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E1 INTRODUCTION

A site wide investigation of the Whitehaven site was undertaken by URS in 2005. A human health quantitative risk assessment (HHQRA) was undertaken based on the site data and using URS derived site specific assessment criteria (SSAC). A number of exceedances of the SSACs were identified indicating that potentially significant risks were present with regard to human health.

In June 2006 URS was commissioned to undertake a detailed investigation of Plot A within the Whitehaven Site and to carry out a detailed risk assessment with regard to human health using relevant data gathered from previous investigations and data from the 2006 investigation.

The risk assessment set out in this appendix is considered to be more rigorous and representative of site conditions than the previous risk assessment for the whole of the Whitehaven site as it incorporates additional geological and geochemical data obtained during the Plot A investigation.

The HHQRA is based upon the UK Department of the Environment, Food and Rural Affairs (DEFRA) and Environment Agency (EA) guidance which is set out in the Contaminated Land Reports including:

- Environment Agency R&D Publication CLR7
- Environment Agency R&D Publication CLR10
- Environment Agency R&D Publication CLR11 (2004) *Model Procedures for the Management of Land Contamination* (referred to as CLR11) and
- The CLEA model.

Using CLR 11 methodology, risk assessment is carried out in three stages:

Stage 1 – Preliminary Risk Assessment

Stage 2 - Generic Quantitative Risk Assessment; and

Stage 3 – Detailed Quantitative risk assessment.

Stage 1 involves the development of a conceptual understanding of the site and the surrounding environment's geology, hydrogeology, observed contamination (and its distribution), and potential receptors. From this conceptual understanding, potential pollutant linkages (*source-pathway-receptor* relationships) are identified. This stage of the risk assessment is set out in Section 5 of the main body of the report.

Risk assessment at Stages 2 and 3 for Plot A is presented in full in this appendix.

E2 STAGE 2 - GENERIC QUANTITATIVE ASSESSMENT

E1.1 Methodology

The generic screening was undertaken by making a comparison of measured chemical concentrations in soil, and shallow groundwater against conservative screening criteria appropriate for a designated potential receptor. This initial screening is designed to identify Potential Contaminants of Concern (PCoC), which could pose a potential risk to human health.

E2.1 Receptors

From a human health perspective, the site is understood to be opened to the public for a general right-to-roam open space usage, with the minimum of site preparation expected (such as the removal of protruding trip hazards, but not cut and fill).

The principal potential receptors directly relevant to the proposed future scenario are therefore considered to be:

- visitors to the public open space.

The risks to potential future maintenance, remediation or redevelopment workers who may be involved in subsurface working are not specifically assessed as part of this assessment. The health and safety of workers in the UK is controlled under the Health and Safety at Work Act 1974 and associated regulations (such as the Control of Substances Hazardous to Health (COSHH) Regulations 2002 (as amended). URS does not therefore consider it appropriate to include these receptors in this assessment at present and advises that separate activity related risk assessments should be carried out as required to highlight the need for any preventative measures (such as the use of PPE) prior to such activities being carried out. The results of this assessment could, however, be used to inform decision-making on this issue.

E2.2 Stage 2 Generic Screening Criteria

Soils data have been compared with soil guideline values (SGVs) for a residential without plant uptake scenario. Where SGVs are not available, soils data have been compared with a hierarchy of screening criteria including:

- URS derived Generic Assessment Criteria (URS GAC);
- Dutch Serious Risk Concentrations (SRC);
- Corrected Dutch Intervention Values (cDIVs); and
- US EPA[1] Region 9 preliminary remediation goals (PRGs).

[1] United States – Environmental Protection Agency

Details of all Stage 2 screening criteria are included in Table E1.

URS GAC are generic risk-based soil concentrations that are protective of chronic risks to human health and have been derived by URS for a list of common contaminants for which SGVs are not available. They have been generated by URS for a number of different generic land uses in accordance with technical guidance on contaminated land exposure assessment (CLEA) issued by the Environment Agency and Defra, and are designed to afford the same degree of protection an SGV would if published for these compounds. The selected generic soil types are similar to those adopted by Defra for the published SGVs for organic substances, toluene and ethylbenzene. The selected GAC have been chosen with due regard for soil organic matter[2] contents in the shallow soil.

The Dutch Intervention Values (DIVs) were developed in the Netherlands to protect the multi-functionality of soils and are based on human toxicological *and* ecotoxicological considerations. Some site-specific soil data collected during the site investigation were used to adjust DIVs appropriately for measured organic carbon and clay content. Further development in the Netherlands led to the production of Serious Risk Concentrations (SRC) for some contaminants using updated toxicological data and are related solely to human health. These SRC are adopted where available in preference of DIV. DIVs were corrected applying a conservative assumed clay content and with due regard for the carbon content of the upper soils.

Where a UK SGV, URS GAC or the DIV/SRC is not available for a substance, the preliminary remediation goals (PRGs) published by Region 9 of the US EPA for residential land-use have been adopted. These are derived for use in the US statutory contaminated land regime and are designed to afford adequate protection to receptors.

The URS GAC, DIVs/ SRCs and PRGs have no legal status in the UK. However, as they have been derived using internationally recognised risk assessment techniques, they are considered to be consistent with current guidance and practice in the UK and acceptable as an initial screen in the absence of published UK SGVs. The hierarchy of sources used is designed such that the contaminants of greatest concern are screened against the most relevant criteria for the UK.

In addition, a report[3] by the UK Environment Agency suggests that the risks from TPH should be assessed using a method where each speciated fraction should be considered additively. This approach has therefore been applied to the data in this investigation by

[2] A conservative value of 0.58% TOC and was adopted as representative of soils for generic screening based on the minimum value used to derive organic UK soil guideline values (SGVs). A conservative assumed value of 10% clay content used based on previous investigation data obtained from the site.

[3] Environment Agency (2005). The UK Approach for Evaluating Human Health Risks from Petroleum Hydrocarbons in Soils. Science Report P5-080/TR3.

deriving a Hazard Quotient[4] (HQ) for each reported fraction for each sample and summing these HQs to create a combined Hazard Index (HI) for each sample. Exposure is considered potentially unacceptable where the HI for a *sample* is greater than unity (HI > 1.0). Where TPH has been reported for fractions without an aliphatic/aromatic split, the most conservative GAC for that fraction has been applied to the data. In addition, where data has been reported as total DRO or total TPH an average of the appropriate fractions calculated from speciated data have been applied to these totals for screening purposes.

Groundwater was not encountered at shallow depth beneath the site and has therefore not been considered as part of this assessment.

E2.3 Soil Contamination Generic Screening

All individual soil sample results from Plot A have been screened against the generic criteria for a residential without gardens scenario. A summary of those determinands whose concentrations exceeded the Stage 2 generic screening criteria is presented in Table E2 below.

E2.4 Stage 2 Summary

With a number of exceptions (discussed below) each of the substances found to exceed the appropriate soil screening criteria for the residential without gardens scenario or groundwater screening criteria were taken forward to the Stage 3 assessment.

- **Iron** - is a naturally occurring element and is not considered a priority substance by Defra and the Environment Agency with respect to human health. One shallow soil sample was analysed for iron from the site during the previous Phase II investigation and was detected at a concentration exceeding, but within the same order of magnitude as the screening criteria (23,463mg/kg). The elevated concentrations are likely from constituents in the made ground comprising iron-rich ash and clinker. This compound was therefore not included in further detailed assessment.

- **Phosphorous** - The phosphorous results for soil and groundwater (from the previous Phase II investigation) are for phosphate (as phosphorous) and as such do not represent concentrations of the elemental form. The generic screening criterion is for elemental phosphorus, not phosphate, and hence URS does not consider that the toxicological basis for the derivation of the phosphorous criterion is relevant to exposure from phosphate compounds. The UK Food Standards

[4] Hazard Quotient = Reported Concentration ÷ Screening Criteria

[5] cyanide and thiocyanate summed together and compared to acute exposure value for generic assessment. Also assessed with DQRA to complete chronic assessment.

Agency conclude in the Expert Group on Vitamins and Minerals (2003) report on Phosphate that it is widely found in common food groups with concentrations up to 4,000 mg/kg (fish). This direct intake to the human body is greater than the maximum concentrations identified on the site. This compound is not considered further with DQRA.

Generic assessment criteria could not be identified for a number of compounds detected in soil and groundwater during the screening process. URS considers it precautionary with regard to human health to take to the Stage 3 assessment any substance reported above the laboratory method detection limit (MDL) for both soils and groundwater, where a generic criterion cannot be sourced.

The compounds 1-methylnaphthalene was detected in two soil locations at concentrations greater than the method reporting limit. A screening value was not available for the generic screen and the compound was therefore included in further detailed assessment.

It should be noted that ammoniacal nitrogen, anionic surfactant (MBAS as lauryl sulphate), calcium, chloride, nitrate, phosphate, magnesium, sodium, sulphide, sulphate, sulphur, total organic nitrogen, total oxidised nitrogen are not considered priority substances by Defra and the Environment Agency with respect to human health and therefore have not been included in further detailed assessment. Generic Results Summary

In summary, those compounds brought forward to DQRA comprise;

Soil

- **Metals, metalloids and inorganic** – arsenic, barium, lead, nickel, cyanide, thiocyanate[5], mercury;
- **PAH** – acenaphthene, acenaphthylene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo[a,h]anthracene, fluoranthene, fluorene, indeno[1,2,3-cd]pyrene, phenanthrene, pyrene, and naphthalene;
- **PCB** – total as Aroclor 1254
- **SVOC** – cis 1,2-dichloroethene, carbazole, dibenzofuran;
- **TPH** – assessed via TPH Criteria Working Group (TPHCWG) fractions; and
- **VOC** – benzene, toluene, xylenes, trichloroethene (TCE).

Table E2 – Summary of Stage 2 Generic Soil Exceedances

Substance	*Screening Level (mg/kg)*	*Min (mg/kg)*	*Max (mg/kg)*	*Number of Exceedances*
Arsenic	20	<DL	66	9
Benzo(a)pyrene	1.1	<DL	1.62	4
Dibenz(a,h)anthracene	1.1	<DL	2.61	1
1-methylnaphthalene	NV	7.9	9.2	2
Naphthalene	6.3	<DL	52.6	4
Nickel	75	<DL	179	4
Trichloroethene	0.138	<DL	3.66	1
Total Phosphorous	1.56	<DL	25,800	12
Total Petroleum hydrocarbons				
TPH *Additive – Hazard Index*	1.0	<DL	14,824	4*

Notes:
NV : no generic screening value available
*based on Hazard Index values exceeding unity (>1). Maximum HI for sample obtained from WS133, 0.2m bgl.
<DL: reported concentration less than laboratory detection limit

E3 STAGE 3 DETAILED QUANTITATIVE RISK ASSESSMENT

E3.1 Methodology

At Stage 3, Site Specific Assessment Criteria (SSAC) have been derived for those determinands that exceed the Stage 2 screening criteria. Concentrations of the determinands are compared to the Stage 3 screening criteria to assess the presence of potentially significant risk to human health.

The methodology used to derive the SSACs is as follows:

- Toxicity Assessment;
- Development of quantitative conceptual exposure models (CEM) for a future public open space land use, characterising human exposure;
- Model choice for each exposure pathway; and
- Derivation of appropriate SSAC for contaminants designed to facilitate the identification of areas of the site that may require some form of risk management.

E3.2 Toxicity and Physchem Assessment

The selection of appropriate human health criteria for use in this risk assessment has been carried out in accordance with the guidelines set out in R&D Publication CLR9 published by Defra and the Environment Agency[6].

Physchem (physical and chemical) parameters for the chemicals assessed at this level have been sourced from the priority listing below:

- Environment Agency Draft Technical Report, Review of the Fate and Transport of Selected Contaminants in the Soil Environment, 2003;
- European Chemicals Bureau European Chemical Substances Information System (http://ecb.jrc.it/);
- US EPA Users Guide for Evaluating Subsurface Vapour Intrusion into Buildings, 2003;
- US National Library of Medicine TOXNET database (http://toxnet.nlm.nih.gov/);

[6] R&D Publication CLR9, Contaminants in Soil: Collation of Toxicological Data and Intake Values for Humans, Defra/EA, 2002.

- US Department of Energy Risk Assessment Information System (http://risk.lsd.ornl.gov/);
- Physical-chemical Properties and Environmental Fate Handbook, CD-ROM, Mackay D., W.Y Shiu, K.C Ma, Chapman & Hall, 2000.

E3.3 Selection of Health Criteria Values

Where able to do so, URS has used relevant toxicological advice published as part of the TOX series of reports by Defra and the Environment Agency for this risk assessment. In the absence of any TOX report, URS has reviewed guidance published by other authoritative bodies in line with R&D CLR9, but at this stage without expert toxicological judgement. These "indicative health criteria" should be considered to be provisional and although reasonable effort has been made to comply with the requirements of R&D Publication CLR9, no guarantee can be provided that these values will be consistent with future publications under the TOX series of reports. The toxicological data sources reviewed for this study are given in Table E3. Toxicological values for the contaminants evaluated in this assessment are detailed in Table E4.

E3.4 Exposure Model Development

Central to the development of land-use specific conceptual exposure models (CEMs) is data contained within CLR10, which consolidates available data on UK exposure for standard land-uses[7]. Exposure parameters in CLR10 have been subsequently updated with information contained in three briefing notes published by the Environment Agency:

- CLEA Briefing Note 1: Update on the Dermal Exposure Pathway (CLEA BN1);
- CLEA Briefing Note 2: Update on Estimating Vapour Intrusion Into Buildings (CLEA BN2); and
- CLEA Briefing Note 3: Update on Supporting Values and Assumptions Describing UK Building Stock (CLEA BN3).

However, as no buildings exist within Plot A the guidance provided in BN2 and BN3 have not been used as part of this assessment.

It is noted that guidance regarding standard exposures for a public open space scenario have not been published. URS has therefore adopted a modified residential without plant uptake scenario, which is considered the most sensitive with regard to both critical receptor and exposure scenarios, for this assessment.

[7] Residential with gardens, residential without gardens, allotments and commercial/ Industrial.

E3.4.1 Exposure Assumptions

The model was run for three exposure scenarios;

- Public open space, shallow soils (0-1m);
- Public open space, deeper soils (>1m, unsaturated zone); and
- Public open space, groundwater.

A public open space is considered to be entirely outdoors with no possibility of the consumption of fruit or vegetables grown at the site. It is possible that wild produce (blackberries etc) may grow on site and be eaten by visitors, however it is considered that exposure via this method is unlikely to be significant. It is assumed that visitors to the site will not excavate the ground nor directly contact perched or shallow groundwater.

Much the same activity could be expected of a 0-6 year old female child (the residential critical receptor) outside in a residential garden as outside in a public space. The exposure parameters are therefore identical to those used for modelling of standard residential land-use with the following exclusions:

Shallow Soils:

- all indoor pathways not considered; and
- consumption of site grown vegetables are not considered.

Deeper Soils and Groundwater:

- Only outdoor vapour pathways considered.

The exposure scenarios for a public open space end use are highly variable, making the selection of modelling parameters subjective, principally because of the diverse exposure scenarios possible. In recognition of this, URS considers that currently it is appropriate to use a modified residential exposure scenario to account for a generic assessment of recreational exposure. This is accepted on the basis that these assumptions are likely to be potentially very health protective, since lower exposure frequencies for an open space use are considered more likely compared with a residential setting. The use of the 0-6 year old female child outdoors as the critical receptor, with the same characteristics as when in a residential garden environment is considered appropriate and suitably conservative.

The following assumptions have been used in modelling exposure:

- critical receptor is a female child;
- the duration of exposure covers the first six years of life;

- the mean body weight for 0-6 year old females in the UK is 14.5 kg;
- the mean body height for 0-6 year old females in the UK is 93 cm;
- for vapour and dust inhalation, the exposure frequency is a maximum 365 days per year, of which on average, 8% is spend outdoors;
- for soil and dust ingestion, the time weighted average exposure frequency is 334 days per year for 0-6 year old females in the UK;
- for dermal contact, the time weighted average exposure to dust is 119 days per year;
- the time weighted average breathing rate outdoors, accounting for passive and active breathing rates and durations, is 0.43 m^3/hour for 0-6 year old females in the UK;
- the soil and dust ingestion rate is 215mg/day for 0-6 year old females in the UK, representing the 75th percentile;
- the 95th percentile of the exposed skin area when outdoors, for the mean total skin area of 0-6 year old females in the UK is 1,076 cm^2;
- skin adherence for soil is 1 mg/m^3, and dust adherence 0.06 mg/m^3 based on a reasonable worst-case proposed by US EPA in 1992, and 2001 respectively.

E3.4.2 General Assumptions

Table E5 details the parameter values used to define the soil, dust and outdoor air fate and transport models used to calculate the exposure point PCOC concentrations.

E3.4.3 Bioaccessibility

A key assumption made in the CLEA methodology is that exposure to a chemical from soil is the same as exposure to a chemical in the form used in relevant toxicological studies, usually food or water for oral studies, and vapour for inhalation studies. The CLEA model essentially estimates intake, which is the amount of chemical entering the body at the point of entry. It takes no account of the bioavailability of a chemical in soil and therefore may over predict exposure compared to the data on which the toxicological studies are based.

Bioaccessibility of a contaminant, which is its effective solubility in conditions that simulate ingestion and digestion can be used to evaluate the relative bioavailability of contaminants in soil compared to forms in food and water.

One such bioaccessibility test that has been used for arsenic in the UK is known as the PBET (Physiologically Based Extraction Test). BGS (2002[8]) and Environment Agency (2005[9]) have evaluated its use in the UK and the reproducibility of the results. A key uncertainty in the use of the test has been the link between such lab-studies and in-vivo experimental data from humans and animals. The link for arsenic is limited and therefore PBET data must be applied with caution.

The PBET test is just one of a number of bioaccessibility tests available (BGS, 2002), and has been used for this project on the basis that it is the most widely used test currently in the UK.

The dominant exposure pathway driving the exposure in the SGV for arsenic is direct ingestion of soil.

The arsenic SGV of 20 mg/kg is based on the assumption that 100% of the arsenic ingested becomes accessible for absorption by the body (as original toxicological data for arsenic is based on groundwater). The significance of the arsenic concentrations detected at this site could be less on the basis of evidence published by the Environment Agency and BGS that suggests that arsenic in UK soils is generally significantly less bioaccessible to humans. The relative bioaccessibility of arsenic in three soil samples[10] taken from the site outside the area of Plot A have previously been tested using the Physiologically Based Extraction Test (PBET) developed by Ruby et al (1996[11]), and modified by BGS (2002), results are summarised in Table E6. The measurement of bioaccessibility is only relevant to the soil ingestion exposure routes, and therefore the site-specific assessment criteria (SSAC) for arsenic was derived with this taken into account.

E3.5 Model Choice

Subsequent to the release of CLEA2002 and accompanying CLR 7-10, and prior to the introduction of CLEA_UK, URS chose to code the published algorithms in CLR10 and accompanying CLEA Briefing Notes 1-3 into an integrated Excel™ spreadsheet model, Human7. Human7 was developed by URS in response to the need to identify a UK compatible risk tool that has the flexibility to derive generic criteria, consistent with the

[8] Measurement of the Bioaccessibility of Arsenic in UK Soils, R&D Project Report P5-062/TR1, (Environment Agency/BRE, 2002)

[9] Science Update on the Use of Bioaccessibility Testing in Risk Assessment of Land Contamination, (Environment Agency, February 2005).

[10] TP510, TP511, TP512

[11] Estimation of Lead and Arsenic Bioavailability Using a Physiologically Based Extraction Test, M.V Ruby, A. Davis, R. Schoof, S. Eberle, C.M Sellstone, Environmental Science and Technology, Volume 30, Number 2, 1996

principles of R&D Publications CLR7 – 10, and yet has the functionality to be used for detailed risk assessment. The algorithms combine contaminant fate and transport and human intake/uptake to a) estimate point of exposure concentrations (for indirect exposure pathways such as dust and vapour pathways), and b) estimate bodily intake and/or uptake of the contaminant, so that average daily exposure (ADE) can be estimated and site-specific assessment criteria (SSAC) calculated. Human7 has been calibrated against UK SGV published to date and has been internally validated. The model and its results have been accepted by UK regulators on all URS projects reviewed to date. It must be noted that Human7 is a deterministic model.

The exposure pathway models used for this assessment are summarised in Table E7.

E3.6 Site-Specific Assessment Criteria (SSAC)

Integrated site-specific assessment criteria (SSAC) have been developed for determinands that exceeded the Stage 2 criteria. The SSACs provide threshold values below which contamination is considered unlikely to be of concern for the given end-use and site conditions identified by the site investigation. Above this threshold, it is considered that there is a need for some form of further action, potentially including either further assessment and/or remedial action.

The SGV for lead (450 mg/kg) has been used as the value in the Stage 3 assessment (as the SSAC value) and is due to the fact that the health criteria value for lead is based on contaminant uptake in the body rather than bodily intake.

Defra/Environment Agency note that as free and simple cyanide has a high acute toxicity[12], short term exposure may be an important consideration when assessing the risks from soils. URS has considered it appropriate to assess the risk of exposure to cyanide in soil using an acute exposure model[13]. A value of 35mg/kg is considered protective of the identified receptor at the site from this one-off acute exposure. A value of 111mg/kg was calculated at Stage 3 to assess the potential risk based on a chronic exposure and therefore the acute value has been used at Stage 3.

For the evaluation of TPH, the maximum derived sample hazard index (HI) using the SSAC is presented.

For comparison to site data, the maximum detected concentration is compared to the appropriate SSAC as an initial “first pass” evaluation of potential risk. The results are summarised in Table E8 for soils.

[12] R&D Publication TOX 5, Contaminants in Soil: Collation of Toxicological Data and Intake Values for Humans. Inorganic Cyanide, Defra/EA, 2002

[13] Soil criteria $_{acute}$ = (Tolerable Daily Intake x body weight) / ingestion rate

In line with current guidance, mean and maximum value tests have been used to assess the soil data. The mean value test described in CLR 7 was used to determine the upper 95% percent confidence limit of the mean (US_{95}) soil value. In addition, the maximum value test was performed to determine whether elevated concentrations were considered representative of the same population of samples. For soils this has been completed separately for all shallow (<1m bgl) and deep data (>1m bgl).

Where the sample population was too small to calculate the US_{95} value, the maximum recorded concentration for the compound was used. Where values were not reported above the MDL, the MDL for that particular compound was used. The averaging area was assumed to comprise the entire area of Plot A as visitors are expected to roam over all or much of the site. The results are given in Tables E9 and E10 for shallow and deep soils respectively.

E3.7 Shallow Soils

The US_{95} soil concentrations of metals and organic determinands in shallow soils did not exceed the Stage 3 criteria. However, individual concentrations of nickel and benzo(a)pyrene were detected at concentrations exceeding SSAC in shallow soil. Neither of these determinands is considered to present potentially significant risk. Shallow soils are considered not to pose a risk to human health for the proposed end use.

E3.8 Deep Soils

The US_{95} soil concentrations of metals and organic determinands in deep soils did not exceed the Stage 3 criteria. Individual target compounds were not detected at concentrations in excess of the Stage 3 criteria. Thus, deep soils are considered not to pose a risk to human health for the proposed end use.

E4 UNCERTAINTY ANALYSIS

E4.1 Introduction

Uncertainty is inherent in quantitative human health risk assessment and in the context of this assessment, this may be derived from four sources – toxicological data, assumptions made characterising human exposure at the site, assumptions made characterising the ground conditions at the site, and the fate and transport algorithms used to predict exposure point concentrations. These issues are discussed below with the exception of toxicological criteria used which are discussed in Section 3.2. A detailed discussion of uncertainty in toxicological data is beyond the scope of this report.

E4.2 Exposure Pathways

Exposure is controlled by whether a pathway exists or not. A significant portion of the site is covered with hardstanding and it is considered that the condition of the site will remain in this state for the proposed future use. The ingestion and dermal pathways dominate the modelled exposure. The variables that have most effect on the calculated SSAC are exposure duration and frequency and the extent to which the pathways are plausible. It may therefore be assumed that complete direct contact pathways (ingestion, dermal contact and inhalation of soil derived dust) will not be plausible in those areas where hardstanding remains in place. Where hardstanding is present, only the outdoor vapour inhalation pathway is viable in assessing potential exposure. However, no risks have been identified assuming all pathways are viable, which is an overly conservative assessment.

E4.3 Exposure Characterisation

The characterisation of human exposure is based on R&D Publication CLR10 and subsequent CLEA Briefing Notes (although for this assessment only CLEA BN1). These are designed to be protective of sensitive receptors by taking into account reasonable and typical land-use patterns in the UK based on social studies and the professional judgement of policy makers to provide a conceptual exposure model (CEM) suitable for generic conditions. These generic conditions were used as the basis of the DQRA, have been justified in the text and are considered conservative assumptions. Generally however, the most sensitive parameters are body weight, exposure frequency, breathing rate and fraction of time indoors. The values used for these parameters are based on European research that focused on the UK population, and for the most sensitive critical receptor – a female child – the parameter values used are considered appropriate.

However, given the lack of guidance regarding public open space, the exposure assumptions are highly subjective and, in the case of this assessment considered potentially very health protective. It is considered that a female child 0 – 6 years of age is the most critical receptor and is exposed to a time weighted average of 119 days dermal

contact, 334 days ingestion and 365 days inhalation to the contamination at Plot A. This is based on the residential scenario, which is considered a more conservative that the proposed open space use for the site. URS has therefore undertaken a sensitivity analysis considering a less conservative time weighted average value of 92 days[14] for each of the pathways modelled. This results in a 2 – 3 fold increase of the SSAC modelled for each compound. For example, the SSAC for acenaphthene was calculated at 1,150mg/kg based on the residential exposure frequency, and was calculated at 2,860mg/kg based on the revised exposure frequency value. However, it remains a reasonably conservative assessment and puts into context who is considered the most likely receptor and what is the most likely exposure scenario at the site. For example, it is conceivable that at an adult walking a dog may be a more applicable receptor in this area and, based on the large size of the site to be opened up to the public in relation to the area of Plot A, a fraction of the exposure time assumed in the assessment may be more of a true representation for the assumed future use. It is accepted that a reasonably conservative assessment of potential risk to human health is a necessity, however this highlights the uncertainty in deriving values which are based on subjective judgement and the evaluation of acceptable potential risk.

The residential conceptual exposure model which has been used as the basis for the assessment is considered a highly health protective assumption for the proposed future use of the site. It is considered that the exposure frequency used in the sensitivity analysis is likely to be more realistic and that a two to three fold increase in the derived SSACs would represent the unacceptable level of risk. However, in the locations where tars have been identified, the detected contaminant concentrations are more than double the derived SSACs and therefore if the pathway were present, the assumptions on exposure frequency would make no practical difference to the conclusion.

E4.4 Ground and Groundwater Conditions

Uncertainty in the ground conditions is usually managed by the appropriate assessment of site-specific data. Generally, the most sensitive parameters are the soil organic carbon content, the depth and thickness of contaminated soil, and soil air permeability. In this case, some site-specific data have been used where available (e.g. TOC), resorting to published UK or US parameter values in the case of groundwater modelling where necessary.

The heterogeneity of the subsurface soils cannot be easily represented in the DQRA modelling. As such, it was necessary to select a single soil type to be representative of all shallow soils and/or deep soils. Overall, it was considered appropriate that a UK Sand type soil was adopted to represent all modelled granular soils at the site.

[14] Exposure Frequencies for a 92 day time weighted average per year based on; 0-1 year old 33 days, 1-6 year old 104 days. The subjective assumption that a 0-1 year old would receive half the exposure based on a residential scenario and an exposure of 2 days per week for children in the 1-6 year age group.

In addition, exposure to soil and groundwater contamination for the purposes of the assessment are considered independent pathways which introduces further conservatism to the assessment. Overall it s considered that whilst soil type may make a small difference to the SSACs, a sandy soil effectively being the worst case, the inherent uncertainty in the model cannot be reduced any significant amount by additional data gathering and this would not affect the conclusions of the risk assessment.

E4.5 Vapour Model

Several parameters associated with the vapour algorithm are often characterised with "default values" due to the scarcity of research into vapour flux originating from sub-surface ground contaminated with volatile contamination are important. These generic parameters are designed to be conservative regardless of site design. The uncertainties/sensitivities associated with the vapour algorithm used in this assessment, as well as other vapour algorithms, are increasingly documented[15,16,17] often with conflicting results in term of whether the algorithms and associated default parameter values over or under-estimate vapour concentrations in particular circumstances.

In addition, differences between actual and modelled vapour predictions are complicated by the following factors:

- The vapour model used assumes a finite source, however does not account for likely vapour degradation within the unsaturated zone as contaminant vapours migrate vertically from the source via diffusion. The effect of degradation would be to lower the predicted outdoor vapour concentrations;
- Any future site design is not known and cannot be quantitatively modelled and validated;
- The vapour model outputs do not take account of vapour contributions from local background and process derived vapours to outdoor air quality. Conversely, air results include not only the contribution from contaminated soil and groundwater but also local background and process-derived vapours; and

[15] Vapour Transfer of Soil Contaminants, R&D Publication P5-018/TR, Environment Agency, 2001.

Vadose Zone Natural Attenuation of Hydrocarbon Vapours, Roggemans *et al*, API Bulletin No.15, 2001.

[16] Migration of Soil Gas Vapours to Indoor Air, Johnson *et al*, API Bulletin No.16, 2002.

[17] Identification of Critical Parameters for the Johnson & Ettinger (1991) Vapour Intrusion Model, P.C Johnson, API Bulletin No. 17, 2002.

- The vapour model does not consider the impact of the presence of a mixture of contaminants on the individual contaminant effective solubility and partial vapour pressure. The presence of a mixture reduces these two parameter values and consequently has the effect of reducing the soil vapour and subsequently ambient air concentrations by restricting the equilibrium soil vapour concentrations as a function of the molar fraction.

E5 CONCLUSIONS

A Stage 2 generic assessment was completed assuming a residential without garden scenario. A number of determinands were identified that exceeded the Stage 2 screening criteria and were therefore brought forward at be assessed at Stage 3 using a detailed quantitative risk assessment.

Due to the heterogeneity of the site subsurface and variability of concentrations of potential contaminants ground conditions were conceptualised as:

- unsaturated “shallow” soils: a sandy soil to 1m bgl; and
- unsaturated “deep” soils: a sandy soil to 3.0m bgl.

Site Specific Assessment Criteria (SSAC) were produced for those compounds identified as a potential concern from Stage 2, with the exception of cyanide which was compared to an acute value. SSACs were derived using the URS Human7 model. Following the comparison of contaminant concentrations against SSAC, assessment in further detail using simple statistical mean value test in accordance with the guidance detailed in CLR7 was carried out.

The results of the Stage 3 assessment indicate that for shallow individual concentrations of nickel (1 no.) and benzo(a)pyrene (2 no.) exceeded the Stage 3 SSAC. The US95 concentrations of all target compounds at Stage 3 did not exceed the SSAC. For deep soils, individual concentrations of target compounds did not exceed the Stage 3 SSAC nor the US95 for any target compound.

Overall, it is concluded that Plot A is considered suitable for use as public open space without the requirement for further action, with the exception of addressing Health and Safety issues (such as the removal of protruding trip hazards etc).

It should be noted that the assessment of potential risks to public open space users has been based on the data made available from all investigations at the site to date and the conceptual site model developed in the course of the works which has been related specifically to the site use and conditions proposed at the time of the study. If at any point in the future a change of site use or conditions were proposed, or if the development of potential new pollutant linkages were to take place (such as intrusive/remedial works at the site mobilising deep soil contamination to ground surface) the assessment of the potential significance of exposure to contamination should be made and, if necessary, to re-assess the potential risks on the basis of a revised CSM.

Tables

Table E1 – Stage 2 Screening Criteria –Soils

Target Compound	MDL (mg/kg)	Human Health (mg/kg)	Source
1,1,1,2-Tetrachloroethane	0.001	0.344	URS GAC
1,1,1-Trichloroethane	0.001	3	cDIV
1,1,2,2-Tetrachloroethane	0.001	6.2	URS GAC
1,1,2-Trichloroethane	0.001	2	cDIV
1,1-Dichloroethane	0.001	3	cDIV
1,1-Dichloroethene	0.001	0.235	URS GAC
1,1-Dichloropropene	0.001	NV	No Criterion
1,2,3-Trichlorobenzene	0.001	8	Dutch SRC: NB based on Res with Gardens
1,2,3-Trichloropropane	0.001	0.034	US EPA Region 9 PRG
1,2,4-Trichlorobenzene	0.10	11	Dutch SRC: NB based on Res with Gardens
1,2,4-Trimethylbenzene	0.001	51.6	US EPA Region 9 PRG
1,2-Dibromo-3-Chloropropane	0.001	0.46	US EPA Region 9 PRG
1,2-Dibromoethane	0.001	0.032	US EPA Region 9 PRG
1,2-Dichlorobenzene	0.10	84	Dutch SRC: NB based on Res with Gardens
1,2-Dichloroethane	0.001	0.011	URS GAC
1,2-Dichloropropane	0.001	0.342	US EPA Region 9 PRG
1,3,5-Trimethylbenzene	0.001	21.3	US EPA Region 9 PRG
1,3-Dichlorobenzene	0.10	531	US EPA Region 9 PRG
1,3-Dichloropropane	0.001	105	US EPA Region 9 PRG
1,4-Dichlorobenzene	0.1	72	Dutch SRC: NB based on Res with Gardens
2,2-Dichloropropane	0.001	NV	No Criterion
2,4,5-Trichlorophenol	0.10	80	Dutch SRC: NB based on Res with Gardens
2,4,6-Trichlorophenol	0.10	111	Dutch SRC: NB based on Res with Gardens
2,4-Dichlorophenol	0.10	21	Dutch SRC: NB based on Res with Gardens
2,4-Dimethylphenol	0.10	1220	US EPA Region 9 PRG
2,4-Dinitrotoluene	0.10	122	US EPA Region 9 PRG
2,6-Dinitrotoluene	0.10	61.1	US EPA Region 9 PRG
2-Chloronaphthalene	0.10	11.9	Dutch SRC: NB based on Res with Gardens
2-Chlorophenol	0.10	4.70	Dutch SRC: NB based on Res with Gardens
2-Chlorotoluene	0.001	158	US EPA Region 9 PRG
2-Methylnaphthalene	0.10	1560	US EPA Region 3
2-Methylphenol	0.10	160	Dutch SRC: NB based on Res with Gardens
2-Nitroaniline	0.10	183	US EPA Region 9 PRG
2-Nitrophenol	0.10	NV	No Criterion
3-Nitroaniline	0.10	18.3	US EPA Region 9 PRG
4-Bromophenyl Phenyl Ether	0.10	NV	No Criterion
4-Chloro-3-Methylphenol	0.10	3	Dutch Indicative Intervention Value
4-Chloroaniline	0.10	244	US EPA Region 9 PRG
4-Chlorophenyl Phenyl Ether	0.10	0.1	No Criterion

4-Chlorotoluene	0.001	NV	No Criterion
4-Isopropyltoluene	0.001	NV	No Criterion
4-Methylphenol	0.10	306	US EPA Region 9 PRG
4-Nitroaniline	0.10	23.2	US EPA Region 9 PRG
4-Nitrophenol	0.10	626	US EPA Region 3
Acenaphthene	0.001	910	URS GAC
Acenaphthylene	0.001	60	URS GAC
Ammoniacal Nitrogen	5.5	NV	No Criterion
Anionic Surfactant	0.5	NV	No Criterion
Anthracene	0.001	16000	URS GAC
Arsenic	1	20	UK SGV
Azobenzene	0.10	4.42	US EPA Region 9 PRG
Barium	2	280	URS GAC
Benzene	0.001	0.034	URS GAC
Benzo(A)Anthracene	0.012	11.1	URS GAC
Benzo(A)Pyrene	0.001	1.10	URS GAC
Benzo(B)Fluoranthene	0.001	11.1	URS GAC
Benzo(G,H,I)Perylene	0.01	1600	URS GAC
Benzo(K)Fluoranthene	0.001	11.1	URS GAC
Beryllium	1	139	URS GAC
Bis(2-Chloroethoxy)Methane	0.10	NV	No Criterion
Bis(2-Chloroethyl)Ether	0.10	0.218	US EPA Region 9 PRG
Bis(2-Ethylhexyl)Phthalate	0.10	34.7	US EPA Region 9 PRG
Boron	1	16000	US EPA Region 9 PRG
Bromobenzene	0.001	27.8	US EPA Region 9 PRG
Bromochloromethane	0.001	NV	No Criterion
Bromodichloromethane	0.001	0.824	US EPA Region 9 PRG
Bromoform	0.001	61.6	US EPA Region 9 PRG
Bromomethane	0.001	3.90	US EPA Region 9 PRG
Butylbenzylphthalate	0.10	12220	US EPA Region 9 PRG
Cadmium	1	30	UK SGV
Calcium	1	NV	No Criterion
Carbazole	0.1	24.3	US EPA Region 9 PRG
Carbon Disulfide	0.001	355	US EPA Region 9 PRG
Carbon Tetrachloride	0.001	0.200	Corrected DIV
Chloride	5	NV	No Criterion
Chlorobenzene (mono)	0.001	17	Dutch SRC
Chloroethane	0.001	3.03	US EPA Region 9 PRG
Chloroform	0.001	0.6	SRC
Chloromethane	0.001	46.9	US EPA Region 9 PRG
Chromium	2	200	UK SGV
Chrysene	0.001	110	URS GAC
Cis 1,2-Dichloroethene	0.001	0.169	URS GAC
Cis 1,3-Dichloropropene	0.001	0.777	US EPA Region 9 PRG
Copper	1	8600	Dutch SRC: NB based on Res with Gardens
Dibenz(a,h)Anthracene	0.10	1.1	URS GAC
Dibenzofuran	0.10	145	US EPA Region 9 PRG

Dibromochloromethane	0.001	1.11	US EPA Region 9 PRG
Dibromomethane	0.001	66.9	US EPA Region 9 PRG
Dichlorodifluoromethane	0.001	93.9	US EPA Region 9 PRG
Dichloromethane	0.001	1.2	URS GAC
Diethylphthalate	0.10	48880	US EPA Region 9 PRG
Dimethylphthalate	0.10	100000	US EPA Region 9 PRG
Di-N-Butylphthalate	0.10	NV	No Criterion
Di-N-Octylphthalate	0.10	2440	US EPA Region 9 PRG
Ethylbenzene	0.001	16	UK SGV
Fluoranthene	0.001	110	URS GAC
Fluorene	0.001	2000	URS GAC
Fluoride Soluble	3	3670	US EPA Region 9 PRG
Hexachlorobenzene	0.10	0.4	Dutch SRC: NB based on Res with Gardens
Hexachlorobutadiene	0.10	6.24	US EPA Region 9 PRG
Hexachlorocyclopentadiene	0.10	365	US EPA Region 9 PRG
Hexachloroethane	0.10	34.7	US EPA Region 9 PRG
Indeno(1,2,3-cd)Pyrene	0.10	11.1	URS GAC
Iron	1	23500	US EPA Region 9 PRG
Isophorone	0.10	512	US EPA Region 9 PRG
Isopropylbenzene	0.001	572	US EPA Region 9 PRG
Lead	5	450	UK SGV
Magnesium	1	NV	No Criterion
MBAS/Anionic surfactant	0.2	NV	No Criterion
Mercury	0.5	15.00	UK SGV
Methyl T-Butyl Ether	0.001	38.3	URS GAC
Mineral Oils	10	NV	No Criterion
Naphthalene	0.001	6.3	URS GAC
N-Butylbenzene	0.001	240	US EPA Region 9 PRG
Nickel	2	75	UK SGV
Nitrate	1	NV	No Criterion
Nitrobenzene	0.10	19.6	US EPA Region 9 PRG
N-Nitroso-Di-N-Propylamine	0.10	0.0695	US EPA Region 9 PRG
PAH Total	10	NV	See individual PAHs
Pentachlorophenol	0.10	4.00	Dutch SRC: NB based on Res with Gardens
pH	1	NV	No Criterion
Phenanthrene	0.001	1000	URS GAC
Phenol	0.10	21900	UK SGV
Phosphate Soluble	1	NV	No Criterion
Phosphorous	1	NV	No Criterion
P-Isopropyltoluene	0.001	NV	No Criterion
Potassium	4	8	No Criterion
Propylbenzene	0.001	240	US EPA Region 3
Pyrene	0.001	1100	URS GAC
Sec-Butylbenzene	0.001	3130	US EPA Region 3
Selenium	0.5	260	UK SGV
Sodium	4	NV	No Criterion
Styrene	0.001	74	Dutch SRC: NB based on Res with Gardens

Sulphate	100	NV	No Criterion
Sulphide	50	NV	No Criterion
Sulphur	0.01	NV	No Criterion
Tert-Butylbenzene	0.001	390	US EPA Region 9 PRG
Tetrachloroethene	0.001	1	No Criterion
Toluene	0.001	3	UK SGV
Thiocyanate	1	NV	No Criterion
Total Cyanide	1	NV	No Criterion
Sum Cyanides	1	35	URS GAC
Total Organic Carbon	0.01	NV	No Criterion
Total Organic Nitrogen	1	NV	No Criterion
Total Oxidised Nitrogen As N	1	NV	No Criterion
Phenols (Monohydric)	0.01	36.7	US EPA Region 9 PRG
Total Phosphorus	1	1.56	US EPA Region 9 PRG
Trans 1,2-Dichloroethene	0.001	69.5	US EPA Region 9 PRG
Trans 1,3-Dichloropropene	0.001	0.777	US EPA Region 9 PRG
Trichloroethane	0.001	2	cDIV
Trichloroethene	0.001	0.138	URS GAC
Trichlorofluoromethane	0.001	386	US EPA Region 9 PRG
Vanadium	1	570	URS GAC
Vinyl Chloride	0.001	0.001	URS GAC
Zinc	1	14600	URS GAC
M,P-Xylene	0.001	NV	see xylenes
O-Xylene	0.001	NV	see xylenes
Sum Xylenes	0.001	7.2	URS GAC
TPH >C8-C10	10	NV	No Criterion
TPH >C10-C12	10	NV	No Criterion
TPH >C12-C16	10	NV	No Criterion
TPH >C16-C21	10	NV	No Criterion
TPH >C21-C35	10	NV	No Criterion
TPH >EC5-EC6 Aliphatic	0.01	8.10	URS GAC
TPH >EC6-EC8 Aliphatic	0.01	15.9	URS GAC
TPH >EC8-EC10 Aliphatic	0.01	3.20	URS GAC
TPH >EC10-EC12 Aliphatic	0.01	16.1	URS GAC
TPH >EC12-EC16 Aliphatic	0.10	600	URS GAC
TPH >EC16-EC21 Aliphatic	0.10	110000	URS GAC
TPH >EC21-EC35 Aliphatic	0.10	NV	No Criterion
Total Aliphatics (EC5-EC35)	0.10	NV	See individual fractions
TPH >EC6-EC7 Aromatic	0.01	13.7	URS GAC
TPH >EC7-EC8 Aromatic	0.01	14.4	URS GAC
TPH >EC8-EC10 Aromatic	0.01	5.1	URS GAC
TPH >EC10-EC12 Aromatic	0.01	27	URS GAC
TPH >EC12-EC16 Aromatic	0.10	130	URS GAC
TPH >EC16-EC21 Aromatic	0.10	1600	URS GAC
TPH >EC21-EC35 Aromatic	0.10	1700	URS GAC
Total Aromatics (EC6-EC35)	0.10	NV	See individual fractions
TPH (Sum Aliphatics&Aromatics C5-C35)	0.10	NV	See individual fractions

TPH Pro C4-C12	0.01	NV	See VOC/individual fractions
TPH-Dro	1	NV	See individual fractions
Total Hydrocarbons	10	NV	See individual fractions

Key:

NV - No value available
UK SGV - UK Soil Guideline Value
URS GAC - URS Generic Assessment Criteria
cDIV - corrected Dutch Intervention Value
Dutch SRC - Dutch Serious Risk Concentration
USEPA Region 9 PRG - United States Environment Protection Agency Region 9 Preliminary Remediation Goal
USEPA Region 3 PRG - United States Environment Protection Agency Region 3 Preliminary Remediation Goal

Note :

- Soils only screened against Human Health criteria and therefore no controlled waters criteria presented
- Values based on Residential without gardens scenario
- Acute value used to assess Cyanides
- sum of Total Cyanide and thiocyanate compared against criteria
- sum of m,p,o - xylene compared against criteria
- Phenols assessed against the value for 2,6-dimethylphenol

Table E3 – Toxicological Data Sources

Organisation	*Key Documents*
Authoritative Bodies in the UK	
Incidental ingestion of surficial soil and fugitive dust outdoors	Joint Annual Reports and COT Statements
Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment (COT)	Joint Annual Reports and COC Statements
Committee on Carcinogenicity of Chemicals in Food, Consumer Products and the Environment (COC)	Joint Annual Reports, COM Statements and COM Papers
Committee on Mutagenicity of Chemicals in Food, Consumer Products and the Environment (COM)	Reports and Statements
Committee on the Medical Effects of Air Pollutants (COMEAP)	EPAQS Substance Specific Reports
Expert Panel on Air Quality Standards (EPAQS)	Minutes of Advisory Meetings
Health and Safety Commission's Advisory Committee on Toxic Substances (ACTS)	Minutes of Advisory Meetings, Advisory Notes and Papers
Advisory Committee on Pesticides (ACP)	EH40/2002 Occupational Exposure Limits 2002 and 2003 Supplement
Health and Safety Executive	UK Drinking Water Standards
Drinking Water Inspectorate	Joint Annual Reports and COT Statements
European Commission's committees	
Scientific Committee for Toxicity, Ecotoxicity and the Environment (CSTEE)	Opinions and Meeting Minutes
European Chemicals Bureau (ECB)	Substance risk assessment reports
Scientific Committee on Food (SCF)	Opinions, Meeting Minutes and Reports (to 1997)
EU Drinking Water Standards	Council Directive 98/83/EC and supporting UK legislation
EU Working Group on Ambient Air Pollution	
International Authoritative Organisations	
World Health Organisation – Drinking Water Standards	Guidelines for Drinking Water Quality (second and third editions)
World Health Organisation – Air Quality Guidelines for Europe	Air Quality Guidelines for Europe (2nd edition)
World Health Organisation – Environmental Health Criteria (EHC)	Environmental Health Criteria Monographs
World Health Organisation – International Programme on Chemical Safety (IPCS)	Concise International Chemical Assessment Documents
World Health Organisation – Joint FAO/WHO Expert Committee on Food Additives (JECFA)	FAO Nutrition Meetings Report Series / WHO Food Additives Series
World Health Organisation – International Agency for Research on Cancer	IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans
Other National Organisations	
US EPA – Integrated Risk Information System (IRIS)	IRIS Guidance Documents (web-based)
National Institute for Public Health and the Environment (RIVM), The Netherlands	Re-evaluation of human-toxicological maximum permissible risk levels, Report 711701025, March 2001
US Agency for Toxic Substances and Disease Registry (ATSDR)	Toxicological Profile Reports

Table E4 – Toxicological Values

Compound	Oral HCV			Source	Inhalation HCV			Source
	ug.kg-1 bw.day-1	Type	MDI ug.day-1		ug.kg-1 bw.day-1	Type	MDI ug.day-1	
Acenaphthene	20	ID	-	Defra/EA		ID	-	-
Acenaphthylene	2	ID	-	Defra/EA		ID	-	-
Arsenic	0.3	ID	-	Defra/EA	0.002	ID	-	Defra/EA
Barium (20% Rule)	4	TDI	-	WHO		TDI	-	-
Benzene	0.29	ID	-	Defra/EA	0.91	ID	-	Defra/EA
Benzo(a)anthracene	0.2	ID	-	Defra/EA		ID	-	-
Benzo(a)pyrene	0.02	ID	-	Defra/EA	0.00007	ID	-	Defra/EA
Benzo(b)fluoranthene	0.2	ID	-	Defra/EA		ID	-	-
Benzo(g,h,i)perylene	30	TDI	0.063	TPHCWG		ID	-	-
Benzo(k)fluoranthene	0.2	ID	-	Defra/EA		ID	-	-
Carbazole	0.5	TDI	-	US EPA		TDI	-	-
Chrysene	2	ID	-	Defra/EA		ID	-	-
Cyanide (chronic)	12	TDI	300	Defra/EA	0.9	TDI	0.06	Defra/EA
Dibenzo[a,h]anthracene	0.02	ID	-	Defra/EA		ID	-	-
1,2-Dichloroethene (cis)	17	TDI	240	WHO		TDI	10	-
Fluoranthene	2	ID	-	Defra/EA		ID	-	-
Fluorene	40	TDI	0.588	US EPA		TDI	-	-
Indeno[1,2,3-cd]pyrene	0.2	ID	-	Defra/EA		ID	-	-
p-Isopropyltoluene	200	TDI	10	Defra/EA	74	TDI	124	Defra/EA
Mercury (inorganic)	0.3	TDI	2.5	Defra/EA	0.3	TDI	-	Defra/EA
2-Methylnaphthalene	4	TDI	-	US EPA		TDI	-	-
Naphthalene	20	TDI	7	Defra/EA	0.86	TDI	2.8	Defra/EA
Nickel (20% Rule)	1	TDI	-	Defra/EA	0.0012	TDI	-	Defra/EA
PCB (Arochlor 1254)	0.02	TDI	-	RIVM	0.3	TDI	-	RIVM
Phenanthrene	20	ID	-	Defra/EA		ID	-	-
Pyrene	20	ID	-	Defra/EA		ID	-	-
Styrene	8	TDI	-	WHO	74	TDI	-	WHO
Toluene	200	TDI	10	Defra/EA	74	TDI	124	Defra/EA
TPH (>EC5-7) aromatic	200	TDI	-	TPHCWG	114	TDI	-	TPHCWG
TPH (>EC7-8) aromatic	200	TDI	-	TPHCWG	114	TDI	-	TPHCWG
TPH (>EC8-10) aromatic	40	TDI	-	TPHCWG	57	TDI	-	TPHCWG
TPH (>EC10-12) aromatic	40	TDI	-	TPHCWG	57	TDI	-	TPHCWG
TPH (>EC12-16) aromatic	40	TDI	-	TPHCWG	57	TDI	-	TPHCWG
TPH (>EC16-21) aromatic	30	TDI	-	TPHCWG		TDI	-	-
TPH (>EC21-35) aromatic	30	TDI	-	TPHCWG		TDI	-	-
TPH (>EC5-6) aliphatic	5000	TDI	-	TPHCWG	5257	TDI	-	TPHCWG
TPH (>EC6-8) aliphatic	5000	TDI	-	TPHCWG	5257	TDI	-	TPHCWG
TPH (>EC8-10) aliphatic	100	TDI	-	TPHCWG	286	TDI	-	TPHCWG
TPH (>EC10-12) aliphatic	100	TDI	-	TPHCWG	286	TDI	-	TPHCWG
TPH (>EC12-16) aliphatic	100	TDI	-	TPHCWG	286	TDI	-	TPHCWG
TPH (>EC16-21) aliphatic	2000	TDI	-	TPHCWG		TDI	-	-
Trichloroethene (TCE)	5.2	ID	-	Defra/EA	5.2	ID	-	Defra/EA
1,2,4-Trimethylbenzene	50	TDI	-	RAIS	1.7	TDI	-	RAIS
1,3,5-Trimethylbenzene	50	TDI	-	RAIS	1.7	TDI	-	RAIS
Vinyl Chloride	0.014	ID	-	Defra/EA	0.3	ID	-	Defra/EA
o-Xylene	179	TDI	20	Defra/EA	63	TDI	112	Defra/EA
m-Xylene	179	TDI	20	Defra/EA	63	TDI	112	Defra/EA
p-Xylene	179	TDI	20	Defra/EA	63	TDI	112	Defra/EA

Notes:
- indicates that no data was available from this source for this compound
ID: Index Dose
TDI: Tolerable Daily Intake
MDI: Mean Daily Intake (background)

Table E5 - General Parameter Assumptions

Parameter	*Units*	*Value*	*Justification*
Outdoor Box Model			
Height of box (0-6 yr old female receptor)	m	0.47	Equal to half the mean body height for the critical receptor, as advised in CLR10.
Length of box	m	15	Length of box the Johnson and Ettinger/ ASTM outdoor air model calibrated to and presented in CLR10. Site specific (and larger) values are considered overly conservative
Wind speed (vapours)	ms^{-1}	3	Value recommended in CLR10
Dust Parameters			
Normalised annual average concentration of dust	$kg.m^3$ per $g/m^2/s$	0.011	Value recommended in CLR10
Flux of respirable particles	$g/m^2/s$	0.00001	Value recommended in CLR10
Fraction of site with building or vegetative cover	-	0.8	Value recommended in CLR10 (based on commercial/industrial)
Equivalent threshold value of wind speed at 7 m agl	m/s	11.32	Value recommended in CLR10
Wind speed distribution function	-	0.194	Value recommended in CLR10
Annual average PM10 concentration	mg/m^3	3.04E-4	Calculated value using formula in CLR10
Fraction of outdoor dust originating from soil	%	100	Value recommended in CLR10
Unsaturated Zone – Shallow soil – CLR10 "Sandy"			
Soil type	-	(CLR10) Sandy	An approximation of the varied granular nature of made ground on site to depths of up to 3.2m.bgl (TP677). Properties akin to published values for UK Sandy soil assumed applicable.
Total porosity	-	0.46	Published value for soil type
Air content	-	0.31	Published value for soil type
Water content	-	0.15	Published value for soil type
Soil bulk density	gcm^{-3}	1.6	Published value for soil type
Fraction of organic carbon	-	0.007	One sample from Made Ground (WS114a)
Effective air permeability	cm^2	7.20E-8	Calculated value for soil type
Dust/soil enrichment factor	-	6	Value recommended in CLR10 for soil type
Unsaturated Zone – Deeper soil – CLR10 "Sandy"			
Soil type	-	(CLR10) Sandy	An approximation of the varied granular nature of made ground on site to depths of up to 3.2m.bgl (TP677). Properties akin to published values for UK Sandy soil assumed applicable.
Total porosity	-	0.46	Published value for soil type
Air content	-	0.31	Published value for soil type
Water content	-	0.15	Published value for soil type
Soil bulk density	gcm^{-3}	1.6	Published value for soil type
Fraction of organic carbon	-	0.007	One sample from Made Ground (WS114a)

Parameter	*Units*	*Value*	*Justification*
Soil & Groundwater parameters			
Depth to groundwater (derivation of soil SSAC)	m	3.0	Groundwater observations and monitoring dips indicate shallow groundwater at the site. Risks from soil are maximised assuming a greater unsaturated thickness hence the reasonably conservative water level of 3.0m.bgl was adopted (Section **Error! Reference source not found.**).
Depth to groundwater (derivation of groundwater SSAC)	m	1.5	Potential risks from groundwater sources are maximised assuming a shallower water table and therefore smaller exposure pathway length. The geometric mean of water levels obtained in 2006 has been adopted (Section **Error! Reference source not found.**).
Depth to shallow soil sources	m	0.5	Allowance made for a nominal diffusive path length of 50 cm below ground surface. CLR guidance suggests 100cm, 50cm is more conservative and considered more representative
Unsaturated soil thickness (derivation of soil SSAC)	m	3.0	Contaminated soils assumed to be present throughout the unsaturated zone and are therefore limited by the modelled depth to groundwater.

Table E6 – PBET Results

Substance	*Bioaccessibility (%)*			
	TP510	*TP511*	*TP512*	*Average*
Arsenic	21.7	13.3	<10.2*	*15.0*

*Value conservatively assumed = 10.2 for calculation of average

Table E7 – Model Choice

Exposure Pathway	*Modelling approach*	*Reference*	*Justification*
Soil and dust ingestion	Direct contact pathway. No fate & transport modelling necessary	CLR10	Preferred UK Regulatory approach
Dermal contact	Direct contact pathway. No fate & transport modelling necessary. Approach uses the concept of compound specific dermal absorption factors to estimate intake from soil adhered to skin surface	CLEA Briefing Note 1 & US EPA 2001	Updated approach to that referenced in CLR 10 (US EPA 1992), and included in an anticipated revision to the CLEA 2002 model, as detailed in CLEA Briefing Note 1.
Dust inhalation	US EPA 1996	CLR10	Preferred UK Regulatory approach
Outdoor air vapour inhalation	ASTM 2000 algorithm used to estimate exposure concentration in ambient air based on vapour diffusion through soil and mixing in an ambient air box model.	CLR10, ASTM E 2081-00	Preferred UK Regulatory approach

Table E8– Stage 3 Soil SSAC – Public Open Space Receptors

Compound	Unsaturated Soils			
	SSAC shallow 0-1m (mg/kg)	SSAC deep 1-3m (mg/kg)	No. Shallow Soil Exceedances	No. Deep Soil Exceedances
Arsenic	104	no path	0	0
Benzo(a)pyrene	1.14	>vap sat	2	0
Dibenz(a,h)anthracene	1.15	>vap sat	0	0
1-methylnaphthalene	NV	>vap sat	0	0
Naphthalene	1130	2570	0	0
Nickel	75	no path	1	0
Trichloroethene	148	353	0	0
Total Petroleum Hydrocarbons				
TPH *Additive – Hazard Index*	1.0*	1.0*	0	0

Notes:
> vap sat : SSAC value derived at a concentration greater than the concentration at which vapour saturation is reached
NV : no value derived due to no exceedances in this horizon
-*based on Hazard Index values exceeding unity (>1).
- SGV used for assessment of Nickel

Table E9 - Stage 3 Shallow Soils US95

Target Compound	Stage 3 criteria	US95	Number of Samples Exceeding Stage 3 Shallow Soil Criterion	US95>Stage 3 Criterion
Arsenic	104	37	0	No
Benzo(a)pyrene	1.15	0.499	2	No
Dibenz(a,h)anthracene	1.15	0.29	0	No
1-Methylnaphthalene	n/a	n/a	n/a	
Naphthalene	1130	1.37	0	No
Nickel	75	45	1	No
Trichloroethene	148	0.001	0	No

Table E10 – Stage 3 Deeper Soils US95

Target Compound	Stage 3 criteria	US95	Number of Samples Exceeding Stage 3 Shallow Soil Criterion	US95>Stage 3 Criterion
Arsenic	n/a	21.09	0	No
Benzo(a)pyrene	>vap	0.45	0	No
Dibenz(a,h)anthracene	>vap	0.49	0	No
1-Methylnaphthalene	>vap	9.07	0	No
Naphthalene	2570	8.38	0	No
Nickel	no path	67.53	0	No path
Trichloroethene	353	0.62	0	No