SINCLAIR KNIGHT MERZ
SKM ENVIROS

Camberwell Old Cemetery, Southwark, London

SOIL DATA ASSESSMENT AND HUMAN HEALTH RISK ASSESSMENT FOR BENZO(A)PYRENE

- Draft V2
- September 2011

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SKM Enviros
Victoria House
Southampton Row
London
WC1B 4EA
Tel: +44 20 7759 2600
Fax: +44 20 7759 2601
Web: www.skmenviros.com

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Executive Summary

SKM Enviros was commissioned by Southwark Council in August 2011 to reassess the existing laboratory data available for an area of placed material at Camberwell Old Cemetery (the site) in line with current guidance and through detailed quantitative risk assessment (DQRA) formulate site specific assessment criteria (SSAC) for benzo(a)pyrene in soil. The results of the DQRA have been compared to soil concentrations to determine whether the material is suitable for use at the cemetery site.

Scope of works	▪ Reassessment of chemical laboratory data previously obtained by SKM Enviros ▪ Development of conceptual model ▪ Production of DQRA assessment for benzo(a)pyrene
Ground conditions	The placed material, hereafter referred to as made ground, generally comprised a brown sandy clay with frequent gravels of flint and chalk, brick fragments, ash, concrete and occasional wood. The Made Ground was present at a thickness ranging from 0.7m in the most southern area, to 5m towards the north. Black sandy clay was identified around TP101 and WS101 (located adjacent to each other) at a depth of 1.5-2.0m bgl. The material comprised plastic, wood, metal, concrete, brick, wire and paper and a degrading waste odour was observed in both locations. The natural in-situ strata was present under the Made Ground and generally comprised a light brown/orange to grey soft clay. The natural strata appeared to slope down from the entrance to the placed material at the southern point to the edges of the mound in the northern most point.
Data Assessment	The results of the data assessment indentified concentrations of PAHs, TPH, lead and cyanide within the soils at the site above the residential without plant uptake screening value. Further statistical analysis calculated the UCL95 for lead at the site at 252mg/kg which is below the relevant general assessment criteria (GAC) of 450mg/kg. Previous assessment of the PAH data had identified a distinction between the more elevated concentrations located in the east of the site. Based on this information the data was split into two soil types (impacted made ground and remaining made ground) and considered separately. Statistical analysis calculated a UCL95 for benzo(a)pyrene of 202mg/kg within the impacted made ground and 3.4mg/kg within the remaining soils Five samples all located within the impacted made ground reported concentrations of TPH above the calculated GACs.
Detailed Quantitative Risk Assessment	Potential end use sensitive receptors are grave diggers and site visitors. The DQRA has resulted in the following criteria for benzo(a)pyrene: ▪ SSAC for the grave diggers is 25.6mg/kg (range of 17.7 – 71.7mg/kg) ▪ SSAC for the site visitors is 18.6mg/kg (range of 9.1- 20.1mg/kg)
Risk Assessment	Comparison of benzo(a)pyrene concentrations and the SSAC for both sensitive end users indicate the following: ▪ The impacted made ground has a concentration above both SSACs and is considered to present a risk to end users ▪ The remaining made ground has a concentration below the SSAC and so does not pose a significant risk to end users.

1. Introduction

SKM Enviros was commissioned by Southwark Council in August 2011 to reassess the existing laboratory data available for an area of placed material at Camberwell Old Cemetery (the site) in line with current guidance and through detailed quantitative risk assessment (DQRA) formulate site specific assessment criteria (SSAC) for benzo(a)pyrene in soil. The results of the DQRA have been compared to soil concentrations to determine whether the material is suitable for use at the cemetery site.

1.1. Background

SKM Enviros (formerly Enviros Consulting) have previously undertaken intrusive site investigation works at Camberwell Old Cemetery at the site of placed material. The placed material is located in the north of the site off one of the main routes through the cemetery. The initial ground investigation undertaken in 2008 comprised 9 trial pits and 10 window sample holes. Further investigation was undertaken in 2009 which comprised the advancement of a further 18 window sample boreholes.

A total of eighty two samples were scheduled for chemical analysis as part of the SKM Enviros investigations. The laboratory analysis reported the presence of localised significantly elevated concentrations of PAHs, TPHs and cyanide and widespread slightly elevated concentrations of benzo(a)pyrene. The risk assessment reported a high risk to grave diggers and a moderate risk to future site visitors from direct contact with impacted soils. Recommendations for remedial works were provided.

The report recommended for a DQRA to be undertaken in order to assess whether the widespread slightly elevated PAHs are at concentrations which pose a risk to future site users.

1.2. Objectives

The overall objective of the work is to provide a further assessment of land quality to support Southwark Council in their decision as to whether the placed material is suitable for use within the cemetery. The specific objectives of the work would be to:

- Undertake a generic risk assessment on all previous soil data;
- Develop a site conceptual model in conjunction with Southwark Council and their cemetery managers;
- Complete a DQRA and generate site specific assessment criteria for PAHs to enable an assessment of risk to receptors;

1.3. Scope of Works

This study comprised the reassessment of chemical laboratory data obtained by SKM Enviros during the site investigations undertaken in 2008 and 2009 (Refs 1 & 2) in line with current guidance, including revisions to the CLEA model and undertaking of revised statistical analysis.

This report defines the conceptual site model (CSM) and sets out and justifies the parameters used within the DQRA for benzo(a)pyrene. The resultant site and substance threshold for PAHs is then compared with the site data obtained from the previous and current investigation. The UK CLEA Model v1.06 has been used for the assessment as this is readily modified to complete the assessment and is compliant with UK regulatory policy.

At this stage, assessment for any other contaminants of concern that have been identified through the data assessment is out of the scope of these works.

1.4. Framework for Contaminated Land Assessment

Contaminated land risk assessment is based on development of a conceptual model for the site. This model is a representation of the relationship between contaminant sources, pathways and receptors developed on the basis of hazard identification. Risk assessment is the process of collating known information on a hazard or set of hazards in order to estimate actual or potential risks to receptors. The guiding principle behind this approach is an attempt to establish connecting links between a hazardous source, via an exposure pathway to a potential receptor, referred to as a ‘pollutant linkage’. If there is no pollutant linkage, then there is no risk. Therefore, only where a viable pollutant linkage is established does this assessment go on to consider the level of risk.

This approach is in accordance with the Department of the Environment Transport and the Regions (DETR) Statutory Guidance on Contaminated Land (Ref. 3) and the Department for Environment, Food & Rural Affairs (DEFRA)/ Environment Agency (EA) Model Procedures (CLR11, Ref. 4). The risk assessment undertaken in this document comprises ‘detailed quantitative risk assessment’ as defined in CLR11.

1.5. Report Structure

This report provides a summary of the site profile from the intrusive investigations (Ref. 1 & 2) in Section 2 and an assessment of the available laboratory data using current guidance within Section 3. The Conceptual Site Model is detailed in Section 4, which sets out and justifies the parameters used, the site specific assessment criteria are derived in Section 5 and compared with the site criteria. Our conclusions are presented in Section 6.

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2. Site Description

2.1. Site Use

The placed material is located in the north of Camberwell Old Cemetery and is accessed off one of the main road routes through the cemetery. A site location plan is presented as Figure 1. The placed material is located close to residential properties on Ryedale. The following land uses border the cemetery:

- North – Ryedale road, with residential properties and Peckham Rye Park beyond;
- East – Underhill Road with residential properties beyond;
- West – Forest Hill Road and Woodvale road with Camberwell New Cemetery and railway line beyond; and
- South – residential properties.

The placed material is level with the ground level of the main cemetery and forms a plateau extending northwards as adjacent ground levels drop. The placed material is thicker further away from the access road at the northern end of the mound and shallower at the southern end. The material is un-surfaced and has vegetation cover present across the majority of the site. Visible brick is present on the surface of the mound.

2.2. Site Profile

Information collected for the site as part of the previous intrusive investigation undertaken by SKM in 2008 and 2009 (Ref. 1 & 2) is summarised below. These investigations comprised the excavation of nine trial pits (TP101-TP109) and drilling of ten window sample boreholes (WS101-WS110) during the 2008 investigation and the drilling of 18 window sample holes (EWS1-EWS18) during the 2009 investigation. An exploratory location plan is presented as Figure 2.

- **Table 1 - Summary of Site profile**

Site Sensitivity	▪ Groundwater – a Low sensitivity was derived (the closest BGS borehole log indicates the aquifer to be protected by approximately 12m of London Clay. Site not located within Groundwater Protection Zone). ▪ Surface Water - a Low sensitivity was derived (no watercourses located within 500m of the site. Little potential for baseflow). ▪ Ecology - a Very Low sensitivity was derived (no ecological sensitive areas have been identified within 1km of the site).
Ground Conditions	The placed material, hereafter referred to as made ground, generally comprised a brown sandy clay with frequent gravels of flint and chalk, brick fragments, ash, concrete and occasional wood. The Made Ground was present at a thickness ranging from 0.7m in the most southern area, to 5m towards the north. Black sandy clay was identified around TP101 and WS101 (located adjacent to each other) at a depth of 1.5-2.0m bgl. The material comprised plastic, wood, metal, concrete, brick, wire and paper and a degrading waste odour was observed in both locations.

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	The natural in-situ strata was present under the Made Ground and generally comprised a light brown/orange to grey soft clay. The natural strata appeared to slope down from the entrance to the placed material at the southern point to the edges of the mound in the northern most point.
Soil Laboratory Analysis	In the Made Ground, the maximum concentrations of inorganic contaminants were all below SGVs for residential end use without plant uptake with the exception of one sample which contained elevated cyanide and two samples which contained elevated lead Asbestos was identified in one of forty samples. The asbestos was identified in WS104 0.7m depth and was identified as white asbestos fibres. Maximum concentrations of a number of PAHs in the Made Ground, exceeded relevant screening values. Two samples of TPH also exceeded the mixture specific thresholds. There were no exceedences of guidelines for inorganic or organic contaminants in the two samples of natural material.

2.3. Generic Qualitative Risk Assessment

A qualitative risk assessment was undertaken (Ref. 2) which considers the likelihood that any of the identified contaminants will pose a risk to human health or the environment. The sources identified are; made ground across the site with widespread elevated concentrations of PAHs and very localised lead, cyanide and TPH and a single occurrence of asbestos fibres. The conceptual model did not consider controlled waters as a receptor due to the presence of a non-aquifer beneath the site and the lack of surface water bodies within 500m. The risk assessment is summarised as follows:

- **Table 2 - Summary of Qualitative Risk Assessment**

Site Use Scenario		Hazard
		Made Ground (PAH, TPH, Lead and Cyanide)
Human Health	Current Use (fenced off land within cemetery)	Moderate / Low Risk
	Future use (Site workers and visitors associated with use as a cemetery)	Moderate Risk
Site Use Scenario		**Hazard**
		Made Ground (asbestos)
Human Health	Current Use (fenced off land within cemetery)	Low Risk [maintaining current level of vegetation]
	Future use (Site workers and visitors associated with use as a cemetery)	Moderate Risk

This report further assesses the risks to site visitors and workers associated with the identified contaminants of concern (PAHs, TPH, lead, cyanide and asbestos) in the soil and use of the land as a cemetery.

3. Generic Data Assessment

The results of the laboratory analysis from both investigations have been combined and statistical assessment has been undertaken on the data to further assess the concentrations measured on site and to compare them with current guidelines. Copies of the laboratory analysis results are presented within Appendix A.

3.1. Derivation of Soil Screening Thresholds Protective of Health

The data has been assessed against SKM Enviros' Generic Assessment Criteria (GACs) these are equivalent to Soil Guideline Values (SGVs). Where available and relevant SGVs published by the Environment Agency have been adopted in GACs. SGVs are available for a limited number of contaminants and where published they apply to a limited range of land uses and soil organic matter (SOM) content. For contaminants with no SGV, and selected SOM content and land uses not covered by the SGV reports, GACs have been calculated using the current version of the Environment Agency CLEA model (version 1.06).

A detailed description of the methodology used to derive SKM Enviros' GACs is provided in Appendix B, together with model output and references.

3.1.1. GACs for Site

It is proposed for the existing cemetery (Camberwell Old) to expand into the area occupied by the placed material. A land use screening scenario of residential use without plant uptake (the closest GAC available for the proposed land use albeit likely to be conservative) has been used as an initial screening value.

3.1.1. Statistical Assessment of Data

An initial screen of the data set is undertaken comparing the results with the relevant SGVs or GACs. If this assessment identifies any exceedances then statistical analysis in line with the CL:AIRE guidance (Ref 19) is undertaken. This calculates a UCL95 for the data set which is compared to the screening value.

3.1.2. Division of Data

The heavy metals and PAHs are relatively immobile and likely to derive from soil components (for instance from ash and clinker in the made ground). The concentrations of these substances are thus likely to vary with the soil type present. Given this the data has initially been divided into made ground and natural ground to assess whether any heavy metal or inorganic contaminants are present at concentrations above the screening thresholds in either strata. Where contaminants have been identified at concentrations above screening thresholds then further consideration has been given to whether the data should be divided further.

3.1. Results of Inorganic Analysis

3.1.1. Inorganics in Made Ground

- **Table 3 - Results of inorganic analysis in made ground**

Determinand	Analyses	GAC (Exceeded)	Minimum	Maximum
Arsenic	80	35 (0)	<3	19
Cadmium	80	12 (0)	<0.2	0.8
Chromium	80	3012 (0)	6.7	50
Copper	80	6203 (0)	<6	140
Lead	80	450 **(6)**	14	890
Mercury	80	11 (0)	<0.4	5.7
Nickel	80	130 (0)	5.6	51
pH	80	-	7.48	8.88
Selenium	80	5.95(0)	<3	<3
Total Cyanide	80	17 **(1)**	<1	27
Zinc	80	40432 (0)	25	480
Vanadium	80	188	13	99

*All results in mg/kg

The results of the soil analysis for inorganic contaminants within the made ground showed concentrations of all contaminants to be below the relevant screening values with the exception of lead which reported six samples at concentrations above the relevant screening value and cyanide which reported one sample with concentrations above the relevant screening value. Further assessment of the elevated lead concentrations is presented within section 3.5.

3.1.1. Inorganics in Natural Ground

- **Table 4 - Results of inorganic analysis in natural ground**

Determinand	Analyses	GAC (Exceeded)	Minimum	Maximum
Arsenic	2	35 (0)	6	8
Cadmium	2	12 (0)	0.3	0.4
Chromium	2	3012 (0)	51	51
Copper	2	6203 (0)	32	35
Lead	2	450 (0)	46	97
Mercury	2	11 (0)	<0.4	0.4
Nickel	2	130 (0)	43	47
pH	2	-	7.92	8.01

Determinand	Analyses	GAC (Exceeded)	Minimum	Maximum
Selenium	2	5.95(0)	<3	<3
Total Cyanide	2	17 (0)	<1	<1
Zinc	2	40432 (0)	120	170
Vanadium	2	188	89	92

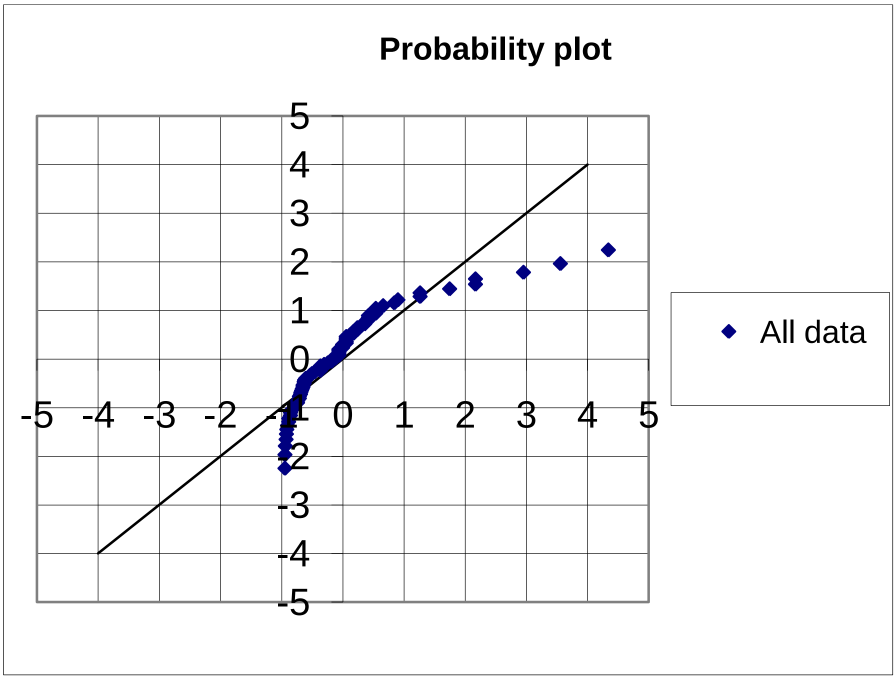
*All results in mg/kg

The results of the soil analysis for inorganic contaminants within the natural soils showed concentrations of all contaminants to be below the relevant screening values.

3.2. Further Assessment of Lead

The laboratory results identified the presence of elevated concentrations of lead within six samples across the site. To understand the probability and likelihood of potential receptors coming into contact with lead, the data set must be analysed statistically.

The statistical approach is consistent with guidance by CLAIRE (Ref. 19) and is outlined in more detail in Appendix C. Analysis using the Shapiro-Wilks test indicates that the lead data is not normally distributed, therefore use of the Chebyshev 95% Upper Confidence Limit is appropriate to describe this data. This is confirmed by the probability plot below.



The Chebyshev UCL95 for lead in the made ground samples is 252 mg/kg, which is significantly below the GAC for residential land use without plant uptake of 450mg/kg.

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3.3. Further Assessment of Cyanide

The results of the assessment identified marginally elevated concentrations of total cyanide within one sample. Cyanide presents an acute risk and therefore one elevated location may have a significant impact on the receptors. However no free cyanide analysis was completed as part of the previous investigation and therefore no further assessment can be undertaken at this stage.

3.4. Asbestos

In total, forty samples were analysed for asbestos. Asbestos fibres were identified by the laboratory in one sample and this was from WS104 at 0.7m. The report indicated the fibres were chrysotile (white) asbestos. This sample was from an area not physically distinct from other Made Ground in the north of the placed material.

3.5. Results of PAH Analysis

3.5.1. Made ground

- **Table 5 - Result of PAH analysis of made ground**

Determinand	Analyses	GAC (Exceeded)	Minimum	Maximum
Benzo(a)anthracene	80	7.6 **(6)**	<0.014	330
Benzo(a)pyrene	80	1 **(49)**	<0.015	300
Benzo(b)fluoranthene	80	10.2 **(12)**	<0.015	330
Benzo(k)fluoranthene	80	10.3 **(8)**	<0.014	170
Chrysene	80	9.7 **(10)**	<0.010	300
Dibenzo(ah)anthracene	80	1 **(16)**	<0.009	54
Indeno(123cd)pyrene	80	10.1 **(8)**	<0.018	170
Naphthalene	80	3.9 **(6)**	<0.009	490

*All results in mg/kg

The laboratory analysis for PAHs within the made ground reported concentrations of (Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenzo(ah)anthracene and Indeno(123cd)pyrene) above the initial screening criteria. Further assessment of PAHs is undertaken in Section 3.5.

3.5.2. Natural Ground

- **Table 6 - Result of PAH analysis of natural ground**

Determinand	Analyses	GAC (Exceeded)	Minimum	Maximum
Benzo(a)anthracene	2	7.6 (0)	0.45	3
Benzo(a)pyrene	2	1 **(1)**	0.47	4
Benzo(b)fluoranthene	2	10.2 (0)	0.65	4.4

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Determinand	Analyses	GAC (Exceeded)	Minimum	Maximum
Benzo(k)fluoranthene	2	10.3 (0)	0.29	2.8
Chrysene	2	9.7 (0)	0.46	3.2
Dibenzo(ah)anthracene	2	1 (0)	0.086	1
Indeno(123cd)pyrene	2	10.1 (0)	0.28	3
Naphthalene	2	3.9 (0)	0.34	0.39

The laboratory analysis for PAHs within the natural ground reported concentrations of benzo(a)pyrene above the relevant screening criteria within one sample. The borehole logs do not indicate any potential source of PAH contamination within this sample and this elevated concentration it is thought likely to have been caused by cross contamination from the above made ground and therefore it may be more appropriate to include this sample within the remaining made ground data set.

3.6. Further Assessment of PAHs

The chemical analyses results presented above indicate widespread elevated concentrations of PAHs in the made ground, and in particular benzo(a)pyrene.

3.6.1. Division of data of Made Ground

As the material has been placed on site over a period of time there may be physically distinct materials deriving from specific loads brought onto site from different sources (e.g. material containing metals and PAHs associated with ash or metals in construction rubble). This may lead to localised areas of contamination related to specific loads placed on the site or areas where physically distinct material has been spread.

Further assessment of the PAH data within the 2009 report (Ref 2) indicated that the more elevated benzo(a)pyrene concentrations were clustered in the east of the site in TP101, EWS1, EWS2 and TP109 and also in the centre of the site at TP108 and EWS5. Due to the paucity of data in between these locations it is unclear if these are linked.

Data from these locations appears to be different to other material found at the site (referred to as impacted material) and within this assessment the data has therefore been reconsidered with these samples and adjacent elevated samples separated from the remainder of the made ground.

- **Table 7 - Result of PAH analysis of Impacted Made Ground**

Determinand	Analyses	GAC (Exceeded)	Minimum	Maximum
Benzo(a)anthracene	9	7.6 **(9)**	14	330
Benzo(a)pyrene	9	1 **(9)**	14	300

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Determinand	Analyses	GAC (Exceeded)	Minimum	Maximum
Benzo(b)fluoranthene	9	10.2 **(9)**	11	330
Benzo(k)fluoranthene	9	10.3 **(8)**	7	170
Chrysene	9	9.7 **(9)**	14	300
Dibenzo(ah)anthracene	9	1 **(9)**	1.9	54
Indeno(123cd)pyrene	9	10.1 **(8)**	7.1	170
Naphthalene	9	3.9 **(7)**	0.56	490

The results show that all or most of the concentrations of PAHs exceeded the GAC within the samples from the impacted areas.

- **Table 8 - Result of PAH analysis of remaining made ground**

Determinand	Analyses	GAC (Exceeded)	Minimum	Maximum
Benzo(a)anthracene	72	7.6 **(2)**	<0.014	14
Benzo(a)pyrene	72	1 **(41)**	<0.015	12
Benzo(b)fluoranthene	72	10.2 **(3)**	<0.015	15
Benzo(k)fluoranthene	72	10.3 **(8)**	<0.014	6.3
Chrysene	72	9.7 **(10)**	<0.010	11
Dibenzo(ah)anthracene	72	1 **(16)**	<0.009	2.1
Indeno(123cd)pyrene	72	10.1 **(8)**	<0.018	7
Naphthalene	72	3.9 **(6)**	<0.009	6.5

For the remaining made ground most of the PAHs reported less than 20% of the samples with concentrations above the GACs. This is with the exception of benzo(a)pyrene which reported concentrations above the GACs within 40 out of the 71 samples analysed.

3.6.2. Statistical Assessment

To understand the probability and likelihood of potential receptors coming into contact with the PAH contaminants the data set must be analysed statistically.

Rather than individually assessing all the PAHs where concentrations above the GAC were recorded, benzo(a)pyrene has been used to represent the PAHs. In order to justify the detailed assessment of benzo(a)pyrene, as opposed to another PAH, the percentage contribution of benzo(a)pyrene to the eight most carcinogenic PAHs has been calculated. The eight most carcinogenic PAHs are based on those with a toxic equivalent factor (TEF) of 0.1 or above. Across all the made ground samples, benzo(a)pyrene comprises between 40% and 71% of the total of the eight PAHs adjusted to take into consideration their TEF. Therefore as it forms the major constituent of this group of PAHs, samples with high benzo(a)pyrene are indicative of those with

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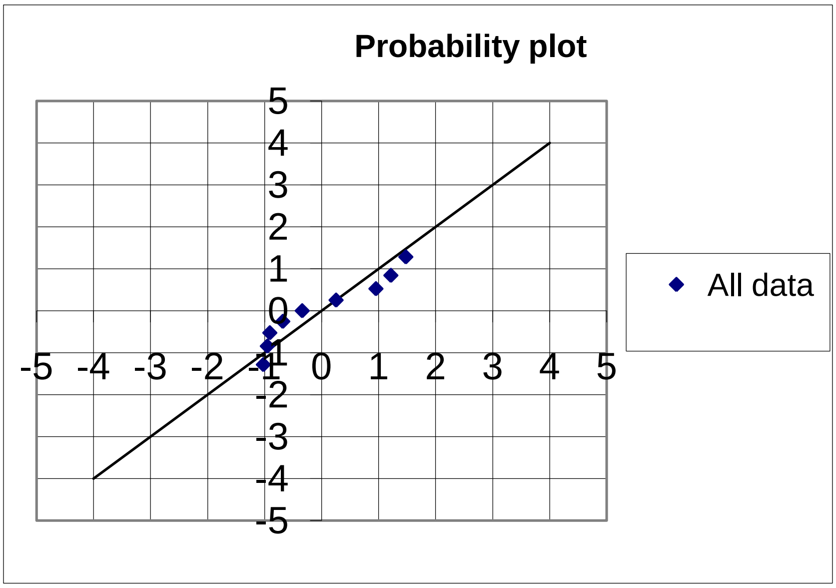
high PAHs. Risks to human health from PAHs as a whole have been assessed using benzo(a)pyrene as a marker compound.

The statistical approach is consistent with guidance by CL: AIRE (Ref. 19) and is outlined in more detail in Appendix C.

3.6.3. Impacted Made Ground

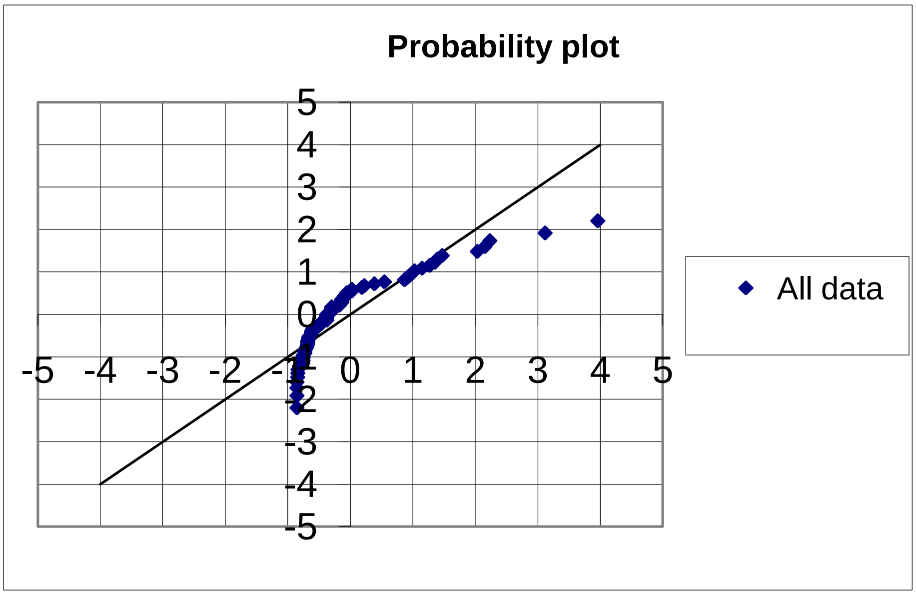
Analysis using the Shapiro-Wilks test indicates that the benzo(a)pyrene data for the impacted made ground is normally distributed, therefore use of the Student t-statistic 95% Upper Confidence Limit is appropriate to describe this data. This is confirmed by the probability plot below.



The Student t UCL95 for benzo(a)pyrene in the impacted made ground samples is 202 mg/kg. This value is significantly above the relevant GAC for residential land use of 1mg/kg.

3.6.4. Remaining Made Ground

Analysis using the Shapiro-Wilks test indicates that the benzo(a)pyrene data is not normally distributed, therefore use of the Chebyshev 95% Upper Confidence Limit is appropriate to describe this data. This is confirmed by the probability plot below.



The Chebyshev UCL95 for benzo(a)pyrene in the remaining made ground samples is 3.4 mg/kg, which is above the GAC for residential land use of 1mg/kg.

3.7. Results of TPH Analysis

A total of 62 samples were analysed for speciated total petroleum hydrocarbons (TPHCWG). The assessment of hydrocarbons has considered the additivity approach as set out in the guidance document 'UK Approach for Evaluating Human Health Risks from Petroleum Hydrocarbons' (Ref. 20). In order to account for the different ratios of hydrocarbon fractions, SKM Enviros has calculated a hazard index for each sample which represents the factor by which the screening values are exceeded. A hazard index less than one indicated the mixture as a whole is below the screening threshold. The results of this assessment are presented within the additivity TPH calculation sheet in Appendix D.

Five samples (EWS1@1.75m, EWS1@3.35m, EWS5@1.55m, TP101@0.35m and TP101@1.7m reported a hazard index of greater than 1 and therefore concentrations of hydrocarbon fractions were above the calculated GACs. The elevated results range from 1.78mg/kg to 11,596mg/kg with the maximum concentration reported within sample EWS1 @1.75m. These samples are all present within the impacted made ground. All samples from the remaining made ground and natural ground were below the relevant screening values.

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3.8. Summary

- Concentrations of lead above the GACs have been measured within six samples of the made ground however statistical analysis has reported the UCL95 to be below this screening value.
- Elevated concentrations of cyanide were reported within one sample of the made ground.
- One sample reported the presence of asbestos (chrysotile) fibres.
- Elevated concentrations of PAHs above residential screening values have been measured in the made ground across the site. Further assessment has shown the higher values to be clustered within the east of the site. Further statistical analysis has shown the UCL95 of this impacted made ground to significantly exceed the screening criteria compared to the remaining made ground which only reports a slight exceedance.
- One sample of the natural ground reported elevated concentrations of benzo(a)pyrene however it is thought that this sample is likely to have been impacted by the above made ground and the results have been included within the assessment for the remaining made ground.
- Five samples from the impacted material also reported TPH concentrations above their sample specific value for the relevant screening criteria (residential without plant uptake).
- All concentrations of TPH within the natural ground and the remaining made ground were below their sample specific value for the relevant screening criteria (residential without plant uptake).

4. DQRA (Conceptual Site Model)

The principal aspect of the DQRA is to define the appropriate site specific parameters representing the conceptual site model (CSM) to input into the CLEA Model. This includes the feasible pollutant linkages that have been identified when considering the source, pathways and human receptors for the use of the site as a cemetery. This chapter provides the rational for the parameterisation of the CSM.

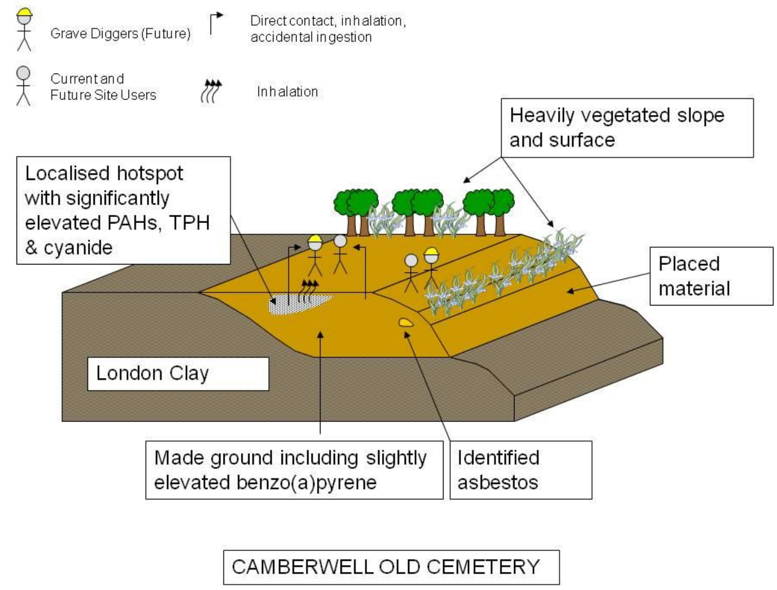
The risk assessment relates to assessing risks from exposure to polycyclic aromatic hydrocarbons (PAHs) and uses benzo(a)pyrene as a marker for this exposure.

4.1. Description of the Scenario

The proposed end use of the site is for an extension to the adjacent Southwark Old Cemetery which will be used for traditional burials. Previous site investigation works have identified the presence of elevated concentrations of benzo(a)pyrene with a maximum concentration of 300mg/kg measured within an area of placed material at the site.

The site is currently disused and due to fencing around the boundaries is not currently accessible to the general public. Following extension of the cemetery to include the site it is expected for visitors to the site to include: council employed grave diggers and families with small children attending funerals and visiting gravesides. The picture below provides a pictorial description of the scenario.

- **Picture 1 – Site Scenario**



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4.1.1. Exposure pathways

The potential exposure pathways to non volatile contaminants such as benzo(a)pyrene in soils are as follows:

- Direct incidental ingestion of soil:
- Dermal contact with soil:
- Inhalation of soil dust outdoors.

Given the location of the closest homes and site offices to the cemetery (offices are located off site at Camberwell New Cemetery) it is considered unlikely that a significant amount of soil will be tracked back home by site visitors. In a similar manner to allotment holders such soil is assumed to fall off shoes and clothes before they enter their homes. A study in 2006 (Ref. 5) on mass transfer of soil indoor indicated that the majority of soil adhered to footwear was deposited within the first seven steps (Ref).

Information from the Southwark Cemetery Manager has confirmed that the council employed grave diggers are based at Camberwell New Cemetery and they travel to Camberwell Old Cemetery when required. At Camberwell New Cemetery they have showers and changing facilities and a mess room where breaks are taken. They are supplied with clothing and boots by the Council including long trousers, t shirts and jumpers. They are expected to change from these into their own clothing and shoes at the end of the day.

In the generic CLEA Model tracking back of soil into buildings (and therefore the indoor exposure pathways) is only included where the building is located on the contaminated site itself. (Ref.6). Therefore, based on the scientific research and the proposed end site usage having no proposed buildings, tracked back soil into houses has not been considered a valid pathway as part of the assessment.

4.1.2. Identification of the Critical Receptor

Polycyclic aromatic hydrocarbons have low acute toxicity. The risks being assessed relate to chronic long term exposure, therefore it is potential regular visitors to the site that are the primary receptors. Regular site visitors are anticipated to include adult grave diggers and adult and child visitors.

The critical receptors are therefore considered to be:

- Council employed grave diggers.

- Site visitors - A female child (aged 1-6) is considered the most susceptible receptor of this scenario. This is because on average a female child weighs less than a male child. Toxicity is considered to relate to body mass and intake and is expressed in the amount of contamination per kilogram bodyweight per day. A female child will have a greater contaminant uptake rate per kilogram bodyweight.

4.2. Assessment of Exposure Parameters – Grave Digger

4.2.1. Exposure Frequency

Given that the amount of tracked back dust is minimal, exposure will depend on the amount of time spent on the site. Although their attendance at site varies according to the number of burials, from discussions with the Cemetery Manager for the site we understand that the main activity on site will occur in the first 18 months. The actual number of graves that can be placed in that area is unknown but is estimated at a maximum of 300. Based on the current rates it is estimated that a total of 210 burials will occur per year. Therefore within the site there will be a total of 210 new burials in the first year and then 90 within the second year. In addition to the new burials there will be re-openings occurring over the following 10 to 15 years, the exact rates are unknown but this will be at a much reduced rate from the initial two years.

Based on information obtained from Southwark's Cemetery Manager we have conservatively assumed that the daily site works will take 4 hours to complete which will allow for excavation of one new grave and backfilling of the grave following a burial. We have therefore assumed a 4 hour exposure period on 210 days per year. Sensitivity analysis has looked at the average exposure for the initial 2-3 year period of the use of the cemetery and also the worst case scenario of burials being undertaken on each working day of the first year.

4.2.2. Body Weight

The grave diggers at the site are currently all male therefore we have used a male body weight within the assessment. However, as there is a possibility that female workers could be present on the site in the future we have considered female body weight and skin factors as part of the sensitivity study.

4.2.3. Soil Ingestion Rate

Soil ingestion rates are difficult to measure. Studies assessing soil ingestion generally comprise tracer studies where the concentration of tracer substances found in soil which are not well absorbed by the body are measured in faeces. The results are then compared with the soil concentrations to which the individual is exposed. Due to the potential for exposure from a wide variety of sources the assessment can be complex and very few tracer studies have been carried out, particularly for adults. We have not been able to identify any studies for manual workers in the UK nor specific studies for manual worker's ingestion of soil in general. We have therefore looked at the UK guidance to try to comply with the UK approach in this scenario. Site specific assessments for soil ingestion are time consuming and intrusive on the site individuals.

USEPA (Ref 7) and Otte et al. (Ref 8) both recommend an average soil and dust ingestion rate of 50 mg day-1. USEPA (1997b) cautioned that the value is highly uncertain and based on a low level of confidence. The default value used in the CLEA model for the combined soil and dust ingestion rate by adults in an allotment is 50 mg/day and this value has been used within this assessment. This is considered to be a conservative estimate as the excavation works are predominantly undertaken using mechanical excavators and hand digging is limited. Paustenbach (Ref 9) concluded that a value between 5 and 25 mg day-1 for the rate of soil ingestion by most adults would be reasonable and therefore the value has been reduced to 25mg/day as part of the sensitivity study.

4.2.4. Exposed skin area

For the grave digger we have assumed the exposed skin area is likely to be similar to that of a gardener in an allotment who is not wearing gloves. We have assumed that the grave diggers wear trousers (Council supplied) but may have their forearms, hands and face exposed. From the USEPA Exposure Factors Handbook and using the mean values for an adult male an exposed body surface area of 0.18 has been estimated. In the sensitivity study we have also looked at wearing long sleeves and gloves and having their heads exposed (i.e. having no hair).

Dermal exposure to indoor dust at home as discussed in section 3.1.1 is not considered as the amount of soil tracked back into houses from site is considered minimal.

The soil adherence factor is influenced by a variety of factors, these include the soil conditions and the types of activities carried out. The USEPA (Ref 10) provides the following results for gardeners and farmers carrying out activities stated.

- **Table 9 - Summary of geometric mean soil adherence factors for farmers and gardeners (from USEPA 1996)**

	Hands	Arms	Legs	Face	Approximate weighted average* of geometric means on exposed area (mg/cm^2)
Gardeners (7 gardeners weeding pruning, digging a trench, picking fruit, cleaning)	0.18 No gloves	0.054 5 of 7 short sleeves, 1 sleeveless	0.022 3 of 7 long trousers	0.047	0.06
Gardeners (8 gardeners weeding	0.20 Intermittent	0.050 7 of 8 short	0.072 6 of 8 long	0.058	0.09

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	Hands	Arms	Legs	Face	Approximate weighted average* of geometric means on exposed area (mg/cm^2)
pruning, digging a trench, picking fruit, cleaning)	use of gloves	sleeves, 1 sleeveless	trousers		
Farmers (4 Manual weeding and mechanical cultivation)	0.41 No gloves	0.059 3 of 4 Short sleeve shirts	0.0058 All long trousers	0.018	0.09
Farmers (6 Manual weeding and mechanical cultivation)	0.47 No gloves	0.13 1 of 6 long sleeve shirts	0.037 4 of 6 long trousers	0.041	0.14

*based on hands 5.2%, forearms 5.9%, lower legs 12.8% and face 3.9% of total body area then adjusted to reflect this exposed area

An adherence factor of 0.3 $mg/cm^2/day$ has been used in line with the standard scenario for an allotment worker as detailed within SR3 (Ref 6). As shown in the above table where adherence ranges from 0.06 to 0.14 mg/cm^2, this is considered conservative. Consideration has been given in the sensitivity study to changing this to 0.14mg/cm^2.

4.2.5. Inhalation rates

Inhalation rates for the critical receptor have been taken from Table 4.13 from the EA science Report SR3 (Ref.6). Inhalation rates have been chosen based on adults being involved in light intensity activity whist working at the site for which a rate of 19.92m^3/day has been recommended.

4.2.6. Soil Types and Parameters

The main pathways are soil ingestion and dermal contact. The soil type, pH and soil organic matter do not affect these pathways. While soil type can affect the dust inhalation pathway this pathway contributes only slightly to the overall exposure. We have however considered the standard sandy loam soil as detailed in SR3 with a soil organic matter of 1% for the site and a surface coverage of 90%. As per table 9.1 of SR3 (London) an air dispersion factor of 290 has been assumed for the 0.5ha site.

4.2.7. Summary of Input Parameters for Grave Digger

- **Table 10 - Summary of Input Parameters (Grave Digger)**

Site specific parameters	Values	Basis	Sensitivity
Body weight	83.2	Assumed based on male (1. 1)	Look at female worker
Inhalation rate (m3/day)	19.92	Based upon values within EA report SR3 (Ref. 6) for adults undertaking light intensity activity.	Conservative
Exposure frequency (days/year)	210	Assumed one grave excavated per day up to maximum number of graves	Assess average number of days over 2 to 3 year period. Increase to

Site specific parameters	Values	Basis	Sensitivity
		per year.	assume worst case of every working day on site
Hours per day (hours/day)	4	Allowance for excavation of one grave and backfilling of one grave	Conservative
Soil Ingestion rate mg/kg/day	50	From CLEA UK Model for allotment workers.	Change to 25 as most of excavations undertaken by excavator
Maximum exposed skin fraction	0.18	Based on exposure to lower legs, hands, forearms and face (Ref. 11)	Assess wearing glove and long sleeves.
Outdoor soil adherence factor	0.3	From CLEA UK Model for allotment workers.	Value considered conservative for cemetery use consider changing to 0.14 reflecting the typical measured range for similar workers
Absorption Factor	0.13	Table 8.2 of SR3 (Ref 6)	Substance specific data

4.2.8. Toxicity data

The CLEA model also relies on a toxicological dose. We have used the index dose previously published by the Environment Agency in 2003 of 20ng/kg bw/day. Since that document was published, there have been a number of publications from the Health Protection Agency and Environment Agency on the approach for carcinogenic substances. The document is still provided for information, but following a wide ranging review of the data it is due to be revised. This was in part due to the fact that the thresholds in soil produced by the CLEA model were below the concentrations in urban soil and hence there is the potential for a disproportionate cost in cleaning urban soil.

4.3. Assessment of Exposure Parameters - Child Visitor

For this scenario it has been assumed that a recently bereaved mother visits the site to tend to a grave bringing a young child with her. The reason for the selection of this scenario is that children have a lower body weight and thus generally have a higher exposure to a given soil concentration. We have assumed that due to the nature of visits and the need for supervision any children younger than 1 year would remain in a buggy.

A survey of cemetery usage has recently been undertaken by Southwark Council (Ref 12). As part of the survey, 40 visitors to Camberwell Old Cemetery were interviewed over two days, one week day and one weekend in May 2011. The survey reported that most of the people interviewed (77%) were visiting the cemetery for the purpose of visiting graves. The remaining people surveyed were either attending a funeral or visiting the cemetery for recreational purposes.

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The survey also reported that the highest proportions of people visit the site on an occasional basis. Lower numbers of people were reported to visit on a weekly or a daily basis although these were of similar proportions. The highest proportions of people surveyed as part of this assessment were female in the 50-65 years age group.

In consultation with Southwark Council, we are aware that parents supervise children more closely to ensure they act respectfully in cemeteries and their behaviour is therefore likely to be different to that in residential gardens or general public open space. In particular this is likely to result in only limited contact with exposed soil. In addition the length of a visit is likely to be shorter than time playing the garden.

4.3.1. Exposure Frequency

We have assumed that for an initial 1 month period, visits could be conducted on a daily basis, followed by a 3 month period of visiting every other day and followed by a further 8 month period of visiting once per week. This would then be followed by an ongoing period of visiting once per month. This equates to 107 days for the first year after the bereavement followed by 12 days for subsequent years. These frequencies are considered conservative but realistic. Although the age at which a child first visits the cemetery will vary, we have conservatively assumed a child is one year at their first visit.

It has been assumed that a visit would last between half an hour to 1 hour. This would be relevant for the inhalation pathway, however as this contributes to <1% of the total screening value, the sensitivity of the length of a visit is unlikely to be significant.

4.3.2. Body Weight and Skin Surface Area

The body weights of children aged 1 to 6 (the critical receptor) have been based on the CLEA default values for females (Ref. 6). The total body skin surface area in CLEA is derived from height and weight, and correlated to exposed skin area. We have therefore used the CLEA default total skin areas for these age groups (Ref. 6).

We have assumed that due to the nature of visits and the need for supervision any children younger than 1 year would remain in a buggy.

4.3.3. Soil Ingestion Rate

As children are likely to be well supervised during a visit to a cemetery direct contact with the soil is likely to be limited. USEPA (Ref 13) recommended 100 mg day-1 as the best estimate of mean combined soil and dust ingestion rate for children under seven years old, this rate is also the CLEA defaults for children aged between 0 and 6 (Ref. 6). The value of 100 mg day-1 includes both

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indoor and outdoor exposure to the contaminant which is not an appropriate assumption within the risk assessment as tracked back dust is not considered a valid pathway of this assessment.

The CLEA Model does not provide a breakdown of the indoor and outdoor contribution to ingestion rate. Therefore, to determine the ratio ingestion indoor/ ingestion outdoor the default value 55/45 used by USEPA in the IEUBK Model has been used as the basis (Ref. 14). The IEUBK Model is currently considered by the EA as the most appropriate risk assessment model to use when assessing the affects of soil contaminated with lead (Ref 21). As an input parameter a conservative outdoor intake rate of the average of the IEUBK and CLEA values has been used, this equates to a value of 60 mg/kg/day.

4.3.4. Exposed skin area

For the child visitor, the exposed skin area is likely to be limited to face, forearms, hands, and lower legs for the summer months, as per SR3 (Ref 6) outdoor exposure for a child in allotment land use. The exposed area is considered conservative as such exposure is less likely in winter.

The dermal model is an events based model, and assumes that one event occurs per day and that soil stays on the skin for 12hours. The adherence factor relates to the amount of soil sticking to the skin during each event. The USEPA (Ref. 15) studies (characterising dermal exposure scenarios) indicate that 0.2mg/cm^2 may be a lower level and 1mg/cm2 is a reasonable upper limit. As would be expected the studies on adherence primarily relate to the soil type. For wet soil, adherence is likely to be higher than for dry soils. In accordance with SR3 (Ref 6) an adherence factor of 1mg of soil / cm^2 of skin is considered typical of wet soils and conservative for dry soils for an exposed child. Thus using an adherence factor of 1mg/cm^2 is considered very conservative for the child visitor at the site but is proposed as an initial screen.

The model used in CLEA assumes one contact event per day and assumes a dermal absorption factor of 0.13 of benzo(a)pyrene absorbed through the skin from that contact event. SR3 (Ref 6) assumes contact duration of 12 hours. This is longer than the time anticipated before washing hands (and, if dirty, face) at the end of the visit. The absorption factor is thus considered to be conservative.

4.3.5. Inhalation rates

Inhalation rates for the critical receptor have been taken from Table 4.13 from the EA science Report SR3 (Ref. 6). Inhalation rates have been chosen based on children being involved in light intensity activity whist visiting the site which range from 10.56 to 15.84m^3 day^{-1} for a 1 to 6 year old.

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4.3.6. Soil Types and Parameters

The main pathways are soil ingestion and dermal contact. The soil type, pH and soil organic matter do not affect these pathways. While soil type can affect the dust inhalation pathway this pathway contributes only slightly to the overall exposure. We have however considered the standard sandy loam soil as detailed in SR3 (Ref 6) with a soil organic matter of 1% for the site. Based on the results from London as per table 9.1 of SR3 (Ref 6) an air dispersion factor of 130 has been assumed for the 0.5ha site.

4.3.7. Summary of Input Parameters for Child aged 1-6

- **Table 11 - Summary of Input Parameters (Child Visitor)**

Site specific parameters	Values	Basis	Sensitivity
Body weight	9.8- 19.7	Assumed based on a female aged 1 to 6 years (Ref. 6)	Based on UK data
Inhalation rate (m3/day)	17.28 – 15.84	Based upon values within EA report SR3 (Ref. 6) for children of the ages of 1 to 6 undertaking light intensity activity.	Conservative
Exposure frequency (days/year)	107 for the first year reducing to 12 for consecutive years	Based on daily visits for one month then visits every other day for three months and then weekly visits for eight months for the first year. Reducing to monthly visits after the first year.	Increase to every other day visits for second six month period of first year. Increase to weekly visits for the next two years. Resulting in 140 days for year 1 and 52 days/year for years 2 and 3.
Hours per day (hours/day)	0.5-1	Estimated time spent on site.	Reducing time of visits to half an hour
Soil Ingestion rate mg/kg/day	60	Average of CLEA Default for children (Ref.6) and IEUBK (ref 14) model.	Change to 45 to show the effect of using the IEUBK ingestion rate only
Maximum exposed skin fraction	0.26 – 0.28	Based on exposure to lower legs, hands, forearms and face (Ref. 6)	Based on UK data, reasonable for allotment land use.
Outdoor soil adherence factor	1	Based on outdoor exposure	Value considered conservative for cemetery use particularly for dry soil.
Absorption Factor	0.13	Table 8.2 of SR3 (Ref 6)	Substance specific data

4.3.8. Toxicity data

The CLEA model also relies on a toxicological dose. We have used the index dose previously published by the Environment Agency in 2002 (Ref 16) of 20ng/kg bw/day, for inhalation a value of 0.07ng/kgbw/day has been used (Ref 16). Since that document there have been a number of publications from the Health Protection Agency and Environment Agency on the approach for carcinogenic substances. The document is still provided for information, but following a wide ranging review of the data it is due to be revised.

In particular a paper on PAHs in food, EFSA (Ref 17) calculated that the $BMDL_{10}$ based on this study to be between 0.07 and 0.2mg/kg bw/day based upon mathematical models selected, with 0.12 mg/kg bw/day representing the best fit. This looked at mixtures of substances where coal tars were present. If an acceptable margin of exposure is 10 000 as indicated by SR2 (Ref 18.) this would lead to an index dose of 7 to 20ng/kg bw/day with a mean value of 12ng/kg bw/day.

The TOX dose produced in the CLEA report from 2003 was 20ng/kg bw/day. We note that the value of 12ng/kg bw/day for PAHs produced by EFSA is similar to the 60% of the toxic equivalent factor for benzo(a)pyrene. This is considered in the sensitivity study where and index dose of 12ng/kgbw/day is applied to both the oral and inhalation exposure

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5. DQRA (CLEA Model Output)

The outputs in Tables 12 and 13 have been produced by the CLEA model using the input parameters within Tables 10 and 11. The model inputs and outputs are included within Appendix E. The results indicate that the child visitor is more sensitive than the grave digger.

- **Table 12 - Summary of Model Output**

Scenario	Site Specific Assessment Criteria for benzo(a)pyrene
Adult male grave digger	25.6mg/kg
1-6 year old – Visiting Cemetery grave	18.6mg/kg

The contribution to pathways both with and without weighting for inhalation and oral index doses are given in Tables 13 and 14. The actual exposure via ingestion and dermal contact have a similar contribution. They also indicate that the actual exposure from inhalation of soil vapour and dust outdoor is negligible. However because the index dose for inhalation used in the modelling is about 300 times lower than the index dose for oral exposure the weighted exposure is comparable for oral/ dermal and inhalation routes. We would note that for other substances such as arsenic where this effect also occurs, the Environment Agency has made a policy decision to focus on oral/dermal exposure only.

- **Table 13 - Contribution to pathways**

	Direct soil ingestion %	Dermal contact with soil and dust	Inhalation of dust	Inhalation of vapour
Adult male grave digger	51.00	48.94	<1%	<1%
Child age 1-6	50.18	49.76	<1%	<1%

- **Table 14 - Contribution to pathways (weighted for inhalation and oral index doses)**

	Direct soil ingestion %	Dermal contact with soil and dust	Inhalation of dust and vapour
Adult male grave digger	41%	40%	19%
Child age 1-6	41%	40%	19%

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5.1. Sensitivity Analysis

Sensitivity analysis has been undertaken for both scenarios, the results are show in Tables 15 and 16 below.

For the grave digger scenario the sensitivity analysis has included changing the number of days per year on site, reducing soil ingestion rates and allowing for wearing long sleeves and gloves.

The changes made are within the reasonable range of values. The assessment of the grave digger has been based initially on a one year exposure. If the exposure is considered over a longer term the criteria would change by 30%. This would counter the effect of changing the index dose in line with the European Food Safety Authority (EFSA) standard should this be used in future guidance

The assessment also indicated that wearing long sleeves and gloves has a significant effect on the threshold and could thus noticeably reduce exposure.

- **Table 15 - Results of Sensitivity Analysis (grave digger scenario)**

Scenario	Site Specific Assessment Criteria	% change
Adult male grave digger	25.6mg/kg	
Changing exposure time to 90 days per year (year 2)	59.7mg/kg	133%
Changing exposure time to 75 days per year (year 3)	71.7mg/kg	180%
Combine exposure over three years	52.3mg/kg	104%
Changing exposure time to 260 days per year	20.7mg/kg	-19%
Changing for female worker	22.8mg/kg	-11%
Reducing soil ingestion rate to 25%	32.9mg/kg	29%
Change for having no hair (i.e. being bald)	23.4mg/kg	-9%
Change for wearing long sleeves and gloves	41.1mg/kg	61%
Soil adherence factor consider changing to 0.14	33.1mg/kg	29%
Change to index dose of 12ng/kgbw/day for both oral/dermal and inhalation exposure	17.7mg/kg	-31%

For the child visitor scenario the sensitivity analysis has included changing the exposure time and the soil ingestion rate. This has shown that reducing the exposure time results in a 51% decrease in the assessment criteria however is it considered that this decrease is counteracted by conservatism within the values used for the inhalation rates and outdoor soil adherence factor.

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- **Table 16 - Results of Sensitivity Analysis (visitor scenario)**

Scenario	Site Specific Assessment Criteria	% change
1-6 year old – Visiting Cemetery grave	18.6mg/kg	
Changing exposure time to allow for increased visits	9.1mg/kg	-51
Changing ingestion rate to 45mg/day	20.9mg/kg	12.4
Changing time spent on site per visit	20.1mg/kg	8.0
Change to index dose of 12ng/kgbw/day for both oral/dermal and inhalation exposure	13.1mg/kg	-3.0

5.2. Comparison with Site data

The results risk assessment have been compared with the results of the statistical analysis undertaken within section 3 of this report and the results are presented within Table 17 below

- **Table 17 – Comparison of SSACs with UCL95 for B(a)P**

Scenario	Site Specific Assessment Criteria	Calculated UCL95 for B(a)P
Impacted Made Ground		
1-6 year old – Visiting Cemetery grave	18.6mg/kg (range of 9.1 to 20.1mg/kg)	202mg/kg
Grave Digger	25.6mg/kg (range of 17.7 to 71.7mg/kg)	
Remaining Made Ground		
1-6 year old – Visiting Cemetery grave	18.6mg/kg (range of 9.1 to 20.1mg/kg)	3.4mg/kg
Grave Digger	25.6mg/kg (range of 17.7 to 71.7mg/kg)	

5.3. Summary of Results

- The screening value for the grave diggers is approximately 25.6mg/kg ranging from 17.7mg/kg to 71.7mg/kg in the sensitivity studies.
- The screening value for the child site visitor is approximately 18.6mg/kg ranging from 9.1m/kg to 20.9mg/kg in the sensitivity studies.
- The calculated UCL95 for the impacted made ground exceeds the SSACs for both scenarios
- The calculated UCL95 for the remaining made ground is below the SSACs for both scenarios.
- The calculated UCL95 for the natural ground is below the SSACs for both scenarios.

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6. Conclusions

The site is located within Camberwell Old Cemetery and it is proposed for this area to be used for traditional burials. Based on this potential end use sensitive receptors have been identified as grave diggers and site visitors.

The site investigations and resulting laboratory analysis have reported the presence of PAH contamination (predominantly benzo(a)pyrene) above the relevant screening values within the made ground across the site.

Assessment of the site data has identified two distinct areas of made ground referenced as 'Impacted Made Ground' and 'Remaining Made Ground'. The conservative average concentration as shown by the UCL95 values has been calculated for both soil horizons and these have been compared to the results of the risk assessment.

The risk assessment has calculated a SSAC of 25.6mg/kg (range of 17.7 – 71.7mg/kg) for the grave diggers and 18.6mg/kg (range of 9.1- 20.1mg/kg) for the site visitors. The SSACs for both scenarios exceed the UCL95 value for the remaining made ground (3.4mg/kg) therefore it can be concluded that this material does not pose a significant risk to the identified receptors.

The UCL95 value for the impacted made ground (202/kg) exceeds the SSAC for both scenarios. It is therefore concluded that this material does present a risk to identified receptors and remedial works will be required to render the site suitable for its proposed use.

Elevated concentration of TPH above sample specific screening values were reported within most of the impacted made ground samples and elevated concentrations of cyanide were reported within one sample of the impacted made ground. The presence of asbestos fibres was identified in an isolated location not associated with the impacted made ground and further remedial works will be required within this area.

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7. References

1) Enviros, Phase Two Land Quality Assessment: Former Camberwell Old Cemetery October 2008, LO0530013

2) Enviros Phase Two Land Quality Assessment: Former Camberwell Old Cemetery April 2009, LO0530013

3) Department of Environment Transport and the Regions. Environmental Protection Act 1990: Part IIA, Circular 02/2000, Contaminated Land. The Stationary Office, March 2000.

4) Department for Environment, Food & Rural Affairs (DEFRA)/ Environment Agency (EA) Model Procedures for the Management of Land Contamination (CLR11), 2003.

5) Hunt A, Johnson DL, Griffith DA. Mass transfer of soil indoors by track-in on footwear. Sci Total Environ. 2006 Nov 1;370(2-3):360-71. Epub 2006 Sep 7.

6) Environment Agency 2009. Updated technical guidance to the CLEA mode, Technical Report SC050021/SR3

7) U.S. EPA. 1997b. Exposure Factors Handbook. Volumes I, II, and III. U.S. EPA/600/P-95/002Fa,b,c. U.S. Environmental Protection Agency, Office of Health and Environmental Assessment, Washington, DC. August. Development, Washington, DC 20460.

8) Otte PF, Lijzen JPA, Otte JG, Swartjes FA, Versluijs CW. 2001. *Evaluation and Revision of the C Soil Parameter Set.* RIVM report 711701021, National Institute of Public Health and the Environment, Bilthoven, The Netherlands.

9) Paustenbach 2000 The practice of exposure assessment: a state of the art review. Journal of Toxicology and Environmental Health Part B, 3:179-291:2000

10) USEPA (2004) Risk Assessment Guidance Superfund Volume 1: Human health Evaluation Manual)

11) USEPA 1997 Exposure Factors Handbook

12) A Robb, LB Southwark Cemeteries Usage Survey Report May 2011

13) US-EPA (2006) Child-Specific Exposure Factors Handbook (External Review Draft), September 2006, EPA/600/R/06/096A

14) M. Van Holderbeke, C. Cornelis, J. Bierkens, R. Torfs. Review of the soil ingestion pathway in human exposure assessment. 2007. BeNekempen.

15) USEPA 1992 Dermal Exposure Assessment: Principles and Applications, Report EPA/600/8-9/011B. Interim Report

16) Department for Environment, Food & Rural Affairs (DEFRA)/ Environment Agency (EA) contaminants in soil: collation of toxicological data and intake values for humans. Benzo[a]pyrene 2002

17) European Food Safety Authority (EFSA) Polyaromatic Hydrocarbons in Food, The EFSA Journal (2008) 724

18) Environment Agency, Human Health Toxicological Assessment of Contaminants in Soil, Science Report – Final SC050021/SR2 2009

19) The Soil Generic Assessment Criteria for Human Health Risk Assessment, Claire/EIC, December 2009.

20) UK Approach for Evaluating Human Health Risks from Petroleum Hydrocarbons, Science Report P5-080/TR3, Environment Agency 2005.

21) SoBRA Meeting on Assessing Risks from Lead June 2011.

Figures

Figure 1 – Site Location Plan

Figure 2 – Exploratory Hole Location Plan

Appendix A Laboratory Analysis

Appendix B Human Health Screening Methodology

Appendix C Statistical Approach

Appendix D TPH Calculation Sheet

Appendix E CLEA Model Inputs and Outputs