 (Environment Agency, 2004), the Defra Statutory Guidance on Part 2A (Defra, 20), relevant EA guidance and the Category 4 Screening Level reports published by Defra and CL:AIRE (Defra, 2014; CL:AIRE, 2014a and b).

The DQRA was carried out following discussions with Six Town Housing and Bury Council.

1.4 Existing reports

The following previous site reports exist for the site:

- Tergeo (2017), Travellers Site, Every Street, Bury, BL9 5BE, Ref. 0293_01, dated March 2017.
- RSK (2018). Soil assessment: Traveller Site (Fernhill Caravan Park), Bury – GQRA, Ref. 11151 R01, dated October 2018.

1.5 Limitations

The comments given in this report and the opinions expressed are based on the ground conditions encountered during the RSK site work and on the results of tests made in the laboratory. However, there may be conditions at the site that have not been found during the investigation, and therefore could not be taken into account.

2 THE SITE

2.1 Site location, surrounding area and description

The site is located within an industrial setting in Fernhill, Bury, and occupies an area of 0.6 hectares. Access to the site is through a gated entrance off Every Street, which is to the north. To the west of the site is a waste transfer station and to the north, beyond Every Street are the playing fields of a primary school. To the east of the site are various companies including tree felling, transportation and material distribution. To the south of the site is another traveller site.

The site accommodates approximately 17 separate traveller families on individual plots. The plots are generally covered in hardstanding although three plots each contain a small landscaped area. A series of raised soil screening mounds are located within the north-west, north-east and south-eastern parts of the site, along the site perimeter.

Further site details are provided in RSK report Ref. 11151 R01.

2.2 Ground conditions

Full details of ground conditions at the site are provided in RSK report Ref. 11151 R01, Section 4.

2.2.1 Soil mounds

In summary the soil within the perimeter soil mounds is described by RSK as two distinct layers by RSK:

- thin topsoil layer comprising light to dark brown slightly silty (in places), gravelly SAND with sandstone, rare brick and concrete and abundant rootlets, generally encountered from the surface to 0.1m below top of mound (BTM).
- Made Ground generally comprising dark brown gravelly SAND with low to medium cobble content and manmade products making up between <5 and 30% of the volume, generally encountered from 0.1m to 0.4m BTM.

2.2.2 Landscaped areas (including plots)

The soil encountered in the landscaped areas of Plots 10 (a soil mound), 15, 17 and the narrow landscaped strips on either side of the main roadway generally comprised topsoil with less man made material than was observed in the soil screening mounds.

The material was generally described as light to dark brown slightly silty gravelly sand SAND with sandstone, rare brick, concrete and abundant rootlets, plastic sheeting and coal, to the maximum investigated depth of 0.2mbgl.

2.3 Contaminant concentrations

The laboratory data used in the current DQRA is the RSK data collected during 2018; Tergeo data relating to samples collected at depth have not been included for a number of reasons. The Tergeo soil samples are not relevant to the likely depth at which a receptor would encounter soil in a residential setting and there is uncertainty as to whether the material at depth represents the same materials as those located towards the surfaces of the mounds. This uncertainty is primarily due to the absence of detailed logs in the Tergeo report, uncertainty as to whether materials within the mounds was appropriately logged by Tergeo and that Tergeo describe the material encountered as clay.

Following statistical analysis, it was reported that three PAHs (benzo(a)pyrene, benzo(b)fluoranthene and dibenzo(a,h)anthracene) exceeded the relevant GAC used in the GQRA presented in RSK report Ref. 11151 R01 for the perimeter soil mounds. Four PAHs (benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene and dibenzo(a,h)anthracene) were reported to exceed the relevant GAC within plots/landscaped areas. All these PAHs are genotoxic. The complete laboratory dataset and GQRA screening is presented in Appendices in RSK report Ref. 11151 R01.

As stated previously, and discussed further in Section 3.4 below, benzo(a)pyrene has been used a surrogate marker within the current DQRA, for assessing the potential risks associated with genotoxic PAHs at the site. Four out of 13 RSK samples exceed the relevant GAC for benzo(a)pyrene within the soil mounds (see Table 1) and four out of six RSK samples exceed the relevant GAC for benzo(a)pyrene within the landscaped areas (see Table 2).

Table 1: Soil exceedances above RSK GAC for a residential with home-grown produce land use – perimeter soil screening mounds

Contaminant	GAC (C4SL) (mg/kg)	Hand pit location and depth (m bgl)	Concentration (mg/kg)
Benzo(a)pyre	5.3	HP02 0 – 0.3 m BTM	6.8
		HP04 0.15 – 04 m BTM	11.4
		HP09 0.2 – 0.3 m BTM	6.08
		HP10 0.2 – 0.3 m BTM	11.9
Notes: BTM = below top of mound			

Table 2: Soil exceedances above RSK GAC for a residential with home-grown produce land use – plots/landscaped areas

Contaminant	GAC (C4SL) (mg/kg)	Hand pit location and depth (m bgl)	Concentration (mg/kg)
Benzo(a)pyrene	5.3	HP13 0 -0.2 m BTM (Plot 17)	7.12
		HP14 0 – 0.1 m BTM (Plot 15)	14.7
		HP16 0 – 0.12 m BTM (roadway verge)	8.54
		HP16 015 – 0.2 m BTM (roadway verge)	13.8
BTM = below top of mound			

2.3.1 Summary statistics

The soil sampling undertaken at the site was a mixture of targeted (plots/landscaped areas) and non-targeted (perimeter mounds) sampling.

As such, the plots/landscaped areas data set compiled for the site, is not considered suitable for undertaking statistical analysis in accordance with *Guidance on Comparing Soil Contamination Data with a Critical Concentration* (CIEH and CL:AIRE, 2008). Taking this into account, the GQRA presented in RSK report Ref. 322144 R01, directly compared individual sample results to the relevant GAC.

As discussed previously and in subsequent sections below (see Section 3.4), the current DQRA is focused on benzo(a)pyrene as a surrogate marker for eight genotoxic PAHs. Descriptive summary statistics for the perimeter soil mounds dataset are summarised in Table 3 for benzo(a)pyrene.

Sampling data collected for a site provides an estimate of the sample mean; the average of the site data. However the true mean remains unknown and will always remain unknown. When considering a dataset for a site, the approach taken for non-targeted samples is to consider the estimated concentration range within which the true mean will fall. This is achieved through the use of confidence limits, which provide a concentration range within which the assessor has a certain level of confidence (normally 95%) within which the true mean will fall. For targeted samples, such as for the plots/landscaped areas, this approach is not applicable and samples are considered individually.

The 95th Upper Confidence Limit (UCL) of the true population mean is used to assess a site under the planning regime. The purpose of the statistical test is to evaluate if there is a 95% probability that the true population mean falls below the GAC. This involves comparing the UCL with the GAC and deciding whether the difference is due simply to chance or is a (statistically) significant difference. If the UCL exceeds the GAC, a potential risk may be present and further investigation is required.

Under Part 2A the opposite situation applies. The statistical test is all about showing that there is a 95% probability that the true population mean falls above the GAC and the test involves comparing the 95th Lower Confidence Limit (LCL) of the true population mean with the GAC.

Table 3: Summary statistics (RSK) – benzo(a)pyrene – perimeter soil mounds

Statistic	Value (mg/kg)	Comments
Maximum	11.9	HP10 0.2-0.3 mBTM
Minimum measured (above LMDL)	0.93	
Minimum reported	0.93	No results were below the LMDL
Mean	4.71	
Median	3.51	
95 th UCL	8.96	
95 th LCL	0.45	
Notes: UCL – Upper confidence limit; LCL – lower confidence limit		

2.4 Data gaps and uncertainty

Little is known about the redevelopment of the site or the provenance of soils used to construct the perimeter soil mounds, the mound within Plot 10 or used in other the landscaping area of the site. As discussed in RSK report Ref. 322144 R01, it is understood that in the late 1980s made ground from an adjoining area was placed on the site as a series of perimeter screening mounds so that the surrounding industrial setting can be screened from site occupants. An understanding of the potential source(s) of the PAHs, lead and asbestos reported in soil at the site is outwith the scope of the current DQRA.

Concentrations, in the shallow soils investigated, exceeding the benzo(a)pyrene GAC are located across the site and do not appear to be concentrated in any particular area of the site.

The initial investigation was not designed for a formal assessment under Part 2A, being focused on undertaking a GQRA and an initial assessment of conditions at the site. It is acknowledged that for a comprehensive investigation and risk assessment to inform a decision of the status of the site under Part 2A (i.e. which of the four categories the site may fall into), additional sampling would normally be undertaken. However, the exploratory hole logs for the site (Appendix D of RSK report Ref. 322144 R01) indicate that the Made Ground is broadly the same comprising dark brown gravelly SAND with low to medium cobble content and manmade products making up between <5 and 30% of the volume. The estimated content of manmade products (e.g. brick, concrete, plastic materials, rubber, glass etc.) varied across the site, with lower estimated concentrations in site areas to the east. Therefore RSK do not consider that additional sampling will significantly alter the conclusions of the current DQRA.

While the material within the perimeter soil mounds is highly heterogenous, RSK has concluded the materials sampled by RSK appears likely to be from the same source and can be considered as forming a single soil population. This conclusion, as discussed

previously, is not extended to the Tergeo data over which there is uncertainty as discussed earlier in the current report.

Less manmade materials were reported in the samples from the plots and landscaped areas, being more akin to a reworked topsoil although this is unlikely to have been site won.

3 BACKGROUND TO HUMAN HEALTH RISK ASSESSMENT

A human health risk assessment is the process to estimate the nature and probability of adverse health effects in humans (the receptor) who may be exposed via one or more pathways (e.g. soil ingestion) to chemicals in contaminated environmental media (the source; e.g. soil, air, water), now or in the future.

Human health risk assessment involves characterisation of the hazard in terms of the quantities of the substances present in a defined area, their toxicological properties and assessment of the potential exposure of receptors to the contaminants. Risk is therefore assessed on the basis of predicted exposure and the anticipated toxicological effects of those exposures.

Depending on the aim of the risk assessment (e.g. to assess the land under the planning regime for a future development, or to assess the land under Part 2A) different soil assessment criteria are used, which related to a different level of potential risk.

3.1 The UK approach to human health risk assessment

The overarching guidance in the United Kingdom relating to risk assessment for contaminated land is that published by the Environment Agency (EA) in 2004 and titled 'Model Procedures for the Management of Land Contamination'. Contaminated Land Report 11 (CLR11) was developed to provide the technical framework for applying a risk management process when dealing with land affected by contamination. The risk management process involves identifying, making decisions on, and taking appropriate action to deal with land contamination in a way that is consistent with government policies and legislation within the UK.

In line with CLR11 (EA, 2004), there are two stages of quantitative risk assessment, generic and detailed. A Generic Quantitative Risk Assessment (GQRA) comprises the comparison of measured soil, groundwater, soil gas and ground gas concentrations with GAC that are appropriate to the contaminant linkage being assessed. Generic Assessment Criteria are based on a generic conceptual model (an understanding of the potential contaminant sources, the receptors that might be exposed to the contaminant(s) and the pathways by which the receptor maybe exposed) for a pre-defined land use (e.g. residential, commercial, public open space, allotments). Such criteria make broad assumptions about receptor behaviour at a site and their likely exposure to contaminants, and are therefore not site-specific. These GAC are strongly precautionary, associated with minimal or low potential risk to human health and are used to screen sites out from further risk or investigation. Such GAC are used within a GQRA such as that presented within RSK report Ref. 11151 R1. Generic assessment

criteria are therefore designed to be conservative and to identify sites that definitely do not pose a significant risk to human health, rather than those that do so.

There are six published pre-defined generic land uses in the UK covering residential with and without home-grown produce, commercial, two public open space land uses, and allotments (see CL:AIRE, 2014a) for which various authoritative bodies have published GAC.

A generic land use may not be appropriate for a risk assessment for several reasons. The conceptual model used to derive the GAC may be different to the intended use of the land or behaviour of the identified receptor(s). If there is an exceedance of a GAC, a Detailed Quantitative Risk Assessment (DQRA) may be required to refine the conceptual model used to derive a site specific assessment criteria (SSAC). SSAC can take account of the actual ages of receptors present at the site, their likely exposure to identified contaminants, site-specific soil characteristics and building types, rather than making generic assumptions. SSAC are therefore more realistic with regards to the proposed use of a site. In addition, SSAC can be refined to remove conservatism associated with GAC and to derive SSAC that are more suitable for assessing significant harm to human health under Part 2A.

Generic assessment criteria and SSAC are discussed in greater details in subsequent sections of this report.

3.2 UK Model – CLEA 1.071

The UK approach to risk assessment involves the use of the EA Contaminated Land Exposure Assessment (CLEA) model when deriving assessment criteria for soils within a human health risk assessment (either generic or site-specific criteria). This model is used in all parts of the UK.

Other models are available and suitable for use within the UK framework, however the CLEA model is produced by the EA with UK specific default parameters embedded and is therefore generally the most appropriate model to use. CLEA uses a series of equations to predict, or simulate, exposure of a 'critical' receptor via a number of exposure pathways. The critical receptor is dependent on the identified land-use. The CLEA model considers up to ten exposure pathways (soil and dust ingestion are combined), although not all may be active depending on the generic land-use and associated receptor modelled.

The CLEA model (version 1.071) has been adopted within the current DQRA.

3.3 Generic assessment criteria

In a GQRA, GAC are compared to reported soil contaminant concentrations at a site either individually or using statistics, and where the reported contaminant concentrations exceed the GAC it can be concluded that there may be a potential risk to human health

and further risk assessment or mitigation measures may be required. Such criteria are normally derived using Health Criteria Values (HCV) set at a tolerable or minimal level of risk to human health, and using precautionary generic assumptions in respect of receptors and exposure to contaminants (EA, 2009).

The GQRA for the site used RSK derived GAC, which are a combination of low and minimal risk. Such assessment criteria are much lower (i.e. a lower concentration) than soil assessment criteria associated with SPOSH and used for an assessment under Part 2A.

3.3.1 Category 4 screening levels

Category 4 Screening Levels (C4SLs) were initially published by CL:AIRE, under contract to Defra, in December 2013, being re-issued as Revision 2 in late 2014. They fall into the category of a 'GAC'. They were designed for use in England where a four category system for considering land under Part 2A is used. In brief, and as discussed earlier in this report, for human health, Category 4 is where land does not pose a significant possibility of significant harm owing to no risk or a low level of risk. Category 1 sites are those where the authority considers there is an unacceptably high probability supported by robust science based evidence that significant harm would occur if no action is taken to stop it.

Category 4 Screening Levels are used in England to screen sites out from further assessment (i.e. they definitely do not meet the criteria for SPOSH). Category 4 Screening Levels represent a new set of generic assessment criteria that are more pragmatic (but still strongly precautionary) compared to the existing similarly derived minimal or tolerable risk soil assessment criteria. They are based on what is termed a low level of toxicological concern (LLTC), rather than the previously used tolerable or minimal risk HCV, which within the context of Part 2A '*..definitely does not approach an intake level that could be defined as causing a Significant Possibility of Significant Harm to human health.*' (CL:AIRE, 2014a). As such they represent a slightly higher level of risk than other minimal risk GAC, although still protective of human health.

Of relevance to the current DQRA is the ability to use the C4SL for benzo(a)pyrene as a surrogate marker for eight genotoxic PAHs.

3.4 Benzo(a)pyrene as a surrogate marker

Polycyclic aromatic hydrocarbons are a large group of hydrocarbons typically encountered in the soil environment as complex mixtures from a wide range of sources. A number of PAHs have been shown to be genotoxic (EFSA, 2008); eight of those PAH are routinely considered within contaminated land risk assessment and are included in the USEPA 16, which is a standard analytical and reporting suite:

- Benzo(a)anthracene
- Benzo(a)pyrene
- Benzo(b)fluoranthene

- Benzo(k)fluoranthene
- Benzo(g,h,i) pyrene
- Chrysene
- Dibenzo(a,h)anthracene
- Indeno(1,2,3-c,d)pyrene

There are two approaches that can be taken to assess the risk posed to human health by genotoxic PAH in soil:

- the use of individual screening criteria for specific individual congeners (normally the USEPA 16), or
- the use of an appropriate surrogate marker to assess the combined risk.

Benzo(a)pyrene is the most extensively studied PAH, ubiquitous in the environment and considered to be the one of the most potent PAH (HPA, 2010). The Health Protection Agency (2010; now Public Health England) recommended the use of a surrogate marker (benzo(a)pyrene) for the risk assessment of genotoxic PAHs within soil, provided the PAH profile within the soil is similar to that reported in the oral carcinogenicity study in mice reported by Culp *et al.*, (1998). The surrogate marker approach is supported by CL:AIRE (2014a), Bull & Collins (2013) and Public Health England (HPA, 2010).

The data within the Culp *et al.*, (1998) study forms the basis for the toxicological inputs to the low risk C4SL for benzo(a)pyrene (i.e. for the LLTC) and the surrogate marker approach has been used in the derivation of the C4SL for benzo(a)pyrene (CL:AIRE, 2014a).

The reported concentration of the surrogate marker in soil samples can be compared to a GAC or SSAC for the surrogate marker. With the surrogate marker approach for genotoxic PAH, exposure to the surrogate marker is assumed to represent exposure to the genotoxic PAHs in the soil matrix, and the level of toxicity of the surrogate marker represents the toxicity of the genotoxic PAH mixture within the soil matrix.

For the benzo(a)pyrene surrogate marker approach to be valid the HPA (2010) recommended various assumptions that must be met. These are evaluated further in subsequent section of this report, in the context of the reported PAH concentrations at the site.

Of relevance to the current DQRA is the ability to use the low risk C4SL as a surrogate marker for the genotoxic PAHs that exceed the GAC used in the GQRA, as previously stated, and to refine exposure and toxicological parameters associated with the C4SL to move towards a SSAC that is closer to SPOSH.

3.5 Site-specific assessment criteria

Where a GAC is not appropriate to the proposed land use, as the underlying generic assumptions are not met, or the GAC is exceeded at the site, SSAC may be required. The traveller site does not meet the generic assumption of a residential land use (e.g. a small terraced house, soft-landscaped garden areas) and the anticipated use of the perimeter soil mounds for recreational use (i.e. treated by residents as a garden area) is

unlikely to meet the assumption for a typical residential land use. GAC were conservatively used for the initial assessment, reported elsewhere, of the site to identify any contaminants in the site soils that may pose a potential risk to human health. However to make a more realistic assessment of risks from these compounds, more site-specific refinements to the screening criteria need to be made.

Site-specific assessment criteria are derived as part of a DQRA. The chosen SSAC, selected on the level of risk being evaluated, is compared to reported soil contaminant concentrations at a site either individually or using statistics. Where the reported contaminant concentrations exceed the SSAC, it can be concluded that there may be a potential risk to human health and mitigation measures are likely to be required.

Derivation of SSAC may involve amendments within the CLEA model to exposure parameters (e.g. soil and dust ingestion rates, receptor age, time spent on site etc.), building type or the toxicological input parameters for the contaminant of concern.

For the purposes of the current risk assessment for the site, derivation of a SSAC for benzo(a)pyrene has been broadly based on the approach taken within the Category 4 Screening Level for benzo(a)pyrene, published by Defra (2014). This approach taken is discussed in greater detail in subsequent sections of the current report.

4 CONCEPTUAL MODEL

A conceptual site model represents the characteristics of the site in diagrammatic or written form that shows the possible relationships between contaminants, pathways and receptors.

The term pollutant (or contaminant) linkage is used to describe a particular combination of contaminant–pathway–receptor.

4.1 Sources

Any sampling strategy throughout the soil profile should be appropriately weighted in accordance with the conceptual model and the identified exposure pathways. A 2010 workshop on PAHs organised by the Society of Brownfield Risk Assessment (SoBRA), that RSK attended, published a workshop report in February 2011 that considers amongst other things site sampling, toxicology and exposure assessment. The report states that if the human health effects are the primary concern in a residential setting, sampling should be concentrated in the top 1m of the soil profile focussing on the top 0.5m (SoBRA, 2011). Furthermore the report states that specific consideration should be given to dedicated sampling of the top 0.3m as this is the actual soil to which human receptors are most likely to be exposed to benzo(a)pyrene, and concentrations in the upper 0.1 m are the most appropriate for considering risks to a child receptor.

All samples collected in the current study were from the upper 0.5m, with the majority being in the upper 0.3m.

Concentrations of benzo(a)anthracene, benzo(b)fluoranthene and dibenzo(a,h)anthracene were reported above the minimal risk GAC used in the GQRA and concentrations of benzo(a)pyrene were reported above the low risk GAC (the C4SL) used in the GQRA in both soil populations evaluated (soil mounds and landscaped areas).

4.1.1 PAH in soil

Polycyclic aromatic hydrocarbons are prevalent in most urban soils in the UK from natural and diffuse pollution sources. They are formed mainly as a result of pyrolytic processes, especially the incomplete combustion of organic materials. Relevant anthropogenic sources include motor vehicle engines, coal and wood fires and refuse incineration. Natural sources include volcanoes and forest fires. Crude oil, shale oil and coal tar contain small amounts of PAHs.

The British Geological Survey (BGS) was commissioned by Defra (October 2011–March 2012) to provide guidance on what ‘normal’ levels of contaminants in English urban soils are, in support of the revision of the English 2012 Statutory Guidance. Benzo(a)pyrene was one of the seven contaminants evaluated based on existing soil data held or

accessible by BGS, with an upper limit of normal urban background concentrations in an urban area reported to be 3.6mg/kg.

4.1.2 PAH toxicity

Benzo(a)pyrene is readily absorbed following inhalation, ingestion and skin exposure (PHE, 2008). For the general public the main route of exposure to PAHs is from inhalation of ambient and indoor air or through the ingestion of food (PHE, 2008). The majority of toxicological studies relate to laboratory animal exposure. Benzo(a)pyrene is considered to be carcinogenic to humans.

4.2 Receptors

Sensitive receptors at this site, relevant to the aim of the investigation and DQRA include:

- current site occupants – adults and children, with a 0 – 6 year old child as the most sensitive receptor

Within the GQRA (RSK report Ref. 11151 R1), a discussion was presented regarding the likely age of children that might be in contact with soil contained within the mounds on site, which are relatively steeply sided and mostly vegetated with long grass. Typically a young child is the most sensitive receptor in a residential setting when considering soil-borne contaminants due to their physiology and behaviour (e.g. greater hand to mouth contact than older children or adults). Whilst very young children are unlikely to be playing on the mounds, and therefore unlikely to be in direct contact with soils, they would potentially be exposed to tracked back soil into dwellings. As such, the current DQRA presents SSAC excluding and including a very young child with the recommendation that the default receptor of a 0-6 year old child is the focus of the DQRA.

Receptors not considered in the current risk assessment are:

- domestic animals (e.g. pets, livestock) present at the site
- maintenance workers
- off-site receptors
- vegetation

4.3 Pathways

Many of the exposure pathways within a residential setting are based on receptor contact with the contaminated ground, or that such contamination is easily mobilised from the surface (e.g. dust and soil tracked back into properties).

The plausible pathways relevant to the aim of the investigation and risk assessment for benzo(a)pyrene are summarised below:

- direct contact with soil-borne PAHs including:
 - soil and dust ingestion (e.g. hand to mouth activity; ingestion of soil-borne dust)
 - inhalation of soil-borne dust
 - dermal contact

Linkages not considered within the current DQRA are

- ingestion of home-grown produce and attached soil, on the basis that there was no evidence of home-grown produce being cultivated at the site

4.4 Potentially complete linkages

Taking into account the identified sources, pathways and receptors discussed above, the potentially complete contaminant linkages at the site are:

- direct contact (soil and dust ingestion / inhalation, dermal contact) with soil-borne PAHs by current site occupants (residential without home-grown produce land use)

4.5 Data gaps, uncertainties and assumptions

It is not definitively known how regularly site residents access the mounds, nor for how long, nor the ages of children accessing the mounds. It is not definitively known if children, or indeed any human receptor, access the landscaped areas adjacent to internal roadways to the extent that they make contact with the soils.

RSK has therefore assumed the most sensitive receptor, accessing either the soil mounds or landscaped areas (including Plots 10, 15 and 17 that were tested at the request of the residents) is a young child.

5 GENERATION OF A SITE SPECIFIC ASSESSMENT CRITERIA

The pathways considered in the conceptual model are:

- direct contact (soil and dust ingestion / inhalation, dermal contact) with soil-borne PAHs by current site occupants (residential without home-grown produce)

The key input parameters used in the modelling to derive a SSAC and to remove conservatism from the C4SL are discussed in the following subsections.

One objective of the current DQRA is to derive a SSAC, or a range of SSAC, to remove conservatism from the GAC used within the GQRA and to present more realistic and more site-specific soil assessment criteria. Additionally, the range of SSAC can be used to evaluate if the site is likely to meet the definition of SPOSH. The DQRA is not intended to derive a single SSAC that is aligned with SPOSH; the DQRA will present a range of SSAC moving towards SPOSH, against which to evaluate reported benzo(a)pyrene concentrations at the site.

The DQRA can also be used to inform if a precautionary approach should be taken to identified receptors. While the site may not meet the definition of SPOSH and therefore intervention is not warranted, the site owners may make their own decision as to the suitability of the site for long-term occupancy.

5.1 Benzo(a)pyrene as a surrogate marker

As discussed in Section 3.4, for the benzo(a)pyrene surrogate marker approach to be valid, the HPA (2010) recommended various assumptions that must be met. These are:

- benzo(a)pyrene must be present in all samples from the site that contain other PAHs, and which are being screened using the surrogate marker
- the profile (or ratio) of the various genotoxic PAHs relative to benzo(a)pyrene is assumed to be similar in all samples from the same averaging area
- the PAH profile of the samples is similar (within an order of magnitude above or below) to that in the matrix used in the study by Culp *et al.*, (1998), based on the ratio of PAH congener concentrations to the benzo(a)pyrene concentration (i.e. congener concentration / BaP concentration)

Benzo(a)pyrene is present in all samples where PAHs are present. The relative ratio of the seven genotoxic PAH to benzo(a)pyrene in the sample population is within the upper and lower limits recommended by the Health Protection Agency (HPA, 2010) for the data set relating to the perimeter soil mounds and for the individual results from the plots/landscaped areas (see Appendix B).



The review has confirmed that the proposed approach of using benzo(a)pyrene as the surrogate marker is acceptable.

5.2 Critical Receptor

The default critical receptor for a residential land use is a 0-6 year old child (CLEA age class 1–6). The CLEA model (v1.071) considers age classes (AC) in one year increments commencing with AC1 (0-1 years) up to AC16 (15-16 years). Following on from this, adults are considered as two age classes: AC17 (16-65 years) and AC18 (65-75 years).

Part 2A sites of potential concern, or investigation of existing developments, are assessed in the context of their current use and reasonably likely future uses of the land that would not require a new or amended grant of planning permission. The demographics of the current residential occupants at the site who access the soil mounds are not definitively known. Therefore three receptors have been used in the derivation of a SSAC; a young child (age range 0-6 years / CLEA AC1-6), child aged 3 to 12 years (CLEA AC4-12) and an older child aged 12 to 16 years (CLEA AC13-16). This is based on discussions with the Six Housing tenancy sustainment team. However, to remain suitably precautionary, the final SSAC derived for the site relate to a 0-6 year old child.

Associated receptor characteristics (body weight and height, inhalation rate and maximum exposed skin fractions) for a residential land use are included in CLEA 1.071 and are summarised in CL:AIRE (2014a). These generic characteristics of the receptor have not been refined within the current DQRA and the C4SL defaults have been used.

5.3 Exposure frequency

The default exposure frequency for a residential land use is summarised in CL:AIRE (2014a). Variations to exposure frequency to remove the associated conservatism (e.g. whether residents would spend all 365 days per year at the site) were initially considered by RSK but due to the limited effect on the resulting assessment criteria, no changes were taken forward in the current DQRA. Furthermore it is considered realistic that occupants of the traveller site may be resident for 365 days per year. As such, the default residential exposure frequency was used in the DQRA.

5.4 Soil to dust transport factor

The soil to dust transport factor will vary according to the chemical selected and sits within the toxicological input parameters section of the model. It is an empirical measure of the tendency of an organic or inorganic compound to transfer into indoor dust from soil. It is used in the CLEA model to estimate the concentration of a contaminant in airborne respirable dust derived from soil, which relates to the inhalation of dust exposure pathway.

The soil to dust transport factor should be contaminant specific but where contaminant specific data are not available, which is the case for the majority of contaminants including benzo(a)pyrene, the EA recommend a default value of 0.5 for derivation of assessment criteria (EA, 2009b). This means that the concentration of a contaminant in respirable dust is assumed to be 50% of the concentration of contaminant in outdoor soil. The C4SL defaults have been used in the current DQRA.

5.5 Dust loading factor

The dust loading factor is the concentration of airborne respirable dust particles indoors, and it is effectively the assumed concentration of PM₁₀ (particles less than 10 µm, also termed 'fined particulates' which can settle in airways and deep in the lungs resulting in health effects) concentration indoors. The CLEA model assumes values of 50 µg m⁻³ for residential land-use.

This factor accounts for the dust concentration in indoor air resulting from resuspension of dust through man-made surface disturbances and depends on the building type and use. The default value of 50 µg m⁻³ has been used within the current DQRA, as a precautionary approach.

5.6 Soil and dust ingestion rate

Direct soil ingestion is considered to be the dominant exposure pathway for receptors exposed to benzo(a)pyrene in soil. Within the residential with home-grown produce land use, the C4SL for benzo(a)pyrene (6% soil organic matter) soil and dust ingestion contributes 87.52% to total exposure and the consumption of home-grown produce and attached soil contributes 7.2%.

The CLEA model combines soil and dust ingestion into a single exposure pathway. This is justified on the basis that it is difficult to differentiate between these two types of exposure (CL:AIRE, 2014a).

The soil and dust ingestion rate is a key uncertainty highlighted by sensitivity analysis undertaken on the CLEA model and documented in Science Report 3 (EA, 2009b) and in the derivation of the C4SL for benzo(a)pyrene (CL:AIRE, 2014a), and specifically with regard to the relative proportions of soil and dust ingested. This uncertainty is due to a limited number of studies on soil and dust ingestion rate having been conducted and that the amount of soil ingested by a child cannot be directly observed (Stanek *et al.*, 2012).

The CLEA model, and the various generic assessment criteria published by Defra (Defra, 2014; CL:AIRE, 2014a) assumes an average daily soil and dust ingestion rate of 100 mg d⁻¹ for AC1 to AC12 and 50 mg d⁻¹ for AC13 to AC18 for the most sensitive land use of a residential land use (irrespective of whether home-grown produce is consumed). These ingestion rates are considered to be highly conservative and likely tend towards an overestimation of exposure for the majority of land uses (CL:AIRE, 2014a).

This parameter is a key uncertainty for a child receptor. When considering a child

receptor (AC1-6), RSK has considered two soil and dust ingestion rates which are discussed further below.

5.6.1 Amendment 1 – child receptor

Soil and dust ingestion rate (AC1-6) of 49.25 mg d⁻¹ (C4SL default 100 mg d⁻¹).

Paustenbach (2000) noted that dust comprises between 50 and 90% of the combined soil and dust ingestion rate. It is also accepted that the proportion of soil within dust is very difficult to quantify with values of dust originated from local soil reported to range from 20-90% depending upon the source or receptor behaviour.

Dust can therefore be assumed to comprise between 50 and 90% of the combined soil and dust ingestion rate, and the range for local soil in dust ranges from 20-90%. Thus for AC1-6 with a soil ingestion rate of 100 mg d⁻¹, assuming 70% (mid-point between 50-90%) of the combined soil and dust ingestion rate comprises dust, and assuming 55% (mid-point between 20-90%) of dust is comprised of soil, this equates to an overall soil ingestion rate of 68.5 mg d⁻¹ (30mg from soil plus 38.5mg from the soil component of dust). However, not all of the soil in dust will be from the site, or indeed resulting from the area of the site where elevated concentrations of benzo(a)pyrene have been reported. Thus, a further assumption has been made that 50% of the soil in any dust is potentially derived from the site with the other 50% from other local sources (e.g. nearby by residential properties, open spaces, roadways etc).

On the above basis, the amended soil and dust ingestion rate that could be used for AC1-6 is 49.25 mg d⁻¹ (30mg soil plus 19.25mg soil component of dust). It is considered that the value of 49.25 mg d⁻¹ is still conservative since it assumes that all direct soil ingestion (i.e. not resulting from dust) is from site-derived soils which is unlikely to be the case when people will also be exposed to soil elsewhere during their daily activities away from the home.

5.6.2 Amendment 2 – child receptor

Soil and dust ingestion rate (AC 1-6) of 26 mg d⁻¹ (C4SL default 100 mg d⁻¹).

A meta-analysis of published tracer studies (using aluminium and silicon) has been used to estimate soil ingestion rates (Stanek *et al.*, 2012). This review, which is discussed in the C4SL main report (CL:AIRE, 2014a), re-assessed mass-balance data from four studies conducted in the United States using 216 children aged between one and seven in summer and autumn. It is considered to be a up to date evaluation of soil ingestion rates and because the meta-analysis was for young children, the study provides a more complete understanding of likely ingestion rates. using reliable trace elements. Additionally, this study removes the conservatism associated with more generic, precautionary ingestion rates and it considered likely to be more representative of likely ingestion rates.

The results indicated a mean soil ingestion rate of 26 mg d⁻¹, a median of 33 mg d⁻¹ and a 95th percentile of 79 mg d⁻¹. These ingestion rates are significantly lower than previous estimates and are less conservative than the default soil and dust ingestion rates used to derive the generic C4SL.

On the above basis, the amended soil and dust ingestion rate that could be used for AC1-6 is 26 mg d⁻¹, which is the mean reported in the above study and is considered to be appropriate when removing conservatism within the exposure input parameters.

5.7 Dermal contact

Dermal contact is not considered a significant exposure pathway for benzo(a)pyrene relative to other exposure pathways. However, when considering a residential land use, of the 10 pathways modelled in CLEA for benzo(a)pyrene dermal contact outdoors is typically the third highest contributor to total exposure. For the generic residential (child receptor) with home-grown produce land use, dermal contact outdoor contributes less than 3% to overall exposure and dermal contact indoors contributes ~2% to overall exposure.

Due to the relatively low contribution of this exposure pathway to total exposure which is dominated by direct soil and dust ingestion (~87% contribution to overall exposure), amendments to this pathway are not considered further in the derivation of the SSAC.

The pertinent C4SL default exposure parameters relating to dermal exposure have been used in the current DQRA. The default soil to skin adherence factors have not been refined and the dermal absorption factor used in the toxicological inputs remains as the default. However, the default dermal absorption factor is indicated to be conservative within the C4SL toxicological parameters for benzo(a)pyrene (CL:AIRE, 2014b).

5.8 Physical parameters

The C4SL default building for a residential land use is a small two storey terraced house. The dwellings at the site are caravans with a number of single storey amenity blocks that are not occupied as dwellings and are therefore not considered within the current DQRA.

Changes to building type in the CLEA model alters parameters such as the building footprint, living space air exchange rate, pressure difference etc.) and has implications when deriving SSAC for volatile contaminants. There are little to no implications for non-volatile contaminants such as PAH, where exposure is dominated by soil and dust ingestion in a residential without home-grown produce land use.

Therefore the default C4SL 'terraced house' building type CLEA inputs have been retained for this DQRA.

5.9 Toxicological parameters

5.9.1 Benzo(a)pyrene as a surrogate marker

As previously discussed, benzo(a)pyrene has been used as a surrogate marker to assess the potential risks associated with soil-borne genotoxic PAHs at the site.

5.9.2 Low level of toxicological concern

Health-based guidance values (HBGV), are an estimated dose in humans that are representative of a specified level of risk over a lifetime. They can be derived for oral, dermal or inhalation routes of exposure. Health-based guidance values include acceptable daily intakes (ADI) typically used for food additives, Health Criteria Values (HCV) that encompass tolerable daily intakes (TDI) for threshold environmental contaminants and index doses (ID) for non-threshold environmental contaminants, or more recently a low level of toxicological concern (LLTC). They are derived for oral exposure and for inhalation exposure.

There are a variety of methods to derive HBGV, focused on selecting a pivotal study and a suitable endpoint through a review of available toxicology data and considering the uncertainty associated with the pivotal study and endpoint. This requires the risk assessor to select a point of departure (POD), which is a pre-defined level of effect or response (e.g. a percentage increase in incidence of an effect) and derive the estimated dose that elicits this response. The resulting dose leading to the specified response is divided by an uncertainty factor (UF) to take account of various unknown factors relating to the study, leading to the generation of a HBGV.

Traditionally such guidance values used in contaminated land risk assessment have been derived for concentrations of chemicals for which long-term human exposure

poses a tolerable or minimal risk to health, rather than for exposures that pose a risk of significant harm or unacceptable intake. The C4SLs use a LLTC ($\text{mg kg}^{-1} \text{ bw day}^{-1}$) in their derivation, which is a new term introduced specifically for the toxicological guidance values used to derive a C4SL. A LLTC, for oral and for inhalation exposure, represents an intake of low concern that remains suitably protective of health, and definitely does not approach an intake level that could be defined as SPOSH. Therefore the LLTC (the HBGV) can be revised upwards towards a less precautionary toxicological input parameter when considering SPOSH.

As part of the derivation of the C4SL for benzo(a)pyrene, a child specific and an adult specific LLTC were derived. Therefore different toxicological input parameters are used when modelling a child receptor or an adult receptor if the defaults are used. However the receptor-specific LLTC relates only to the inhalation LLTC rather than the oral LLTC. Exposure via inhalation is not typically a significant exposure pathway for benzo(a)pyrene; the exception to this is when soil concentration are very high and the inhalation of indoor dust becomes a more dominant exposure pathway.

Within the current DQRA the C4SL default inhalation LLTC has been used and is not refined or discussed further within the current DQRA.

The default oral LLTC derived for benzo(a)pyrene is derived based on the study by Culp *et al.*, (1998) with the POD being the benchmark dose representing a 10% risk of tumours above background in the experimental species (the BMD_{10}) divided by an uncertainty factor (UF). Full details are presented in the C4SL report for benzo(a)pyrene (CL:AIRE, 2014b); the default C4SL LLTC uses a POD of $0.21 \text{ mg kg}^{-1} \text{ bw day}^{-1}$ divided by an UF of 5000 resulting in an oral LLTC of $0.042 \text{ } \mu\text{g kg}^{-1} \text{ bw day}^{-1}$ [note the difference in units]. The UF is based on a factor of 10 for intraspecies differences, 10 for interspecies differences and 50 for additional uncertainties associated with the pivotal study.

Simply explained, the UF of 5000 means the oral LLTC represents a dose which is 5000 times lower than that which was shown to give rise to tumours in 10% of experimental animals in the Culp *et al.*, (1998) study. The resulting oral LLTC using a BMD_{10} and an UF of 5000 is described (see CL:AIRE, 2014b) as broadly equating to a notional cancer risk level of 1 in 50,000. This UF is one way of implementing a 'margin of exposure' approach to deriving assessment criteria for non-thresholded carcinogens such as benzo(a)pyrene. The 'margin' (i.e. the UF) applied to the POD is a value representing a specified level of concern. The margin of exposure approach is widely used by the European Food Safety Agency (EFSA, 2005) in respect of genotoxic chemical carcinogens.

There is no guidance, or precedent, on what margin of exposure might be associated with a higher level of concern (Benford *et al.*, 2010) and in particular a level of concern associated with significant harm. Such a margin of exposure would, to a large extent, be a socio-political decision rather than scientific interpretation. A margin of exposure of $>10,000$ is considered not to be of concern to human health and is often associated with

minimal risk. As the margin of exposure decreases this equates to a higher level of risk and a correspondingly higher HBGV.

During the derivation of C4SL (CL:AIRE, 2014a) it was suggested a margin of exposure of 5000 could relate to low concern or risk and this is the value that was used at the UF in the derivation of the C4SL for benzo(a)pyrene. Consequently a margin of exposure some way below 5000 is likely to relate to significant harm. However, what level this might be is a matter of debate but must be significantly below 5000 since that is the value adopted for the development of the benzo(a)pyrene which is still being strongly precautionary and protective of health.

An UF of 2500 would mean the oral LLTC represents a dose which is 2500 times lower than that which was shown to give rise to tumours in 10% of experimental animals in the Culp *et al.*, (1998) study and an UF of 1000 would mean the oral LLTC represents a dose which is only 1000 times lower. In essence, the lower the UF the less precautionary the resulting HBGV will be and the closer the HBGV will be to SPOSH.

When undertaking a DQRA consideration can be given to altering the chosen POD and/or reducing the UF to result in a higher risk level.

Within the current DQRA, SSAC have been derived using:

- an oral LLTC of $0.084 \mu\text{g kg}^{-1} \text{ bw day}^{-1}$ based on the (default) BMD_{10} of $0.21 \text{ mg kg}^{-1} \text{ bw day}^{-1}$ and an UF of 2500.

It should be noted, as discussed above, that further amendments can be made to the LLTC by altering the UF to 1000 or altering POD from a BMD_{10} (i.e. 10% incidence) to a higher tumour incidence (e.g. 15% or 20%) both of which would result in a HBGV more representative of SPOSH. An increase from 10% to 20% would be a doubling of acceptable risk, which may be representative of the 'significant possibility' aspect of SPOSH. This refinement to the POD or to further lowering the UF has not been taken forward in the current DQRA.

5.9.3 Bioavailability and bioaccessibility

The main exposure pathway to a residential receptor for benzo(a)pyrene present in soil is via soil and dust ingestion. Therefore the total amount of benzo(a)pyrene present in the soil is not necessarily a true reflection of the risk posed to human receptors at the site; the amount of benzo(a)pyrene that is absorbed into the body following ingestion is a more accurate assessment of potential risk.

When a contaminant is ingested either in food or within soil, not all of that contaminant will be taken up by the body. Some will be excreted in the urine and/or faeces. Consequently this should, where possible, be taken into consideration within a human health risk assessment for soil-borne contaminants. How much of a chemical that is taken up by the body will be influenced by the form of the chemical and/or site-specific soil characteristics.

When reliable data on bioavailability, or reliable estimates of bioavailability, are available these can be used to improve the accuracy of risk assessment and the derivation of SSAC. This can be undertaken in the CLEA model when deriving SSAC. Bioavailability can only be ascertained through *in vivo* testing (e.g. laboratory animal toxicity tests typically involving juvenile swine or rodents), which are not routinely undertaken. Laboratory *in vivo* tests require rigorous ethical assessment prior to being granted a licence, are costly and time consuming. Therefore an estimate, or surrogate, of bioavailability is required if such a refinement is to be made.

Within the CLEA model, adjustments can be made for relative bioavailability ($RBA_{\text{soil,tox}}$). As a precautionary assumption, when deriving GAC, the bioavailability of a contaminant is typically assumed to be 100% (i.e. an $RBA_{\text{soil,tox}}$ of 1.0; all of the chemical taken into the body is absorbed and becomes available to the target tissue). An $RBA_{\text{soil,tox}}$ of 1.0 means that the absolute bioavailability of the chemical in the soil sample is the same as the absolute bioavailability in the media used in the relevant toxicological studies on which the HBGV is based.

The pivotal study (Culp *et al.*, 1998) on which the HBGV (i.e. the LLTC in the C4SL for benzo(a)pyrene) is based is a two year mouse bioassay. The study has also been used by EFSA when evaluating the risks posed by PAHs in food (EFSA, 2008, Benford *et al.*, 2010). The study measured the carcinogenic potential of two coal tar mixtures with varying PAH / benzo(a)pyrene concentrations that were fed (gastric lavage) to female mice over a two year period, resulting in increased incidences of tumours in the liver, lungs, kidney, pituitary, tongue and a number of sites within the gastro-intestinal tract. Coal tar diets were prepared by freezing the coal tar mixture in liquid nitrogen and blending with an appropriate amount of NIH-31 meal (NIH-31 is used as the standard diet in rodent production colonies). Benzo(a)pyrene content was used as a marker of the carcinogenic PAHs in the coal tar mixtures. As such, the absolute bioavailability of benzo(a)pyrene in soil at a site may be broadly similar to the absolute bioavailability in the media (NIH-31 meal) used in the pivotal study on which the LLTC is based.

No adjustment for bioavailability was made in the current DQRA and the default C4SL assumption of 100% (i.e. an $RBA_{\text{soil,tox}}$ of 1.0) was used in the derivation of the SSAC.

5.10 Model selection

The EA CLEA model (v1.071) is an exposure assessment tool used to estimate the magnitude of exposure to soil contaminants, taking into account the behaviour and characteristics of the exposed human receptor(s).

5.11 Assessment criteria selection

The CLEA model, and the UK approach (CL:AIRE, 2014a) taken for a contaminant that results in localised, rather than systemic, effects such as benzo(a)pyrene, identifies assessment criteria from each exposure pathway (oral or inhalation) and the most sensitive (i.e. the lowest) is adopted as the assessment criteria.

This approach ensure the modelled assessment criteria is protective of the most sensitive exposure pathway / point of contact within the body.

6 SITE SPECIFIC RISK ASSESSMENT

6.1 Derivations of site-specific assessment criteria

Using the site-specific conceptual exposure model presented previously, a number of SSAC have been derived for a sandy loam soil type with a soil pH of 7 and a soil organic matter of 6%. Altering the soil type, soil pH and soil organic matter will have very little impact on the resulting SSAC. CLEA output model runs are presented in Appendix C.

The amendments made to the default C4SL input parameters (CL:AIRE 2014a) for a residential without home-grown produce land use (using a terraced house as the building type) and specifically for benzo(a)pyrene (CL:AIRE 2014b) are summarised in Table 4. Default exposure parameters (i.e. C4SL exposure parameters as detailed in CL:AIRE 2014a) have been used unless otherwise stated.

An in-depth discussion of the refinements made has been presented in Section 5. It should be noted that the SSAC presented below represent a stepped removal of conservatism. It is considered that they can be further revised, beyond scenario 3 in Table 4, to remove remaining conservatism and move further towards a concentration that could be considered to represent SPOSH and be aligned with Category 1 or 2 under the 2012 Statutory Guidance (Defra, 2012). When deriving the series of more site-specific and less conservative assessment criteria, consideration was given following each exposure scenario to the mean (where appropriate), maximum and 95th LCL as presented in Table 3 previously.

Within Table 4, the critical receptor is a 0-6 year old child (AC1-AC6). In addition to the exposure scenarios presented in Table 4, RSK has modelled the original C4SL exposure parameters and toxicological inputs, for children of different age classes as the only adjustment. This was undertaken to provide an initial assessment of potential risks to an older child. For AC4-AC6 (age >3 to 6 years) the resulting assessment criteria is 6.67 mg/kg; for AC13-AC16 (age >12 to 16 years) the resulting assessment criteria is 33.02 mg/kg.

These two age class ranges were chosen on the basis that a very young child (i.e. <3 years) is considered unlikely to play unsupervised on soft landscaped areas and as such their exposure would be negligible (i.e. hand to mouth contact or direct soil ingestion would be limited by adult supervision or by not accessing the landscaped areas or mounds). The second scenario solely considered an older child, which may reflect that children of this age (i.e. >12 years) may stay at home during the day while younger children are at school. This scenario was discussed in Section 5.2.1 of RSK report Ref. 11151 R01).

Table 4: Site specific assessment criteria and top three relative pathway contributions to total exposure (%)

		Contribution (%) to total exposure		
Exposure scenario	SSAC (mg/kg)	Direct soil and dust ingestion	Dermal contact (outdoor)	Dermal contact (indoor)
Original C4SL				
Scenario - Original C4SL Critical receptor: AC1- AC6 Soil and dust ingestion rate:100 mg d-1 UF: 5000	5.34	94.32	3.17	2.29
SSAC scenarios				
Scenario 1 Amendments to original C4SL: Soil & Dust ingestion rate: 49.25 mg d ⁻¹	10.24	89.11	6.08	4.40
Scenario 2 Amendments to original C4SL: Soil & Dust ingestion rate: 26 mg d ⁻¹	17.68	81.19	10.50	7.59
Scenario 3 Amendments to original C4SL: Soil & Dust ingestion rate: 49.25 mg d ⁻¹ UF: 2500	20.47	89.11	6.08	4.40

6.2 Linkages for assessment

The plausible pathways relevant to the aim of the investigation and risk assessment are summarised below, as reproduced from Section 5.5 of RSK report Ref. 11151 R01:

- direct contact (soil and dust ingestion and/or inhalation and dermal contact) with potentially contaminated shallow soils in the perimeter soil mounds by site residents
- direct contact (soil and dust ingestion / inhalation, dermal contact and/or ingestion) with potentially contaminated shallow soils in the plots/landscaped areas adjacent to internal roadways by site residents

6.3 Assessment of benzo(a)pyrene concentrations – perimeter soil mounds

As discussed previously the soil sampling undertaken at the site was non-targeted for the perimeter soil mounds and considered to be targeted for the plots/landscaped areas.

Consideration has initially been given to the sampling mean concentration, LCL and maximum reported concentration for the RSK perimeter soil mounds dataset. Statistical analysis has then been undertaken for each exposure scenario for a Part 2A assessment (i.e. to assess if there is likely to be SPOSH), using a Null Hypothesis that the level of contamination in the land of interest is the same as or lower than the SSAC; and the Alternative Hypothesis is that the level of contamination is higher than the critical concentration. If the Null Hypothesis is rejected, the assessor can conclude that contaminant concentrations are high relative to the SSAC (and a basis for intervention under the Part 2A regime potentially exists). If the Null Hypothesis is not rejected, contamination levels may be the same as, or lower than, the SSAC and a basis for regulation is unlikely to be warranted (i.e. there is unlikely on the balance of probabilities to be SPOSH).

For the younger child (AC4-AC6), the perimeter soil mounds mean concentration (4.71mg/kg) and LCL (0.45mg/kg) are below the SSAC. The maximum reported concentration (11.9mg/kg), and three individual results are above this assessment criteria SSAC. The statistical assessment concludes that the Null Hypothesis is not rejected and therefore contamination levels may be the same as, or lower than, the SSAC and a basis for regulation is unlikely to be warranted.

For older child (AC13-AC16), the perimeter soil mounds mean concentration (4.71mg/kg), LCL (0.45mg/kg) and maximum reported concentration (11.9 mg/kg) and all individual results are below this assessment criteria. The statistical assessment concludes that the Null Hypothesis is not rejected and therefore contamination levels may be the same as, or lower than, the SSAC and a basis for regulation is unlikely to be warranted. This scenario, with only age class adjustments, indicates that for an older child, accessing soil within the perimeter mounds, potential risks are considered to be negligible.

6.3.1 Exposure scenario 1 – child receptor AC1-AC6

Exposure scenario 1 resulted in a SSAC of 10.24 mg/kg. This scenario reduced the child soil and dust ingestion rate to a more realistic and less conservative 49.25 mg d⁻¹, whilst modelling the most sensitive receptor as a 0-6 year old child.

The mean concentration (4.71mg/kg) and LCL (0.45mg/kg) are below the SSAC. The maximum reported concentration (11.9mg/kg), and two individual results (11.4mg/kg and 11.9 mg/kg) are marginally above the SSAC. The statistical assessment concludes that the Null Hypothesis is not rejected and therefore contamination levels may be the same as, or lower than, the SSAC and a basis for regulation is unlikely to be warranted.

It should be noted further refinements can be made to build on this exposure scenario to remove conservatism associated with the soil and dust ingestion rates (and taking into account likely contact with the vegetated and steep sided mounds) and take the SSAC towards a concentration that is more likely to be associated with SPOSH.

6.3.2 Exposure scenario 2 - child receptor AC1-AC6

Exposure scenario 2 resulted in a SSAC of 17.68mg/kg. This scenario further reduced the child soil and dust ingestion rate to 26mg d⁻¹, which is based on a meta-analysis of published tracer studies used to estimate soil ingestion rates (Stanek *et al.*, 2012). The meta-analysis was for young children, and provides a more complete understanding of soil ingestion among children and used reliable trace elements in the analysis. This was discussed in more detail in Section 5.

The mean concentration (4.71mg/kg), LCL (0.45mg/kg), maximum reported concentration (11.9mg/kg) and all individual results are below the SSAC. The statistical assessment concludes that the Null Hypothesis is not rejected and therefore contamination levels may be the same as, or lower than, the SSAC and a basis for regulation is unlikely to be warranted.

This exposure scenario, taking into account a recent study into soil ingestion rates is considered to more accurately reflect the likely exposure at the site, while still considering the most sensitive receptor.

6.3.3 Exposure scenario 3 – child receptor AC1-AC6

Exposure scenario 3 resulted in a SSAC of 20.47mg/kg. This scenario combined reducing the soil and dust ingestion rate to 49.25mg d⁻¹ with an UF of 2500. These two refinements reduce conservatism associated with soil and dust ingestion (although it is considered the soil and dust ingestion rate could justifiably be reduced further) and moves the level of risk associated with the HBGV towards that which is closer to SPOSH.

However, it should be noted that further refinements can be made to build on this exposure scenario to remove conservatism (e.g. using the further reduced soil and dust ingestion rate of 26mg d⁻¹) and take the SSAC towards a concentration that is more likely to be associated with SPOSH.

The mean concentration (4.71mg/kg), LCL (0.45mg/kg), maximum reported concentration (11.9mg/kg) and all individual results are below the SSAC. The statistical assessment concludes that the Null Hypothesis is not rejected and therefore contamination levels may be the same as, or lower than, the SSAC and a basis for regulation is unlikely to be warranted.

Therefore it is not considered that further refinement are required to the SSAC when considering the current dataset for the perimeter soil mounds.

6.3.4 Summary

Various SSAC have been derived, initially refining single parameters (for exposure, specifically related to soil and dust ingestion which is the dominant exposure pathway) and subsequently combining multiple refinements. It is considered that the derived SSAC are a move towards but not representative of SPOSH. Further refinements could be made to individual input parameters or combinations of parameters to move closer to a concentration that could be considered to represent SPOSH. This would lead to higher SSAC than those presented in Section 6.1. This was not considered necessary in the current DQRA following the derivation of the above SSAC which resulted in the highest modelled SSAC of 20.47mg/kg (exposure scenario 3). The results lead to a conclusion that intervention under Part 2A is not warranted and concentrations of PAHs within the perimeter soil mounds are unlikely to pose a significant risk to human health.

Based on the above assessment, using the derived range of SSAC, it is concluded that the site is unlikely to pose a significant possibility of significant harm to a young children who may reside at the site and access the soil mounds.

6.4 Assessment of benzo(a)pyrene concentrations – plots/landscaped areas

As discussed previously the soil sampling undertaken at the site is considered to be targeted for the plots/landscaped areas. Consequently results have been compared individually to the modelled SSAC. Samples from the three plots were collected at the request of site residents and do not form a comprehensive assessment of soils within these plots. Therefore the discussion below is for indicative purposes only.

6.4.1 Plot 10 (HP17)

All reported contaminant concentrations for the single sample from Plot 10 (soil mound) fell below the GAC used in the GQRA (see RSK report Ref. 11151 R01). Therefore Plot 10 is not considered further as soils, based on the single sample, are not considered to pose a risk to human health.

6.4.2 Plot 13 (HP17)

The single sample from Plot 13 contained elevated concentration, above the GAC used in the GQRA, for three PAHs with a reported benzo(a)pyrene concentration of 7.12mg/kg. This benzo(a)pyrene concentration is below all modelled SSAC for a young child (see Table 4).

Based on the single sample, soils in the landscaped area of Plot 13 are not considered to pose a significant risk to human health.

6.4.3 Plot 15 (HP14)

The single sample from Plot 15 contained an elevated concentration, above the GAC used in the GQRA, for a single PAH (dibenzo(a,h)anthracene) with a reported benzo(a)pyrene concentration of 3.61mg/kg. Reported concentrations are therefore below the GAC for benzo(a)pyrene used in the GQRA (see RSK report Ref. 11151 R01), which can be used as a low risk surrogate marker for the genotoxic PAHs. As such, no assessment of reported concentrations against SSAC is required.

Based on the single sample, soils in the landscaped area of Plot 15 are not considered to pose a significant risk to human health; the reported concentration is below the conservative GAC used in the initial assessment.

6.4.4 Landscaping along roadways (HP16)

Two samples were collected (0-0.12 mbgl and 0.15-0.2 mbgl) along the internal roadway. Higher concentrations of PAHs were recorded in the slightly deeper sample. Taking the maximum reported concentration of benzo(a)pyrene (13.8 mg/kg), this exceeds the SSAC derived for a child in AC4-AC6, but is below the two of the three exposure scenarios presented in Table 4.

Based on the two samples, soils in the landscaped areas of the internal roadways are not considered to pose a significant risk to human health.

6.5 Sensitivity analysis

Uncertainty in the conceptual model for the derivation of the SSAC and individual input parameters can be considered by undertaking a sensitivity analysis. This typically involves identifying key parameters in the model which are then varied over a likely range. The aim of a sensitivity analysis is to provide increased confidence in the model results (i.e. in the SSAC).

It is considered that the range of exposure scenarios modelled and presented in Table 4, varying either exposure parameters, toxicological parameters, or both, fulfils the aim of providing increased confidence in the range of SSAC derived.

The dominant exposure pathway for benzo(a)pyrene is soil and dust ingestion, which has been the subject of two refinements which show the sensitivity of this parameter to altering the relative pathway contributions (see Table 4).

No further sensitivity analysis is considered to be required.

7 CONCLUSIONS AND RECOMMENDATIONS

The sampling undertaken by RSK at the site in June 2018 was not intended to provide a dataset with which to evaluate the site under Part 2A nor to consider if soils at the site are likely to meet the definition of SPOSH, or fall within Categories 1 or 2 under the Part 2A regime. Consequently the risk assessment undertaken and presented in the current DQRA should be treated with some caution. However, RSK consider that additional sampling is unlikely to significantly alter the conclusions relating to the potential risk to human health posed by PAHs in the perimeter soil mounds or the landscaped areas.

Soil sampling in three individual plots at the site was undertaken at the request of residents during the intrusive investigation. Although these plots are relatively small it is unlikely that a single soil sample will adequately characterise soils in these plots or provide a comprehensive dataset against which to consider risks to health. As such, the assessment within the current DQRA should be treated with some caution.

The contaminated land regime under Part 2A is a risk based approach to the identification and remediation of existing developed land, where contamination, in the context of human health, poses an unacceptable risk (significant harm) to health or a significant possibility of such harm. Unacceptable risk, unacceptable intake or unacceptable exposure is not defined in the legislation or Statutory Guidance and there are no generic soil assessment criteria for assessing unacceptable risk.

The overarching aim of the current DQRA was to derive a SSAC, or a range of SSAC, against which to evaluate if there is likely to be SPOSH associated with soil borne contaminants at the site, or if further intrusive investigation and associated risk assessment may be required. The DQRA was not intended to derive a single SSAC that is aligned with SPOSH; rather the DQRA was intended to present a range of SSAC moving towards SPOSH against which to evaluate reported benzo(a)pyrene concentrations at the site. A number of SSAC were derived for the site, gradually removing conservatism.

As stated above, the current DQRA did not intend to derive a single SSAC above which it could be concluded that conditions at the site, if these concentrations of benzo(a)pyrene were reported, met the definition of SPOSH. The range of refinements that were made for a child receptor lead to the conclusion that the concentrations of genotoxic PAHs at the site are not considered to meet the definition of SPOSH and intervention under Part 2A is not warranted. Further refinements could be made to the SSAC presented in Section 6, but this was not necessary within the current DQRA due to range of benzo(a)pyrene concentrations reported in soils at the site.

The GQRA undertaken (see RSK report Ref. 11151 R1) concluded that additional risk assessment was required in relation to PAHs in site soils. The GQRA confirmed that, under the planning regime as it exists today, the land would not be considered as suitable for use. Such a conclusion is not, however, the basis for regulatory intervention under the contrasting regime for Part 2A. Part 2A was introduced to provide an improved

system for the identification and remediation of land where historical contamination is causing unacceptable risks to human health or the wider environment, assessed in the context of the current use and circumstances of the land. This assessment is therefore very different to an assessment for suitability for use for new developments.

The current DQRA, based on the sampling undertaken to date and the caveats discussed within the report, concludes that soils at the site do not pose a significant possibility of significant harm to human health and intervention under Part 2A is not warranted. This is based on the current use of the site, likely activities at the site and observations made by RSK regarding use of the perimeter mounds.

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APPENDIX A

SERVICE CONSTRAINTS

1. This report and the site investigation carried out in connection with the report (together the "Services") were compiled and carried out by RSK Environment Limited (RSK) for **Six Town Housing** (the "client") in accordance with the terms of a contract between RSK and the "client", dated **22/08/18**. The Services were performed by RSK with the skill and care ordinarily exercised by a reasonable environmental consultant at the time the Services were performed. Further, and in particular, the Services were performed by RSK taking into account the limits of the scope of works required by the client, the time scale involved and the resources, including financial and manpower resources, agreed between RSK and the client.
2. Other than that expressly contained in paragraph 1 above, RSK provides no other representation or warranty whether express or implied, in relation to the Services.
3. Unless otherwise agreed in writing the Services were performed by RSK exclusively for the purposes of the client. RSK is not aware of any interest of or reliance by any party other than the client in or on the Services. Unless expressly provided in writing, RSK does not authorise, consent or condone any party other than the client relying upon the Services. Should this report or any part of this report, or otherwise details of the Services or any part of the Services be made known to any such party, and such party relies thereon that party does so wholly at its own and sole risk and RSK disclaims any liability to such parties. **Any such party would be well advised to seek independent advice from a competent environmental consultant and/or lawyer.**
4. It is RSK's understanding that this report is to be used for the purpose described in the introduction to the report. That purpose was a significant factor in determining the scope and level of the Services. Should the purpose for which the report is used, or the proposed use of the site change, this report may no longer be valid and any further use of or reliance upon the report in those circumstances by the client without RSK's review and advice shall be at the client's sole and own risk. Should RSK be requested to review the report after the date of this report, RSK shall be entitled to additional payment at the then existing rates or such other terms as agreed between RSK and the client.
5. The passage of time may result in changes in site conditions, regulatory or other legal provisions, technology or economic conditions which could render the report inaccurate or unreliable. The information and conclusions contained in this report should not be relied upon in the future without the written advice of RSK. In the absence of such written advice of RSK, reliance on the report in the future shall be at the client's own and sole risk. Should RSK be requested to review the report in the future, RSK shall be entitled to additional payment at the then existing rate or such other terms as may be agreed between RSK and the client.
6. The observations and conclusions described in this report are based solely upon the Services which were provided pursuant to the agreement between the client and RSK. RSK has not performed any observations, investigations, studies or testing not specifically set out or required by the contract between the client and RSK. RSK is not liable for the existence of any condition, the discovery of which would require performance of services not otherwise contained in the Services. For the avoidance of doubt, unless otherwise expressly referred to in the introduction to this report, RSK did not seek to evaluate the presence on or off the site of asbestos, electromagnetic fields, lead paint, heavy metals, radon gas or other radioactive or hazardous materials.
7. The Services are based upon RSK's observations of existing physical conditions at the Site gained from a walk-over survey of the site together with RSK's interpretation of information including documentation, obtained from third parties and from the client on the history and usage of the site. The Services are also based on information and/or analysis provided by independent testing and information services or laboratories upon which RSK was reasonably entitled to rely. The Services clearly are limited by the accuracy of the information, including documentation, reviewed by RSK and the observations possible at the time of the walk-over survey. Further RSK was not authorised and did not attempt to independently verify the accuracy or completeness of information, documentation or materials received from the client or third parties, including laboratories and information services, during the performance of the Services. RSK is not liable for any inaccurate information or conclusions, the discovery of which inaccuracies required the doing of any act including the gathering of any information which was not reasonably available to RSK and including the doing of any independent investigation of the information provided to RSK save as otherwise provided in the terms of the contract between the client and RSK.
8. The intrusive environmental site investigation aspects of the Services is a limited sampling of the site at pre-determined borehole and soil vapour locations based on the operational configuration of the site. The conclusions given in this report are based on information gathered at the specific test locations and can only be extrapolated to an undefined limited area around those locations. The extent of the limited area depends on the soil and groundwater conditions, together with the position of any current structures and underground facilities and natural and other activities on site. In addition chemical analysis was carried out for a limited number of parameters [as stipulated in the contract between the client and RSK] [based on an understanding of the available operational and historical information,] and it should not be inferred that other chemical species are not present.
9. Any site drawing(s) provided in this report is (are) not meant to be an accurate base plan, but is (are) used to present the general relative locations of features on, and surrounding, the site. Features (boreholes, trial pits etc) annotated on site plans are not drawn to scale but are centred over the approximate location. Such features should not be used for setting out and should be considered indicative only.



APPENDIX B

SURROGATE MARKER TABLES

Perimeter soil mounds

PAH	Ratio relative to BaP from Culp et al., (1998)	Upper Limit	Lower Limit	Mean concentration (mg/kg)	Minimum concentration (mg/kg)	Maximum concentration (mg/kg)	Ratio relative to BaP	Ratio within upper and lower limit?
Benzo(a)pyrene	N/A	N/A	N/A	4.71	0.93	11.9	1	N/A
Benzo(a)anthracene	1.24	12.43	0.12	6.24	1.24	15.1	1.32	Y
Chrysene	1.16	11.61	0.12	6.4	1.26	17.7	1.36	Y
Benzo(b)fluoranthene	1.08	10.85	0.11	5.43	1.08	14.8	1.15	Y
Benzo(k)fluoranthene	0.37	3.72	0.04	2.11	0.35	6.3	0.45	Y
Indeno(1,2,3-cd)pyrene	0.73	1.38	0.01	3.04	0.59	7.34	0.65	Y
Dibenz(a,h)anthracene	0.14	7.27	0.07	0.68	0.11	2.03	0.14	Y
Benzo(ghi)perylene	0.82	8.22	0.08	2.39	0.5	6.2	0.51	Y

HP13

PAH	Ratio relative to BaP from Culp et al., (1998)	Upper Limit	Lower Limit	Mean concentration (mg/kg)	Minimum concentration (mg/kg)	Maximum concentration (mg/kg)	Ratio relative to BaP	Ratio within upper and lower limit?
Benzo(a)pyrene	N/A	N/A	N/A	7.12	7.12	7.12	1	N/A
Benzo(a)anthracene	1.24	12.43	0.12	7.82	7.82	7.82	1.10	Y
Chrysene	1.16	11.61	0.12	10.3	10.3	10.3	1.45	Y
Benzo(b)fluoranthene	1.08	10.85	0.11	8.79	8.79	8.79	1.23	Y
Benzo(k)fluoranthene	0.37	3.72	0.04	3.56	3.56	3.56	0.50	Y
Indeno(1,2,3-cd)pyrene	0.73	1.38	0.01	4.52	4.52	4.52	0.63	Y
Dibenz(a,h)anthracene	0.14	7.27	0.07	0.99	0.99	0.99	0.14	Y
Benzo(ghi)perylene	0.82	8.22	0.08	4.04	4.04	4.04	0.57	Y

HP14

PAH	Ratio relative to BaP from Culp et al., (1998)	Upper Limit	Lower Limit	Mean concentration (mg/kg)	Minimum concentration (mg/kg)	Maximum concentration (mg/kg)	Ratio relative to BaP	Ratio within upper and lower limit?
Benzo(a)pyrene	N/A	N/A	N/A	14.7	14.7	14.7	1	N/A
Benzo(a)anthracene	1.24	12.43	0.12	18.2	18.2	18.2	1.24	Y
Chrysene	1.16	11.61	0.12	21.8	21.8	21.8	1.48	Y
Benzo(b)fluoranthene	1.08	10.85	0.11	18.4	18.4	18.4	1.25	Y
Benzo(k)fluoranthene	0.37	3.72	0.04	7.64	7.64	7.64	0.52	Y
Indeno(1,2,3-cd)pyrene	0.73	1.38	0.01	8.84	8.84	8.84	0.60	Y
Dibenz(a,h)anthracene	0.14	7.27	0.07	1.94	1.94	1.94	0.13	Y
Benzo(ghi)perylene	0.82	8.22	0.08	7.75	7.75	7.75	0.53	Y

HP15

PAH	Ratio relative to BaP from Culp et al., (1998)	Upper Limit	Lower Limit	Mean concentration (mg/kg)	Minimum concentration (mg/kg)	Maximum concentration (mg/kg)	Ratio relative to BaP	Ratio within upper and lower limit?
Benzo(a)pyrene	N/A	N/A	N/A	3.61	3.61	3.61	1	N/A
Benzo(a)anthracene	1.24	12.43	0.12	4.47	4.47	4.47	1.24	Y
Chrysene	1.16	11.61	0.12	4.2	4.2	4.2	1.16	Y
Benzo(b)fluoranthene	1.08	10.85	0.11	4.09	4.09	4.09	1.13	Y
Benzo(k)fluoranthene	0.37	3.72	0.04	1.33	1.33	1.33	0.37	Y
Indeno(1,2,3-cd)pyrene	0.73	1.38	0.01	2.11	2.11	2.11	0.58	Y
Dibenz(a,h)anthracene	0.14	7.27	0.07	0.36	0.36	0.36	0.10	Y
Benzo(ghi)perylene	0.82	8.22	0.08	1.77	1.77	1.77	0.49	Y

HP16 (two samples)

PAH	Ratio relative to BaP from Culp et al., (1998)	Upper Limit	Lower Limit	Mean concentration (mg/kg)	Minimum concentration (mg/kg)	Maximum concentration (mg/kg)	Ratio relative to BaP	Ratio within upper and lower limit?
Benzo(a)pyrene	N/A	N/A	N/A	11.17	8.54	13.8	1	N/A
Benzo(a)anthracene	1.24	12.43	0.12	12.815	9.23	16.4	1.15	Y
Chrysene	1.16	11.61	0.12	17.15	11.7	22.6	1.54	Y
Benzo(b)fluoranthene	1.08	10.85	0.11	14.05	10.8	17.3	1.26	Y
Benzo(k)fluoranthene	0.37	3.72	0.04	5.625	4.16	7.09	0.50	Y
Indeno(1,2,3-cd)pyrene	0.73	1.38	0.01	6.845	5.14	8.55	0.61	Y
Dibenz(a,h)anthracene	0.14	7.27	0.07	1.665	1.29	2.04	0.15	Y
Benzo(ghi)perylene	0.82	8.22	0.08	6.035	4.46	7.61	0.54	Y

HP17

PAH	Ratio relative to BaP from Culp et al., (1998)	Upper Limit	Lower Limit	Mean concentration (mg/kg)	Minimum concentration (mg/kg)	Maximum concentration (mg/kg)	Ratio relative to BaP	Ratio within upper and lower limit?
Benzo(a)pyrene	N/A	N/A	N/A	1.11	1.11	1.11	1	N/A
Benzo(a)anthracene	1.24	12.43	0.12	1.24	1.24	1.24	1.12	Y
Chrysene	1.16	11.61	0.12	1.33	1.33	1.33	1.20	Y
Benzo(b)fluoranthene	1.08	10.85	0.11	1.41	1.41	1.41	1.27	Y
Benzo(k)fluoranthene	0.37	3.72	0.04	0.46	0.46	0.46	0.41	Y
Indeno(1,2,3-cd)pyrene	0.73	1.38	0.01	0.69	0.69	0.69	0.62	Y
Dibenz(a,h)anthracene	0.14	7.27	0.07	0.13	0.13	0.13	0.12	Y
Benzo(ghi)perylene	0.82	8.22	0.08	0.56	0.56	0.56	0.50	Y



APPENDIX C

CLEA MODEL RUNS

CLEA Software Version 1.071

Page 1 of 5

Report generated 17/09/2018

Report title Scenario 1 - Resi without home-grown, S&D ingestion rate 49.25 mg/d

Created by Jo Wilding at RSK

BASIC SETTINGS

Land Use Residential without produce (C4SL)

Building Small terraced house

Receptor Female (res C4SL)

Start age class 1

End age class 6

Exposure Duration 6 years

Soil Sandy loam

Exposure Pathways

Direct soil and dust ingestion



Consumption of homegrown produce



Soil attached to homegrown produce



Dermal contact with indoor dust



Dermal contact with soil



Inhalation of indoor dust



Inhalation of soil dust



Inhalation of indoor vapour



Inhalation of outdoor vapour





Land Use Residential without produce (C4SL)

Receptor Female (res C4SL)

Age Class	Exposure Frequencies (days yr ⁻¹)						Occupation Periods (hr day ⁻¹)		Soil to skin adherence factors (mg cm ²)		Direct soil ingestion rate (g day ⁻¹)	Body weight (kg)	Body height (m)	Inhalation rate (m ³ day ⁻¹)	Max exposed skin factor		Total skin area (m ²)
	Direct soil ingestion	Consumption of homegrown produce	Dermal contact with indoor dust	Dermal contact with soil	Inhalation of dust and vapour, indoor	Inhalation of dust and vapour, outdoor	Indoors	Outdoors	Indoor						Indoor (m ² m ⁻²)	Outdoor (m ² m ⁻²)	
									Indoor	Outdoor							
1	180	0	180	170	365	365	23.0	1.0	0.06	0.10	0.05	5.60	0.7	5.4	0.32	0.26	3.43E-01
2	365	0	365	170	365	365	23.0	1.0	0.06	0.10	0.05	9.80	0.8	8.0	0.33	0.26	4.84E-01
3	365	0	365	170	365	365	23.0	1.0	0.06	0.10	0.05	12.70	0.9	8.9	0.32	0.25	5.82E-01
4	365	0	365	170	365	365	23.0	1.0	0.06	0.10	0.05	15.10	0.9	10.1	0.35	0.28	6.36E-01
5	365	0	365	170	365	365	19.0	1.0	0.06	0.10	0.05	16.90	1.0	10.1	0.35	0.28	7.04E-01
6	365	0	365	170	365	365	19.0	1.0	0.06	0.10	0.05	19.70	1.1	10.1	0.33	0.26	7.94E-01
7	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	22.10	1.2	12.0	0.22	0.15	8.73E-01
8	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	25.30	1.2	12.0	0.22	0.15	9.36E-01
9	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	27.50	1.3	12.0	0.22	0.15	1.01E+00
10	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	31.40	1.3	12.0	0.22	0.15	1.08E+00
11	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	35.70	1.4	12.0	0.22	0.14	1.19E+00
12	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	41.30	1.4	15.2	0.22	0.14	1.29E+00
13	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	47.20	1.5	15.2	0.22	0.14	1.42E+00
14	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	51.20	1.6	15.2	0.22	0.14	1.52E+00
15	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	56.70	1.6	15.2	0.21	0.14	1.60E+00
16	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	59.00	1.6	15.2	0.21	0.14	1.63E+00
17	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	70.00	1.6	15.7	0.33	0.27	1.78E+00
18	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	70.90	1.6	13.6	0.33	0.27	1.80E+00

Consumption Rates



Age Class	Consumption rates (g FW kg ⁻¹ bodyweight day ⁻¹) by Produce Group											
	MEAN RATES						90TH PERCENTILE RATES					
	Green veg	Root veg	Tuber veg	Herb. Fruit	Shrub fruit	Tree fruit	Green veg	Root veg	Tuber veg	Herb. Fruit	Shrub fruit	Tree fruit
1	3.47E+00	5.22E+00	9.22E+00	8.90E-01	1.07E+00	1.87E+00	7.12E+00	1.07E+01	1.60E+01	1.83E+00	2.23E+00	3.82E+00
2	3.34E+00	1.61E+00	3.14E+00	1.93E+00	2.60E-01	5.84E+00	5.87E+00	2.83E+00	6.60E+00	3.39E+00	4.60E-01	1.03E+01
3	3.34E+00	1.61E+00	3.14E+00	1.93E+00	2.60E-01	5.84E+00	5.87E+00	2.83E+00	6.60E+00	3.39E+00	4.60E-01	1.03E+01
4	3.34E+00	1.61E+00	3.14E+00	1.93E+00	2.60E-01	5.84E+00	5.87E+00	2.83E+00	6.60E+00	3.39E+00	4.60E-01	1.03E+01
5	2.54E+00	1.20E+00	2.65E+00	1.25E+00	1.10E-01	2.89E+00	4.53E+00	2.14E+00	4.95E+00	2.24E+00	1.90E-01	5.16E+00
6	2.54E+00	1.20E+00	2.65E+00	1.25E+00	1.10E-01	2.89E+00	4.53E+00	2.14E+00	4.95E+00	2.24E+00	1.90E-01	5.16E+00
7	2.54E+00	1.20E+00	2.65E+00	1.25E+00	1.10E-01	2.89E+00	4.53E+00	2.14E+00	4.95E+00	2.24E+00	1.90E-01	5.16E+00
8	2.54E+00	1.20E+00	2.65E+00	1.25E+00	1.10E-01	2.89E+00	4.53E+00	2.14E+00	4.95E+00	2.24E+00	1.90E-01	5.16E+00
9	2.54E+00	1.20E+00	2.65E+00	1.25E+00	1.10E-01	2.89E+00	4.53E+00	2.14E+00	4.95E+00	2.24E+00	1.90E-01	5.16E+00
10	2.54E+00	1.20E+00	2.65E+00	1.25E+00	1.10E-01	2.89E+00	4.53E+00	2.14E+00	4.95E+00	2.24E+00	1.90E-01	5.16E+00
11	2.54E+00	1.20E+00	2.65E+00	1.25E+00	1.10E-01	2.89E+00	4.53E+00	2.14E+00	4.95E+00	2.24E+00	1.90E-01	5.16E+00
12	1.03E+00	4.90E-01	1.60E+00	5.10E-01	4.00E-02	1.18E+00	1.87E+00	8.90E-01	3.05E+00	9.30E-01	8.00E-02	2.13E+00
13	1.03E+00	4.90E-01	1.60E+00	5.10E-01	4.00E-02	1.18E+00	1.87E+00	8.90E-01	3.05E+00	9.30E-01	8.00E-02	2.13E+00
14	1.03E+00	4.90E-01	1.60E+00	5.10E-01	4.00E-02	1.18E+00	1.87E+00	8.90E-01	3.05E+00	9.30E-01	8.00E-02	2.13E+00
15	1.03E+00	4.90E-01	1.60E+00	5.10E-01	4.00E-02	1.18E+00	1.87E+00	8.90E-01	3.05E+00	9.30E-01	8.00E-02	2.13E+00
16	1.03E+00	4.90E-01	1.60E+00	5.10E-01	4.00E-02	1.18E+00	1.87E+00	8.90E-01	3.05E+00	9.30E-01	8.00E-02	2.13E+00
17	1.26E+00	6.00E-01	1.18E+00	6.90E-01	9.00E-02	1.27E+00	2.36E+00	1.12E+00	2.35E+00	1.29E+00	1.80E-01	2.38E+00
18	1.35E+00	6.40E-01	1.25E+00	7.40E-01	1.00E-01	1.36E+00	2.34E+00	1.12E+00	2.36E+00	1.28E+00	1.80E-01	2.37E+00

Top 2 applied? Yes

Where top 2 method is applied, two produce categories use 90th percentile rates, while the remainder use the mean. Produce categories vary on a chemical-by-chemical basis. Where top 2 method is not used, all produce categories for all chemicals assume 90th percentile rates.

Building Small terraced house**Soil** Sandy loam

Building footprint (m ²)	2.80E+01
Living space air exchange rate (hr ⁻¹)	5.00E-01
Living space height (above ground, m)	4.80E+00
Living space height (below ground, m)	0.00E+00
Pressure difference (soil to enclosed space, Pa)	3.10E+00
Foundation thickness (m)	1.50E-01
Floor crack area (cm ²)	4.23E+02
Dust loading factor (µg m ⁻³)	5.00E+01

Porosity, Total (cm ³ cm ⁻³)	5.30E-01
Porosity, Air-Filled (cm ³ cm ⁻³)	2.00E-01
Porosity, Water-Filled (cm ³ cm ⁻³)	3.30E-01
Residual soil water content (cm ³ cm ⁻³)	1.20E-01
Saturated hydraulic conductivity (cm s ⁻¹)	3.56E-03
van Genuchten shape parameter <i>m</i> (dimensionless)	3.20E-01
Bulk density (g cm ⁻³)	1.21E+00
Threshold value of wind speed at 10m (m s ⁻¹)	7.20E+00
Empirical function (F _x) for dust model (dimensionless)	1.22E+00
Ambient soil temperature (K)	2.83E+02
Soil pH	7.00E+00
Soil Organic Matter content (%)	6.00E+00
Fraction of organic carbon (g g ⁻¹)	3.48E-02
Effective total fluid saturation (unitless)	5.12E-01
Intrinsic soil permeability (cm ²)	4.75E-08
Relative soil air permeability (unitless)	6.42E-01
Effective air permeability (cm ²)	3.05E-08

Soil - Vapour Model

Depth to top of source (no building) (cm)	0
Depth to top of source (beneath building) (cm)	65
Default soil gas ingress rate?	Yes
Soil gas ingress rate ($\text{cm}^3 \text{s}^{-1}$)	2.50E+01
Building ventilation rate ($\text{cm}^3 \text{s}^{-1}$)	1.87E+04
Averaging time surface emissions (yr)	6
Finite vapour source model?	No
Thickness of contaminated layer (cm)	200

Air Dispersion Model

Mean annual windspeed at 10m (m s^{-1})	5.00
Air dispersion factor at height of 0.8m *	2400.00
Air dispersion factor at height of 1.6m *	0.00
Fraction of site cover ($\text{m}^2 \text{m}^{-2}$)	0.75

* Air dispersion factor in $\text{g m}^{-2} \text{s}^{-1}$ per kg m^{-3} **Soil - Plant Model**

	Dry weight conversion factor	Homegrown fraction		Soil loading factor	Preparation correction factor
		Average	High		
	$\text{g DW g}^{-1} \text{FW}$	dimensionless		$\text{g g}^{-1} \text{DW}$	dimensionless
Green vegetables	0.096	0.05	0.33	1.00E-03	2.00E-01
Root vegetables	0.103	0.06	0.40	1.00E-03	1.00E+00
Tuber vegetables	0.210	0.02	0.13	1.00E-03	1.00E+00
Herbaceous fruit	0.058	0.06	0.40	1.00E-03	6.00E-01
Shrub fruit	0.166	0.09	0.60	1.00E-03	6.00E-01
Tree fruit	0.157	0.04	0.27	1.00E-03	6.00E-01

Gardener type None

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Page 1 of 11

Report generated 17-Sep-18

Report title Scenario 1 - Resi without home-grown, S&D ingestion rate 49.25 mg/d

Created by Jo Wilding at RSK



Environment
Agency

RESULTS

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	Average Daily Exposure ($\text{mg kg}^{-1} \text{ bw day}^{-1}$)	Distribution by Pathway (%)
	Direct soil ingestion Consumption of homegrown produce and attached soil Dermal contact with soil and dust Inhalation of dust Inhalation of vapour Background (oral) Background (inhalation)	Direct soil ingestion Consumption of homegrown produce and attached soil Dermal contact with soil and dust Inhalation of dust Inhalation of vapour (indoor) Inhalation of vapour (outdoor) Background (oral) Background (inhalation)
1 Benzo[a]pyrene (C4SL child)	3.74E-05 0.00E+00 4.40E-06 1.69E-07 4.42E-09 0.00E+00 0.00E+00	89.11 0.00 10.48 0.40 0.01 0.00 0.00
2 Lead (C4SL child)	1.39E-03 0.00E+00 0.00E+00 6.72E-06 0.00E+00 0.00E+00 0.00E+00	99.52 0.00 0.00 0.48 0.00 0.00 0.00
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Page 1 of 5

Report generated 17/09/2018

Report title Scenario 2 - Residential without home-grown, S&D ingestion rate 26 mg/d

Created by Jo Wilding at RSK

BASIC SETTINGS

Land Use Residential without produce (C4SL)

Building Small terraced house

Receptor Female (res C4SL)

Start age class 1

End age class 6

Exposure Duration 6 years

Soil Sandy loam

Exposure Pathways

Direct soil and dust ingestion



Consumption of homegrown produce



Soil attached to homegrown produce



Dermal contact with indoor dust



Dermal contact with soil



Inhalation of indoor dust



Inhalation of soil dust



Inhalation of indoor vapour



Inhalation of outdoor vapour





Land Use Residential without produce (C4SL)

Receptor Female (res C4SL)

Age Class	Exposure Frequencies (days yr ⁻¹)						Occupation Periods (hr day ⁻¹)		Soil to skin adherence factors (mg cm ²)		Direct soil ingestion rate (g day ⁻¹)	Body weight (kg)	Body height (m)	Inhalation rate (m ³ day ⁻¹)	Max exposed skin factor		Total skin area (m ²)
	Direct soil ingestion	Consumption of homegrown produce	Dermal contact with indoor dust	Dermal contact with soil	Inhalation of dust and vapour, indoor	Inhalation of dust and vapour, outdoor	Indoors	Outdoors	Indoor						Indoor (m ² m ⁻²)	Outdoor (m ² m ⁻²)	
									Indoor	Outdoor							
1	180	0	180	170	365	365	23.0	1.0	0.06	0.10	0.03	5.60	0.7	5.4	0.32	0.26	3.43E-01
2	365	0	365	170	365	365	23.0	1.0	0.06	0.10	0.03	9.80	0.8	8.0	0.33	0.26	4.84E-01
3	365	0	365	170	365	365	23.0	1.0	0.06	0.10	0.03	12.70	0.9	8.9	0.32	0.25	5.82E-01
4	365	0	365	170	365	365	23.0	1.0	0.06	0.10	0.03	15.10	0.9	10.1	0.35	0.28	6.36E-01
5	365	0	365	170	365	365	19.0	1.0	0.06	0.10	0.03	16.90	1.0	10.1	0.35	0.28	7.04E-01
6	365	0	365	170	365	365	19.0	1.0	0.06	0.10	0.03	19.70	1.1	10.1	0.33	0.26	7.94E-01
7	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	22.10	1.2	12.0	0.22	0.15	8.73E-01
8	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	25.30	1.2	12.0	0.22	0.15	9.36E-01
9	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	27.50	1.3	12.0	0.22	0.15	1.01E+00
10	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	31.40	1.3	12.0	0.22	0.15	1.08E+00
11	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	35.70	1.4	12.0	0.22	0.14	1.19E+00
12	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	41.30	1.4	15.2	0.22	0.14	1.29E+00
13	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	47.20	1.5	15.2	0.22	0.14	1.42E+00
14	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	51.20	1.6	15.2	0.22	0.14	1.52E+00
15	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	56.70	1.6	15.2	0.21	0.14	1.60E+00
16	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	59.00	1.6	15.2	0.21	0.14	1.63E+00
17	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	70.00	1.6	15.7	0.33	0.27	1.78E+00
18	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	70.90	1.6	13.6	0.33	0.27	1.80E+00

Consumption Rates



Age Class	Consumption rates (g FW kg ⁻¹ bodyweight day ⁻¹) by Produce Group											
	MEAN RATES						90TH PERCENTILE RATES					
	Green veg	Root veg	Tuber veg	Herb. Fruit	Shrub fruit	Tree fruit	Green veg	Root veg	Tuber veg	Herb. Fruit	Shrub fruit	Tree fruit
1	3.47E+00	5.22E+00	9.22E+00	8.90E-01	1.07E+00	1.87E+00	7.12E+00	1.07E+01	1.60E+01	1.83E+00	2.23E+00	3.82E+00
2	3.34E+00	1.61E+00	3.14E+00	1.93E+00	2.60E-01	5.84E+00	5.87E+00	2.83E+00	6.60E+00	3.39E+00	4.60E-01	1.03E+01
3	3.34E+00	1.61E+00	3.14E+00	1.93E+00	2.60E-01	5.84E+00	5.87E+00	2.83E+00	6.60E+00	3.39E+00	4.60E-01	1.03E+01
4	3.34E+00	1.61E+00	3.14E+00	1.93E+00	2.60E-01	5.84E+00	5.87E+00	2.83E+00	6.60E+00	3.39E+00	4.60E-01	1.03E+01
5	2.54E+00	1.20E+00	2.65E+00	1.25E+00	1.10E-01	2.89E+00	4.53E+00	2.14E+00	4.95E+00	2.24E+00	1.90E-01	5.16E+00
6	2.54E+00	1.20E+00	2.65E+00	1.25E+00	1.10E-01	2.89E+00	4.53E+00	2.14E+00	4.95E+00	2.24E+00	1.90E-01	5.16E+00
7	2.54E+00	1.20E+00	2.65E+00	1.25E+00	1.10E-01	2.89E+00	4.53E+00	2.14E+00	4.95E+00	2.24E+00	1.90E-01	5.16E+00
8	2.54E+00	1.20E+00	2.65E+00	1.25E+00	1.10E-01	2.89E+00	4.53E+00	2.14E+00	4.95E+00	2.24E+00	1.90E-01	5.16E+00
9	2.54E+00	1.20E+00	2.65E+00	1.25E+00	1.10E-01	2.89E+00	4.53E+00	2.14E+00	4.95E+00	2.24E+00	1.90E-01	5.16E+00
10	2.54E+00	1.20E+00	2.65E+00	1.25E+00	1.10E-01	2.89E+00	4.53E+00	2.14E+00	4.95E+00	2.24E+00	1.90E-01	5.16E+00
11	2.54E+00	1.20E+00	2.65E+00	1.25E+00	1.10E-01	2.89E+00	4.53E+00	2.14E+00	4.95E+00	2.24E+00	1.90E-01	5.16E+00
12	1.03E+00	4.90E-01	1.60E+00	5.10E-01	4.00E-02	1.18E+00	1.87E+00	8.90E-01	3.05E+00	9.30E-01	8.00E-02	2.13E+00
13	1.03E+00	4.90E-01	1.60E+00	5.10E-01	4.00E-02	1.18E+00	1.87E+00	8.90E-01	3.05E+00	9.30E-01	8.00E-02	2.13E+00
14	1.03E+00	4.90E-01	1.60E+00	5.10E-01	4.00E-02	1.18E+00	1.87E+00	8.90E-01	3.05E+00	9.30E-01	8.00E-02	2.13E+00
15	1.03E+00	4.90E-01	1.60E+00	5.10E-01	4.00E-02	1.18E+00	1.87E+00	8.90E-01	3.05E+00	9.30E-01	8.00E-02	2.13E+00
16	1.03E+00	4.90E-01	1.60E+00	5.10E-01	4.00E-02	1.18E+00	1.87E+00	8.90E-01	3.05E+00	9.30E-01	8.00E-02	2.13E+00
17	1.26E+00	6.00E-01	1.18E+00	6.90E-01	9.00E-02	1.27E+00	2.36E+00	1.12E+00	2.35E+00	1.29E+00	1.80E-01	2.38E+00
18	1.35E+00	6.40E-01	1.25E+00	7.40E-01	1.00E-01	1.36E+00	2.34E+00	1.12E+00	2.36E+00	1.28E+00	1.80E-01	2.37E+00

Top 2 applied? Yes

Where top 2 method is applied, two produce categories use 90th percentile rates, while the remainder use the mean. Produce categories vary on a chemical-by-chemical basis. Where top 2 method is not used, all produce categories for all chemicals assume 90th percentile rates.

Building Small terraced house**Soil** Sandy loam

Building footprint (m ²)	2.80E+01
Living space air exchange rate (hr ⁻¹)	5.00E-01
Living space height (above ground, m)	4.80E+00
Living space height (below ground, m)	0.00E+00
Pressure difference (soil to enclosed space, Pa)	3.10E+00
Foundation thickness (m)	1.50E-01
Floor crack area (cm ²)	4.23E+02
Dust loading factor (µg m ⁻³)	5.00E+01

Porosity, Total (cm ³ cm ⁻³)	5.30E-01
Porosity, Air-Filled (cm ³ cm ⁻³)	2.00E-01
Porosity, Water-Filled (cm ³ cm ⁻³)	3.30E-01
Residual soil water content (cm ³ cm ⁻³)	1.20E-01
Saturated hydraulic conductivity (cm s ⁻¹)	3.56E-03
van Genuchten shape parameter <i>m</i> (dimensionless)	3.20E-01
Bulk density (g cm ⁻³)	1.21E+00
Threshold value of wind speed at 10m (m s ⁻¹)	7.20E+00
Empirical function (F _x) for dust model (dimensionless)	1.22E+00
Ambient soil temperature (K)	2.83E+02
Soil pH	7.00E+00
Soil Organic Matter content (%)	6.00E+00
Fraction of organic carbon (g g ⁻¹)	3.48E-02
Effective total fluid saturation (unitless)	5.12E-01
Intrinsic soil permeability (cm ²)	4.75E-08
Relative soil air permeability (unitless)	6.42E-01
Effective air permeability (cm ²)	3.05E-08

Soil - Vapour Model

Depth to top of source (no building) (cm)	0
Depth to top of source (beneath building) (cm)	65
Default soil gas ingress rate?	Yes
Soil gas ingress rate ($\text{cm}^3 \text{s}^{-1}$)	2.50E+01
Building ventilation rate ($\text{cm}^3 \text{s}^{-1}$)	1.87E+04
Averaging time surface emissions (yr)	6
Finite vapour source model?	No
Thickness of contaminated layer (cm)	200

Air Dispersion Model

Mean annual windspeed at 10m (m s^{-1})	5.00
Air dispersion factor at height of 0.8m *	2400.00
Air dispersion factor at height of 1.6m *	0.00
Fraction of site cover ($\text{m}^2 \text{m}^{-2}$)	0.75

* Air dispersion factor in $\text{g m}^{-2} \text{s}^{-1}$ per kg m^{-3} **Soil - Plant Model**

	Dry weight conversion factor	Homegrown fraction		Soil loading factor	Preparation correction factor
		Average	High		
	$\text{g DW g}^{-1} \text{FW}$	dimensionless		$\text{g g}^{-1} \text{DW}$	dimensionless
Green vegetables	0.096	0.05	0.33	1.00E-03	2.00E-01
Root vegetables	0.103	0.06	0.40	1.00E-03	1.00E+00
Tuber vegetables	0.210	0.02	0.13	1.00E-03	1.00E+00
Herbaceous fruit	0.058	0.06	0.40	1.00E-03	6.00E-01
Shrub fruit	0.166	0.09	0.60	1.00E-03	6.00E-01
Tree fruit	0.157	0.04	0.27	1.00E-03	6.00E-01

Gardener type None

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Page 1 of 11

Report generated 17-Sep-18

Report title Scenario 2 - Residential without home-grown, S&D ingestion rate 26 mg/t

Created by Jo Wilding at RSK



Environment
Agency

RESULTS

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Page 1 of 5

Report generated 17/09/2018

Report title Scenario 3 - Residential without home-grown, S&D ingestion 49.25 mg/d, UF 2500

Created by Jo Wilding at RSK

BASIC SETTINGS

Land Use Residential without produce (C4SL)

Building Small terraced house

Receptor Female (res C4SL)

Start age class 1

End age class 6

Exposure Duration 6 years

Soil Sandy loam

Exposure Pathways

Direct soil and dust ingestion



Consumption of homegrown produce



Soil attached to homegrown produce



Dermal contact with indoor dust



Dermal contact with soil



Inhalation of indoor dust



Inhalation of soil dust



Inhalation of indoor vapour



Inhalation of outdoor vapour





Land Use Residential without produce (C4SL)

Receptor Female (res C4SL)

Age Class	Exposure Frequencies (days yr ⁻¹)						Occupation Periods (hr day ⁻¹)		Soil to skin adherence factors (mg cm ²)		Direct soil ingestion rate (g day ⁻¹)	Body weight (kg)	Body height (m)	Inhalation rate (m ³ day ⁻¹)	Max exposed skin factor		Total skin area (m ²)
	Direct soil ingestion	Consumption of homegrown produce	Dermal contact with indoor dust	Dermal contact with soil	Inhalation of dust and vapour, indoor	Inhalation of dust and vapour, outdoor	Indoors	Outdoors	Indoor						Indoor (m ² m ⁻²)	Outdoor (m ² m ⁻²)	
									Indoor	Outdoor							
1	180	0	180	170	365	365	23.0	1.0	0.06	0.10	0.05	5.60	0.7	5.4	0.32	0.26	3.43E-01
2	365	0	365	170	365	365	23.0	1.0	0.06	0.10	0.05	9.80	0.8	8.0	0.33	0.26	4.84E-01
3	365	0	365	170	365	365	23.0	1.0	0.06	0.10	0.05	12.70	0.9	8.9	0.32	0.25	5.82E-01
4	365	0	365	170	365	365	23.0	1.0	0.06	0.10	0.05	15.10	0.9	10.1	0.35	0.28	6.36E-01
5	365	0	365	170	365	365	19.0	1.0	0.06	0.10	0.05	16.90	1.0	10.1	0.35	0.28	7.04E-01
6	365	0	365	170	365	365	19.0	1.0	0.06	0.10	0.05	19.70	1.1	10.1	0.33	0.26	7.94E-01
7	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	22.10	1.2	12.0	0.22	0.15	8.73E-01
8	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	25.30	1.2	12.0	0.22	0.15	9.36E-01
9	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	27.50	1.3	12.0	0.22	0.15	1.01E+00
10	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	31.40	1.3	12.0	0.22	0.15	1.08E+00
11	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	35.70	1.4	12.0	0.22	0.14	1.19E+00
12	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	41.30	1.4	15.2	0.22	0.14	1.29E+00
13	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	47.20	1.5	15.2	0.22	0.14	1.42E+00
14	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	51.20	1.6	15.2	0.22	0.14	1.52E+00
15	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	56.70	1.6	15.2	0.21	0.14	1.60E+00
16	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	59.00	1.6	15.2	0.21	0.14	1.63E+00
17	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	70.00	1.6	15.7	0.33	0.27	1.78E+00
18	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	70.90	1.6	13.6	0.33	0.27	1.80E+00

Consumption Rates



Age Class	Consumption rates (g FW kg ⁻¹ bodyweight day ⁻¹) by Produce Group											
	MEAN RATES						90TH PERCENTILE RATES					
	Green veg	Root veg	Tuber veg	Herb. Fruit	Shrub fruit	Tree fruit	Green veg	Root veg	Tuber veg	Herb. Fruit	Shrub fruit	Tree fruit
1	3.47E+00	5.22E+00	9.22E+00	8.90E-01	1.07E+00	1.87E+00	7.12E+00	1.07E+01	1.60E+01	1.83E+00	2.23E+00	3.82E+00
2	3.34E+00	1.61E+00	3.14E+00	1.93E+00	2.60E-01	5.84E+00	5.87E+00	2.83E+00	6.60E+00	3.39E+00	4.60E-01	1.03E+01
3	3.34E+00	1.61E+00	3.14E+00	1.93E+00	2.60E-01	5.84E+00	5.87E+00	2.83E+00	6.60E+00	3.39E+00	4.60E-01	1.03E+01
4	3.34E+00	1.61E+00	3.14E+00	1.93E+00	2.60E-01	5.84E+00	5.87E+00	2.83E+00	6.60E+00	3.39E+00	4.60E-01	1.03E+01
5	2.54E+00	1.20E+00	2.65E+00	1.25E+00	1.10E-01	2.89E+00	4.53E+00	2.14E+00	4.95E+00	2.24E+00	1.90E-01	5.16E+00
6	2.54E+00	1.20E+00	2.65E+00	1.25E+00	1.10E-01	2.89E+00	4.53E+00	2.14E+00	4.95E+00	2.24E+00	1.90E-01	5.16E+00
7	2.54E+00	1.20E+00	2.65E+00	1.25E+00	1.10E-01	2.89E+00	4.53E+00	2.14E+00	4.95E+00	2.24E+00	1.90E-01	5.16E+00
8	2.54E+00	1.20E+00	2.65E+00	1.25E+00	1.10E-01	2.89E+00	4.53E+00	2.14E+00	4.95E+00	2.24E+00	1.90E-01	5.16E+00
9	2.54E+00	1.20E+00	2.65E+00	1.25E+00	1.10E-01	2.89E+00	4.53E+00	2.14E+00	4.95E+00	2.24E+00	1.90E-01	5.16E+00
10	2.54E+00	1.20E+00	2.65E+00	1.25E+00	1.10E-01	2.89E+00	4.53E+00	2.14E+00	4.95E+00	2.24E+00	1.90E-01	5.16E+00
11	2.54E+00	1.20E+00	2.65E+00	1.25E+00	1.10E-01	2.89E+00	4.53E+00	2.14E+00	4.95E+00	2.24E+00	1.90E-01	5.16E+00
12	1.03E+00	4.90E-01	1.60E+00	5.10E-01	4.00E-02	1.18E+00	1.87E+00	8.90E-01	3.05E+00	9.30E-01	8.00E-02	2.13E+00
13	1.03E+00	4.90E-01	1.60E+00	5.10E-01	4.00E-02	1.18E+00	1.87E+00	8.90E-01	3.05E+00	9.30E-01	8.00E-02	2.13E+00
14	1.03E+00	4.90E-01	1.60E+00	5.10E-01	4.00E-02	1.18E+00	1.87E+00	8.90E-01	3.05E+00	9.30E-01	8.00E-02	2.13E+00
15	1.03E+00	4.90E-01	1.60E+00	5.10E-01	4.00E-02	1.18E+00	1.87E+00	8.90E-01	3.05E+00	9.30E-01	8.00E-02	2.13E+00
16	1.03E+00	4.90E-01	1.60E+00	5.10E-01	4.00E-02	1.18E+00	1.87E+00	8.90E-01	3.05E+00	9.30E-01	8.00E-02	2.13E+00
17	1.26E+00	6.00E-01	1.18E+00	6.90E-01	9.00E-02	1.27E+00	2.36E+00	1.12E+00	2.35E+00	1.29E+00	1.80E-01	2.38E+00
18	1.35E+00	6.40E-01	1.25E+00	7.40E-01	1.00E-01	1.36E+00	2.34E+00	1.12E+00	2.36E+00	1.28E+00	1.80E-01	2.37E+00

Top 2 applied? Yes

Where top 2 method is applied, two produce categories use 90th percentile rates, while the remainder use the mean. Produce categories vary on a chemical-by-chemical basis. Where top 2 method is not used, all produce categories for all chemicals assume 90th percentile rates.

Building Small terraced house**Soil** Sandy loam

Building footprint (m ²)	2.80E+01
Living space air exchange rate (hr ⁻¹)	5.00E-01
Living space height (above ground, m)	4.80E+00
Living space height (below ground, m)	0.00E+00
Pressure difference (soil to enclosed space, Pa)	3.10E+00
Foundation thickness (m)	1.50E-01
Floor crack area (cm ²)	4.23E+02
Dust loading factor (µg m ⁻³)	5.00E+01

Porosity, Total (cm ³ cm ⁻³)	5.30E-01
Porosity, Air-Filled (cm ³ cm ⁻³)	2.00E-01
Porosity, Water-Filled (cm ³ cm ⁻³)	3.30E-01
Residual soil water content (cm ³ cm ⁻³)	1.20E-01
Saturated hydraulic conductivity (cm s ⁻¹)	3.56E-03
van Genuchten shape parameter <i>m</i> (dimensionless)	3.20E-01
Bulk density (g cm ⁻³)	1.21E+00
Threshold value of wind speed at 10m (m s ⁻¹)	7.20E+00
Empirical function (F _x) for dust model (dimensionless)	1.22E+00
Ambient soil temperature (K)	2.83E+02
Soil pH	7.00E+00
Soil Organic Matter content (%)	6.00E+00
Fraction of organic carbon (g g ⁻¹)	3.48E-02
Effective total fluid saturation (unitless)	5.12E-01
Intrinsic soil permeability (cm ²)	4.75E-08
Relative soil air permeability (unitless)	6.42E-01
Effective air permeability (cm ²)	3.05E-08

Soil - Vapour Model

Depth to top of source (no building) (cm)	0
Depth to top of source (beneath building) (cm)	65
Default soil gas ingress rate?	Yes
Soil gas ingress rate ($\text{cm}^3 \text{s}^{-1}$)	2.50E+01
Building ventilation rate ($\text{cm}^3 \text{s}^{-1}$)	1.87E+04
Averaging time surface emissions (yr)	6
Finite vapour source model?	No
Thickness of contaminated layer (cm)	200

Air Dispersion Model

Mean annual windspeed at 10m (m s^{-1})	5.00
Air dispersion factor at height of 0.8m *	2400.00
Air dispersion factor at height of 1.6m *	0.00
Fraction of site cover ($\text{m}^2 \text{m}^{-2}$)	0.75

* Air dispersion factor in $\text{g m}^{-2} \text{s}^{-1}$ per kg m^{-3} **Soil - Plant Model**

	Dry weight conversion factor	Homegrown fraction		Soil loading factor	Preparation correction factor
	g DW g^{-1} FW	Average	High		
		dimensionless		g g^{-1} DW	dimensionless
Green vegetables	0.096	0.05	0.33	1.00E-03	2.00E-01
Root vegetables	0.103	0.06	0.40	1.00E-03	1.00E+00
Tuber vegetables	0.210	0.02	0.13	1.00E-03	1.00E+00
Herbaceous fruit	0.058	0.06	0.40	1.00E-03	6.00E-01
Shrub fruit	0.166	0.09	0.60	1.00E-03	6.00E-01
Tree fruit	0.157	0.04	0.27	1.00E-03	6.00E-01

Gardener type None

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Page 1 of 11

Report generated 17-Sep-18

Report title Scenario 3 - Residential without home-grown, S&D ingestion 49.25 mg/d,

Created by Jo Wilding at RSK



Environment
Agency

RESULTS

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