Riverside Energy Park

Environmental Statement

Appendix C.3 Human Health Risk Assessment
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Appendix C.3

Human Health Risk Assessment

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C.3.1. Introduction

3.1.1 This assessment considers the likely effects of long term human exposure from persistent pollutants emitted to the atmosphere from the proposed energy recovery facility (ERF) at Riverside Energy Park (REP). The contents of this Appendix supports the Air Quality Assessment presented in Chapter 7 of the Environmental Statement (ES).

Scope of the Assessment

3.1.2 The impact of exposure to the majority of air pollutants through inhalation can be assessed by comparison of predicted concentrations to air quality standards. The impact of exposure to these pollutants is provided in the air quality assessment in Chapter 7 of the ES. REP would also give rise to a number of pollutants which cannot be directly compared against air quality standard in order to evaluate their likely effects on human health. For these pollutants, likely health effects could occur through exposure routes other than inhalation alone. As such, an assessment needs to be made of the overall human exposure to the substances by the local population and then the risk caused by this exposure.

3.1.3 The assessment presented in this Appendix considers the potential impact of substances released by REP on the health of the local population at the point of maximum exposure. These pollutants are those that are ‘persistent’ in the environment and have several pathways (i.e. in addition to inhalation) from the point of release to the human receptor. Other pollutants which only have pathways via inhalation are assessed in Appendix C.2. The pollutants assessed within this appendix are specifically those which have the potential to enter the food chain and may stay within the environment for longer periods of time. Essentially they can be described as dioxins/furans, trace metals, and dioxin-like polychlorinated biphenyls (PCBs) and these are the particular pollutants that have been considered in this assessment. These substances are present in very small quantities and are typically measured in mass units of nanograms (ng = 10-9g), picograms (pg = 10-12 g) and femtograms (fg = 10-15 g).

3.1.4 Unlike pollutants such as nitrogen dioxide, which have short term, acute effects on the respiratory system, dioxins/furans and dioxin-like PCBs have the potential to cause likely effects through long term, cumulative exposure. A lifetime is the conventional period over which these long-term cumulative likely effects are evaluated. A lifetime is considered to be 70 years. The pollutants which have short term, acute effects on respiratory systems have been excluded from this assessment as they are assessed in Appendix C.2.

3.1.5 The exposure scenarios used in this assessment represent a reasonable worst case assumption and should be treated as an extreme view of the risks to human health. While individual high-end exposure estimates may represent actual exposure possibilities (although at very low frequency), the possibility of all high-end exposure assumptions occurring in the same individual is, for practical reasons, never realised. Therefore, intakes provided in this assessment should be considered as an extreme upper estimate of the realistic exposure that would be experienced by the real population of the locality.

C.3.2. Approach to the Assessment

3.2.1 This assessment of dioxin/furan emissions from REP is based primarily on the United States (US) Environmental Protection Agency (EPA) Human Health Risk Assessment Protocol (HHRAP) methodology. The HHRAP has been assembled into a commercially available software model, Industrial Risk Air Pollution (IRAP).

3.2.2 The HHRAP approach firstly seeks to quantify the hazard faced by the receptor and the exposure of the receptor to the substances identified as potentially hazardous. The assessment of the risk of exposure is then carried out, as follows:

3.2.3 Quantification of the exposure: an exposure evaluation determines the dose and intake of key indicator chemicals for an exposed person. The dose is defined as the amount of a substance contacting body boundaries (in the case of inhalation, the lungs) and intake is the amount of the substance absorbed into the body. The evaluation is based upon reasonable worst-case, conservative scenarios, with respect to the following:

- Location of the exposure individual and duration of exposure;
- Exposure rate; and
- Emission rate from the source.

3.2.4 Risk characterisation: following the steps above, the risk is characterised by examining the toxicity of the chemicals to which the individual has been exposed, and evaluating the significance of the calculated dose in the context of probabilistic risk.

C.3.3. Methodology for Estimating Exposure to Emissions

Introduction

3.3.1 An exposure assessment for the purposes of characterising the health impact of REP emissions requires the following steps:

- Measurement or estimation of emissions from the source;
- Modelling the fate and transport of the emitted substances through the atmosphere and the through soil, water and biota following deposition onto land. Concentrations of the emitted chemicals in the environmental media are estimated at the point of exposure, which may be through inhalation or ingestion; and
- Calculation of the human uptake of these chemicals after coming into contact with the affected media and the subsequent distribution in the body.

3.3.2 Regarding step 3, the exposure assessment considers the uptake of polychlorinated dibenzo-para-dioxins and polychlorinated dibenzofurans (PCDD/Fs, also abbreviated to 'dioxins/furans') and metals by various categories of human receptors.

Potential Exposure Pathways

3.3.3 There are two primary exposure 'routes' through which humans may come into contact with chemicals that may be of concern:

- Direct, via inhalation; or
- Indirect, via ingestion of water, soil, vegetation, animals and animal products that become contaminated through the food chain.

3.3.4 There are four other potential exposure pathways of concern following the introduction of substances into the atmosphere. These include:

- Ingestion of drinking water;
- Dermal (skin) contact with soil;
- Incidental ingestion of soil; and
- Dermal (skin) contact with water.

Exposure Pathways Considered in the Assessment

3.3.5 The following exposure pathways have been considered in this assessment:

- Inhalation;
- Ingestion of food; and

- Ingestion of soil.

3.3.6 Dermal contact with soil is an insignificant exposure pathway and has been not been considered further in this assessment. This is on the basis that the nature of the event is infrequent and sporadic, dermal absorption factors for this route are very low and the plausible dose that will be experienced over the lifetime of an individual is low.

3.3.7 Similarly, swimming, fishing and other recreational activities associated with dermal contact with water are sporadic and unlikely to result in significant exposure of any contamination into the human body. For this reason, the dermal contact with water has not been included as an exposure pathway in this assessment.

3.3.8 The ingestion of drinking water from surface water sources is only considered a potential exposure pathway where drinking water is obtained from a local surface water body. Thames Water Utilities Limited provides drinking water supplies for the majority of residential properties located in close proximity to REP . Therefore, the contamination of drinking water supplies has not been considered in this assessment.

3.3.9 In relation to exposure pathways arising from ingestion, the following have been considered:

- Milk from home-reared cows;
- Eggs from home-reared chickens;
- Home-reared beef;
- Home-reared pork;
- Home-reared chicken;
- Home-grown vegetable and fruit produce;
- Breast milk; and
- Soil (incidental).

3.3.10 The inclusion of all food groups in the assessment is a reasonable worst case assumption that both arable and pasture land are present in the vicinity of the predicted maximum annual average ground level concentration. Realistically this is a highly unlikely scenario, however this has been adopted to reduce the possibility of exposures being underestimated. The HHRAP only considers exposure through ingestion of home-reared meat and animal products for farmers and the families of farmers. In addition, the HHRAP only considers exposure through ingestion of fish when a local waterbody is present and fish from the waterbody is used to supplement the diet of a fisher (and family), for example trout or salmon farms. There are no waterbodies in close proximity to the site where fish caught will supplement the diet of receptor on a regular basis. For this reason, a fisher receptor has been excluded from the assessment.

Emissions of Compounds Of Potential Concerns (COCP)

Compounds of Potential Concern

3.3.11 The substances which have been considered in this assessment are referred to as Compounds of Potential Concern (COPCs). Substances included in this assessment are those detailed in the EPA HHRAP COPC database for the assessment of long-term likely health effects. For REP, , the following have been considered as COPCs:

- PCDD/Fs (individual congeners) and dioxin-like PCBs;
- Benzo(a)pyrene;
- Antimony (Sb);
- Arsenic (As);
- Cadmium (Cd);
- Chromium (Cr), trivalent and hexavalent;
- Mercury (Hg);
- Lead (Pb); and
- Nickel (Ni).
- Thallium (Tl)

Source Parameters

3.3.12 REP would comprise two individual flues combined within a single stack. Source parameters are consistent with those used for the air quality assessment, and shown in **Table C.3.1**.

Table C.3.1: Emission Source Parameters

Parameter	Flue 1	Flue 2
Discharge Location (m)	549461, 180749	549455, 180749
Stack height (m)	90	
Internal Stack Diameter (m)	2.2	
Flue gas velocity (m/s)	19.6	
Oxygen (wet) (%v/v)	5.0	
Oxygen (dry) (%v/v)	6.4	
Moisture Content (%v/v)	21.4	

Parameter	Flue 1	Flue 2
Temperature (°C)	120	
Actual flow rate each (Am³/s)	74.45	
Normalized flow rate, dry, 11% oxygen each (Nm³/s)	59.54	

Metals Emissions

3.3.13 The individual emissions concentrations for metals considered in the HHRA are presented in **Table C.3.2**. For Group 1 metals (cadmium and thallium) and Group 2 metals (mercury), these have been derived from information provided in Defra report on Emissions from Waste Management Facilities[1]. For Group 3 metals, emissions have been derived from information provided by Environmental Agency[2]. Some of the Group 3 metals are excluded from this assessment as they pose little or no likely health effects in long term and as such are not included within the EPA HHRAP COPC database; these are cobalt, copper, manganese, and vanadium. This approach of estimating emission rates is different to that used for the air quality assessment.

Table C.3.2: Emission Concentrations and Rates for Metals Used in the HHRAP

Pollutant	Emission Concentration (mg/Nm³)	Emission Rate from REP stack (g/s)
Antimony [a]	0.00~~1~~14	1.67×10^{-4}
Arsenic [a]	0.001	1.19×10^{-4}
Cadmium [b]	0.0014	1.61×10^{-4}
Chromium III [b]	0.011~~300~~	1.31×10^{-3}
Chromium VI [a]	0.000035	4.17×10^{-6}
Lead [a]	0.0109	1.30×10^{-3}
Mercury [b]	0.0032	3.81×10^{-4}
Nickel [a]	0.015	1.79×10^{-3}
Thallium [b]	0.0014	1.61×10^{-4}

[1] WR0608 Emissions from Waste Management Facilities, Report for Defra, ERM (July 2011)

[2] Appendix A of Guidance on assessing group 3 stack emissions from incinerators, Environmental Agency (version 4.0)

[a] Mean measured concentrations from Table A1 Appendix A of guidance on assessing group 3 stack emissions from incinerators
[b] Derived from WR0608 Emissions from Waste Management Facilities, Report for Defra, ERM (July 2011)

3.3.14 The loss of mercury to the global cycle has been accounted for in accordance with the HHRAP methodology. It is therefore assumed that of the total mercury emitted, 51.8% is lost to the global cycle, 48.0% is deposited as divalent mercury and 0.2% is emitted as elemental mercury. Human exposure to elemental mercury is only considered in the IRAP model to occur through direct inhalation of the vapour phase elemental form. Human exposure of divalent mercury occurs through direct and indirect inhalation pathways in the form of vapour and particle-bound mercuric chloride. The following emission rates for mercury have been assumed:

- Elemental mercury at 7.62×10^{-7} g/s
- Mercuric chloride at 1.83×10^{-4} g/s

PCDD/Fs and Other Organic Emissions

3.3.15 The term dioxins described a family of compounds consisting of 75 individual dioxins. Each dioxin compound comprises two benzene rings interconnected with two oxygen atoms. The position of chlorine or other halogen atoms on the benzene rings distinguishes each dioxin compound from one another.

3.3.16 Furans have a similar structure to dioxins. There are 135 individual furan compounds.

3.3.17 Individual dioxin and furan compounds are referred to as congeners. The toxicity and physical properties in relation to atmospheric behaviour are different for each congener. It is therefore important that the exposure methodology determines the fate and transport of PCDD/Fs on a congener specific basis. This is done by taking account of the varying volatility and toxicity of different congeners. Therefore, information is required on a congener specific basis for the PCDD/F annual mean ground level concentrations. A standard congener profile for municipal waste incinerators is presented in **Table C.3.3** for the purposes of this assessment. The international toxic equivalency factors as provided within Industrial Emissions Directive (2010/75/EU)[3] have been used to derive the toxic equivalent emissions (I-TEQ). As a reasonable worst-case assumption, the PCDD/F emissions are at the maximum emission limit of 0.1 ng I-TEQ/Nm^3.

Table C.3.3: PCDD/F Congener Profile for the Facility

Congener	Annual Mean Emission Concentration (ng/Nm^3) [a]	I-TEF Toxic Equivalent Factors	Annual Mean Emission Concentration (ng I-TEQ/Nm^3)
2,3,7,8-TCDD	0.0031	1.0	0.0031
1,2,3,7,8-PeCDD	0.025	0.5	0.012
1,2,3,4,7,8-HxCDD	0.029	0.1	0.0029

[3] Industrial Emissions Directive. Directive 2010/75/EU of the European Parliament and the Council

Congener	Annual Mean Emission Concentration (ng/Nm^3) [a]	I-TEF Toxic Equivalent Factors	Annual Mean Emission Concentration (ng I-TEQ/Nm^3)
1,2,3,7,8,9-HxCDD	0.021	0.1	0.0021
1,2,3,6,7,8-HXCDD	0.026	0.1	0.0026
1,2,3,4,6,7,8-HpCDD	0.17	0.01	0.0017
OCDD	0.40	0.001	0.00040
2,3,7,8-TCDF	0.027	0.1	0.0028
2,3,4,7,8-PeCDF	0.054	0.5	0.027
1,2,3,7,8-PeCDF	0.028	0.05	0.0014
1,2,3,4,7,8-HxCDF	0.22	0.1	0.022
1,2,3,7,8,9-HxCDF	0.0042	0.1	0.00040
1,2,3,6,7,8-HxCDF	0.081	0.1	0.0081
2,3,4,6,7,8-HxCDF	0.087	0.1	0.0087
1,2,3,4,6,7,8-HpCDF	0.44	0.01	0.0044
1,2,3,4,7,8,9-HpCDF	0.043	0.01	0.00040
OCDF	0.36	0.001	0.00040
Total (ng/Nm^3)	2.0	-	0.1

[a] Congener profile obtained from Table 7.2a DOE (1996) Risk Assessment of Dioxin Releases from Municipal Waste Incineration Processes Contract No. HMIP/CPR2/41/1/181

3.3.18 For dioxin-like PCBs (aroclor 1016), the total emission has been obtained from the Defra report WR 0608.2. A maximum emission concentration of 3.6×10^{-9} is assumed, based on the information provided in the Defra report. As it is not clear whether this is for total PCBs or dioxin-like PCBs, a reasonable worst-case is assumed to consist entirely of dioxin-like PCBs. It is also considered that this is the total PCB emission and that these data are presented as the toxic equivalent concentration (3.6×10^{-9} mg TEQ/Nm^3). A toxic equivalent factor of 0.1 has been used to provide an actual emission concentration for dioxin-like PCBs (3.6×10^{-8} mg/Nm^3). This equivalence factor is also used to convert the total actual dose back to the toxic equivalent dose.

3.3.19 The pollutant emissions rates for REP, as inputted into the IRAP model, are presented in **Table C.3.4**.

Table C.3.4: PCDD/Fs and Other Organic Emission Rates for REP used in the HHRAP

Congener	Emission Concentration (µng/Nm^{3})	Emission Rate (g/s)
2,3,7,8-TCDD	3.10×10^{-9}	3.69×10^{-10}
1,2,3,7,8-PeCDD	2.50×10^{-8}	2.98×10^{-9}
1,2,3,4,7,8-HxCDD	2.90×10^{-8}	3.45×10^{-9}
1,2,3,7,8,9-HxCDD	2.10×10^{-8}	2.50×10^{-9}
1,2,3,6,7,8-HxCDD	2.60×10^{-8}	3.10×10^{-9}
1,2,3,4,6,7,8-HpCDD	1.70×10^{-7}	2.02×10^{-8}
OCDD	4.00×10^{-7}	4.76×10^{-8}
2,3,7,8-TCDF	2.80×10^{-8}	3.33×10^{-9}
2,3,4,7,8-PeCDF	5.40×10^{-8}	6.43×10^{-9}
1,2,3,7,8-PeCDF	2.80×10^{-8}	3.33×10^{-9}
1,2,3,4,7,8-HxCDF	2.20×10^{-7}	2.62×10^{-8}
1,2,3,7,8,9-HxCDF	4.20×10^{-9}	5.00×10^{-10}
1,2,3,6,7,8-HxCDF	8.10×10^{-8}	9.65×10^{-9}
2,3,4,6,7,8-HxCDF	8.70×10^{-8}	1.04×10^{-8}
1,2,3,4,6,7,8-HpCDF	4.40×10^{-7}	5.24×10^{-8}
1,2,3,4,7,8,9-HpCDF	4.30×10^{-8}	5.12×10^{-9}
OCDF	3.60×10^{-7}	4.29×10^{-8}
Substance	**Emission Concentration (mg/Nm^{3})**	**Emission Rate (g/s)**
Benzo(a)pyrene	2.10×10^{-4}	2.50×10^{-5}
aroclor1016	3.60×10^{-8}	4.29×10^{-9}
Antimony [1]	0.0014	1.67×10^{-4}
Arsenic [1]	0.0010	1.19×10^{-4}

Cadmium [2]	0.0014	1.61×10^{-4}
Chromium III [3]	0.0110	1.31×10^{-3}
Chromium VI [1]	0.0000	4.17×10^{-6}
Lead [1]	0.0109	1.30×10^{-3}
Mercury [4]	0.0032	3.81×10^{-4}
Nickel [1]	0.0150	1.79×10^{-3}
Thallium [2]	0.0014	1.61×10^{-4}

[1] Mean value has been used from the Case specific screening listed in Appendix A of EA Guidance on assessing group3 metal stack emissions

[2] Assuming 2.7% of relevant group as from WR0608 Emissions from Waste Management Facilities, Report for Defra, ERM (July 2011)

[3] Assuming 2.2% of relevant group as from WR0608 Emissions from Waste Management Facilities, Report for Defra, ERM (July 2011)

[4] Assuming 6.4% of relevant group as from WR0608 Emissions from Waste Management Facilities, Report for Defra, ERM (July 2011)

Dispersion Modelling

3.3.20 The air quality assessment has utilised the UK Atmospheric Dispersion Modelling System (ADMS, version 5.2.2) to predict ground level pollutant concentrations. The IRAP model has been designed only to accept output files from the US EPA ISC or AERMOD dispersion models. The following procedure has been used to generate model files from the ADMS outputs suitable for input into the IRAP model:

- Generation of AERMOD input and output files for the study area;
- Generation of ADMS output data using the approach outlined in the HHRAP;
- Inserting the ADMS results into the AERMOD output files.

3.3.21 All emission properties, building heights and other relevant factors are the same as those used in the air quality assessment. The building heights used are the worst-case Rochdale envelope for conservative results. The HHRAP requires information on deposition, in addition to airborne pollutant concentrations. The ADMS model has therefore been run to predict the following:

- Airborne concentrations of vapour, particle and particle-bound pollutants emitted;
- The wet deposition rate of vapour, particle and particle-bound pollutants; and
- The dry-deposition rate of vapour, particle and particle-bound pollutants.

3.3.22 For dry deposition of particles and particle bound contaminants a fixed deposition velocity of 0.01 m/s has been used.

Dispersion Modelling Results

3.3.23 A summary of dispersion modelling results relevant to the risk assessment are presented in **Table C.3.5**. Out of the five years of London City Airport meteorological data used in the air quality assessment, predicted annual mean concentrations for REP were the highest using the 2017 dataset. The 2017 dataset has therefore also been selected for the risk assessment.

Table C.3.5: Maximum Annual Average Particle Phase Concentrations and Particle Phase Deposition Rates

Pollutant	Maximum Annual Average Concentration	Maximum Annual Average Deposition
Metals and PAHs	**(ng/m^3)**	**(mg/m^2 year)**
Antimony	0.0092	0.0291
Arsenic	0.0065	0.0208
Cadmium	0.0088	0.0280
Chromium III	0.0720	0.2284
Chromium VI	0.0002	0.0007
Lead	0.0714	0.2263
Mercury	0.0209	0.0664
Nickel	0.0982	0.3114
Thallium	0.0088	0.0280
Benzo(a)pyrene	0.0014	0.0044
PCDD/Fs and Dioxin-like PCBs	**(fg/m^3)**	**(ng/m^2 year)**
2,3,7,8-TCDD	0.0203	0.0644
1,2,3,7,8-PeCDD	0.1637	0.5190
1,2,3,4,7,8-HxCDD	0.1899	0.6020
1,2,3,7,8,9-HxCDD	0.1375	0.4360
1,2,3,6,7,8-HxCDD	0.1702	0.5398
1,2,3,4,6,7,8-HpCDD	1.1130	3.5292
OCDD	2.6187	8.3040

Pollutant	Maximum Annual Average Concentration	Maximum Annual Average Deposition
2,3,7,8-TCDF	0.1833	0.5813
2,3,4,7,8-PeCDF	0.3535	1.1210
1,2,3,7,8-PeCDF	0.1833	0.5813
1,2,3,4,7,8-HxCDF	1.4403	4.5672
1,2,3,7,8,9-HxCDF	0.0275	0.0872
1,2,3,6,7,8-HxCDF	0.5303	1.6816
2,3,4,6,7,8-HxCDF	0.5696	1.8061
1,2,3,4,6,7,8-HpCDF	2.8806	9.1344
1,2,3,4,7,8,9-HpCDF	0.2815	0.8927
OCDF	2.3569	7.4736
aroclor1016	0.2357	0.7474

C.3.4. Input Parameters for the IRAP Model

3.4.1 The IRAP model requires a range of input parameters to be defined, including:

- The physical and chemical properties of the COPCs;
- Site information, including site specific data;
- Receptor information – for each receptor type (e.g. adult or child, resident, farmer or fisher)

3.4.2 IRAP provides default input values for the parameters. These input values are based upon the HHRAP and have been used for the majority of parameters in this assessment.

Input Parameters for the COPCs

3.4.3 A database of the physical and chemical parameters for each of the 206 COPCs is contained within the IRAP model. The database is based on the default values provided in the HHRAP and these values have been used in this assessment.

3.4.4 Each COPC behaves differently in the environment, and their presence and accumulation in food products (meat, fish, animal products, vegetation, soil and water) varies. An example of the default input parameters for cadmium and 2,3,7,8-TCDD (the most toxic of the PCDD/Fs) are provided in **Table C.3.6**.

Table C.3.6: IRAP input parameters for Cadmium and 2,3,7,8 -TCDD

Parameter Description	Symbol	Units	Cadmium	2,3,7,8-TCDD
Chemical Abstract Number	CAS No.	-	7440-43-9	1746-01-6
Molecular Weight	MW	g/mol	112.4	322
Melting point of chemical	T_m	K	593.2	578.7
Vapour pressure	V_p	atm	5.5×10^{-12}	1.97×10^{-12}
Aqueous solubility	S	mg/L	123000	1.93×10^{-5}
Henry's Law constant	H	atm-m^3 /mol	0.031	3.29×10^{-5}
Diffusivity of COPC in air	D_a	cm^2/s	0.0772	0.104
Diffusivity of COPC in water	Dw	cm^2/s	9.6×10^{-6}	5.6×10^{-6}
Octanol-water partition coefficient	K_ow	-	0.85	6,309,573
Organic carbon-water partition coefficient	K_oc	mL/g	0	3,890,451

Parameter Description	Symbol	Units	Cadmium	2,3,7,8-TCDD
Soil-water partition coefficient	Kd_s	mL/g	75	38,904
Suspended sediments/surface water partition coefficient	Kd_sw	L/kg	75	291,784
Bed sediment/sediment pore water partition coefficient	Kd_bs	mL/g	75	155,618
COPC loss constant due to biotic and abiotic degradation	K_sg	a^{-1}	0	0.03
Fraction of COPC air concentration in vapour phase	f_v		0.009	0.664
Root concentration factor	RCF	mL/g	0	39,999
Plant-soil bioconcentration factor for below ground produce	br_root_veg	-	0.064	1.03
Plant-soil bioconcentration factor for leafy vegetables	br_leafy_veg	-	0.125	0.00455
Plant-soil bioconcentration factor for forage	br_forage	-	0.364	0.00455
COPC air-to-plant biotransfer factor for leafy vegetables	bv_leafy_veg	-	0	65,500
COPC air-to-plant biotransfer factor for forage	bv_forage	-	0	65,500
COPC biotransfer factor for milk	ba_milk	day/kg	6.5×10^{-6}	0.0055
COPC biotransfer factor for beef	ba_beef	day/kg	1.2×10^{-4}	0.026
COPC biotransfer factor for pork	ba_pork	day/kg	1.9×10^{-4}	0.032
Bioconcentration factor for COPC in eggs	Bcf_egg	-	0.0025	0.06
Bioconcentration factor for COPC in chicken	Bcf_chicken	-	0	3.32

Parameter Description	Symbol	Units	Cadmium	2,3,7,8-TCDD
Plant-soil bioconcentration factor for grain	br_grain	-	0.062	0.00455
Plant-soil bioconcentration factor for eggs	br_egg	-	0.0025	0.011
COPC biotransfer factor for chicken	br_chicken	day/kg	0.11	0.019

3.4.5 Toxicity factors (reference doses and unit risk factors) are used in the IRAP model to determine the carcinogenic risk or hazard associated with each COPC via the two exposure pathways - ingestion or inhalation. The toxicity factors for each of the COPCs are provided in **Table C.3.7**.

3.4.6 For non-carcinogenic risk, the Reference Dose (ingestion) and Reference Concentration (inhalation) is used to determine the level of risk associated with each COPC. For carcinogenic risk, the Carcinogenic Slope Factors are used to determine the risk from ingestion, whilst the Unit Risk Factors are used to determine the risk from inhalation.

Table C.3.7: Toxicity Factors for the COPCs Considered in the Assessment.

COPC	Ingestion Reference Dose	Inhalation Reference Dose	Ingestion Carcinogenic Slope Factor	Inhalation Unit Risk Factor
Symbol	**RfD**	**RfC**	**Ing_csf**	**Inh_URF**
Units	**mg kg^{-1} d^{-1}**	**mg m^{-3}**	**kg d mg^{-1}**	**m^3 μg^{-1}**
Metals				
Antimony	0.0004	0.0014	0	0
Arsenic	0.0003	0.00003	1.5	0.0043
Cadmium	0.0004	0.0002	0.38	0.0018
Chromium III	1.5	5.3	0	0
Chromium VI	0.003	0.000008	0	0.012
Lead	0.000429	0.0015	0.0085	0.000012
Nickel	0.02	0.0002	0	0.00024
Thallium	0.00008	0	0	0

COPC	Ingestion Reference Dose	Inhalation Reference Dose	Ingestion Carcinogenic Slope Factor	Inhalation Unit Risk Factor
Elemental Mercury	0.0000857	0.0003	0	0
Mercuric Chloride	0.0003	0.0011	0	0
Methyl Mercury	0.0001	0.00035	0	0
Benzo(a)pyrene	0	0	7.3	0.0011
PCDD/Fs				
2,3,7,8-TCDD	1×10^{9}	0	150000	38
1,2,3,7,8-PeCDD	0	0	150000	38
1,2,3,4,7,8-HxCDD	0	0	15000	3.8
1,2,3,7,8,9-HxCDD	0	0	6200	3.8
1,2,3,6,7,8-HXCDD	0	0	6200	3.8
1,2,3,4,6,7,8-HpCDD	0	0	1500	0.38
OCDD	0	0	15	0.011
2,3,7,8-TCDF	0	0	15000	3.8
2,3,4,7,8-PeCDF	0	0	75000	11.4
1,2,3,7,8-PeCDF	0	0	7500	1.14
1,2,3,4,7,8-HxCDF	0	0	15000	3.8
1,2,3,7,8,9-HxCDF	0	0	15000	3.8
1,2,3,6,7,8-HxCDF	0	0	15000	3.8
2,3,4,6,7,8-HxCDF	0	0	15000	3.8
1,2,3,4,6,7,8-HpCDF	0	0	15000	3.8
1,2,3,4,7,8,9-HpCDF	0	0	1500	0.38
OCDF	0	0	15	0.011
Aroclor 1016	7×10^{-5}	2.5×10^{-4}	0	0

COPC	Ingestion Reference Dose	Inhalation Reference Dose	Ingestion Carcinogenic Slope Factor	Inhalation Unit Risk Factor
Aroclor 1254	2×10^{-5}	7×10^{-5}	0	0

REP Site Specific Parameters

3.4.7 Information regarding the REP site location and its surroundings are required in the IRAP model. The following parameters are required:

- The proportion of animal feed (grain, silage and forage) grown on contaminated soils and the quantity of animal feed and soil consumed by the various animal species considered.
- The interception fraction for above ground vegetation, forage and silage and length of vegetation exposure to deposition. The yield/ standing crop biomass is also required.
- Input data for assessing risks associated with breast milk, including:
  - body weight of infant;
  - exposure duration;
  - proportion of ingested COPC stored in fat;
  - proportion of mother's weight that is fat;
  - fraction of fat in breast milk;
  - fraction of ingested contaminant that is absorbed; and
  - half-life of dioxins in adults and ingestion rate of breast milk.
  - other physical parameters (e.g. soil dry bulk density, density of air, soil mixing zone depth).

3.4.8 The IRAP default values, based on the HHRAP, have been used for these parameters. A number of parameters related to the REP site location are also required which do not have default values included in the IRAP model as these are site specific and affect the take-up of the pollutants. These parameters include:

- Annual average evapotranspiration rate of 49 cm/annum (assumed to be 70% of total precipitation);
- Annual average irrigation of 0 cm/annum;
- Annual average precipitation of 74 cm/annum (based on local meteorological data for London City Airport for 2017);
- Annual average runoff of 7 cm/annum (assumed to be 10% of total precipitation);

- An annual average wind velocity of 3.94.6 m/s (based on 2017 London City meteorological data); and

- Soil mixing zone depth and soil mixing zone depth for produce of 2 cm has been used

Receptor Information

3.4.9 There are two receptor types included in the IRAP model: resident and farmer. These receptor types are then further subdivided into adult or child receptors. For each receptor type considered in the assessment, the following information is required:

- Food (meat, dairy products and vegetables), water and soil consumption rates for each receptor type. Only farmers are assumed to consume locally-reared animals.

- Fraction of contaminated food, water and soil consumed by each receptor type.

- Input data for inhalation and ingestion exposure including: exposure duration, exposure frequency and exposure time. For inhalation, exposure rate is also considered and for ingestion the body weight of a receptor is taken into account.

3.4.10 The default IRAP values, based on the HHRAP, have been used to define the characteristics of receptors in this assessment.

C.3.5. Exposure Assessment

Selection of Receptors

3.5.1 The IRAP model allows the user to identify and categorise land use areas to be considered in the assessment (e.g. farmland, urban area, waterbodies). The area within the immediate vicinity of REP is industrial in nature and residential exposure is limited. The closest residential areas to the REP site are located within Belvedere to the south-east of the site, at Thamesmead to the west and Rainham to the north-east. There are also residential areas located at Abbey Wood, Dagenham, Creekmouth, Erith, Lessness Heath, Northumberland Heath, South Hornchurch and Wennington. Therefore, eleven areas in total have been considered in the assessment.

3.5.2 The area surrounding the REP site is predominantly urban in nature and therefore farming areas are limited. However, areas to the east and south east of the site have been identified as farming areas, including Rainham Marshes and Crayford Marshes. Therefore, two areas defined as farming areas have been considered in the assessment.

3.5.3 The results of the dispersion modelling are used within the IRAP model to determine the locations of maximum impacts over each defined land-use area. The maximum impacts referred to include maximum predicted air concentrations, wet and dry deposition rates for each phase (particle, particle-bound and vapour phase). Up to nine receptor locations per defined area can be selected, however locations of the various maxima are often co-located leading to anywhere between one and nine receptors being selected for each area.

3.5.4 For REP , 18 residential receptors and 4 farmer receptors have been assessed. Adult and child receptors have been considered for each receptor type. The locations of receptors are described in **Table C.3.8**. Predicted hazards and risks for locations outside of the assessed areas will be lower than those at locations considered in the assessment.

Table C.3.8: Sensitive Receptors Considered in the Assessment

Receptor Name	Receptor ID	Grid Reference	
		x	y
Farmer East	FE	551400	181300
Farmer South East 1	FSE1	553400	178000
Farmer South East 2	FSE2	553300	178000
Farmer South East 3	FSE3	554100	177900
Resident Abbey Wood 1	RAW1	547200	180100
Resident Abbey Wood 2	RAW2	547300	179400
Resident Belvedere 1	RB1	547400	180100

Receptor Name	Receptor ID	Grid Reference	
		x	y
Resident Belvedere 2	RB2	549600	179800
Resident Creekmouth 1	RC1	546500	182200
Resident Creekmouth 2	RC2	547300	183000
Resident Dagenham	RD	550200	183200
Resident Erith	RE	550700	178800
Resident Lessness Heath 1	RLH1	548600	178200
Resident Lessness Heath 2	RLH2	549500	178300
Resident Northumberland Heath 1	RNH1	551100	178000
Resident Northumberland Heath 2	RNH2	551000	178000
Resident Northumberland Heath 3	RNH3	550900	178000
Resident Rainham 1	RR1	552500	181700
Resident Rainham 2	RR2	552100	182100
Resident South Hornchurch	RSH	551200	182700
Resident Thamesmead	RT	547700	180700
Resident Wennington	RW	553900	180900

Assessment of Non-Carcinogenic and Carcinogenic Risk

Non-Carcinogenic Risk

3.5.5 The non-carcinogenic effect of the emissions on human health are assessed in relation to the hazard quotient (HQ). The HQ for the ingestion exposure pathway is calculated by dividing the Average Daily Dose (ADD) by the reference dose (RfD).

$$HQ = \frac{ADD}{RfD}$$

3.5.6 For inhalation, the HQ is calculated by dividing the Exposure Concentration (EC) by the reference concentration (RfC). The reference doses and reference concentrations for each COPC are presented in **Table C.3.7**.

$$HQ = \frac{EC}{RfC}$$

3.5.7 The HQ's for each COPC and exposure pathway are combined to generate a Hazard Index (HI). A HI equal to the criterion value of 1.0 indicates a potential health effect as the maximum daily intake would be equal to the reference dose. The HI is the sum of the individual COPC/pathway HQs and assumes that there are no synergistic or antagonist health effects arising from the release. In addition, a lower HI is interpreted as a lesser risk to human health.

Carcinogenic Risk

3.5.8 Carcinogenic risk relates to the increased lifetime risk associated with the total dose received by receptors as a result of exposure to REP 's emissions. For each COPC, the USEPA has calculated a Carcinogenic Slope Factor (CSF). These are calculated for ingestion exposure whereas for inhalation exposure, a Unit Risk Factor (URF) has been adopted.

$$Risk = ADD \times CSF$$

Where ADD is the sum of the average daily dose from all ingestion exposure routes

$$Risk = EC \times CSF$$

Where EC is the exposure concentration

3.5.9 A summary of the factors used in this assessment are provided in **Table C.3.7**. These factors are used for to calculate the carcinogenic risk for each pollutant and exposure pathway. The risk associated with ingestion exposure to any contaminant is calculated by multiplying ADD with the CSF. The risk associated with inhalation is calculated by multiplying EC with URF.

3.5.10 Where the CSF or URF is zero, this indicates that the COPC is non-carcinogenic via the exposure route.

Impact Assessment for REP

Assessment of Non-Carcinogenic Effects

3.5.11 The HI calculated by IRAP for emissions from REP for each of the receptors (adult and child) is presented in **Table C.3.9**. The HIs are well below the criterion of 1.0 so the risk of likely adverse non-carcinogenic effects resulting for REP is considered to be highly unlikely. The largest predicted HI occurs for the Farmer East Child and Rainham 1 Child. These represent 0.5% and 0.12% of the assessment criterion of 1.0. Therefore, the risk can be considered negligible.

Table C.3.9: Hazard Index for Resident and Farmer Receptors

Receptor Name	Hazard Index (HI)	
	Adult	Child
Farmer East	**0.00340**	**0.00502**
Farmer South East 1	0.00073	0.00108
Farmer South East 2	0.00072	0.00106
Farmer South East 3	0.00068	0.00100
Resident Abbey Wood 1	0.00021	0.00031
Resident Abbey Wood 2	0.00011	0.00016
Resident Belvedere 1	0.00022	0.00032
Resident Belvedere 2	0.00015	0.00040
Resident Creekmouth 1	0.00012	0.00017
Resident Creekmouth 2	0.00009	0.00014
Resident Dagenham	0.00020	0.00029
Resident Erith	0.00017	0.00025
Resident Lessness Heath 1	0.00011	0.00016
Resident Lessness Heath 2	0.00013	0.00019
Resident Northumberland Heath 1	0.00011	0.00017
Resident Northumberland Heath 2	0.00012	0.00018
Resident Northumberland Heath 3	0.00012	0.00019
Resident Rainham 1	0.00062	0.00090
Resident Rainham 2	**0.00087**	**0.00127**
Resident South Hornchurch	0.00065	0.00096
Resident Thamesmead	0.00046	0.00068
Resident Wennington	0.00016	0.00023

Receptor Name	Hazard Index (HI)	
	Adult	Child
Criterion	**1.0**	

Assessment of Likely Carcinogenic Effects

3.5.12 The total lifetime risk for emissions from REP for the most impacted of the receptors is shown in Table **C.3.10**. These were the Farmer East (1 in 181,333) and Rainham 1 adult (1 in 9,576,709). Expressed as an annual risk, these risk estimates become 12,993,347 and 670,369,661assuming a lifetime of 70 years. Such risks are well within an annual risk of 1 in 1 million conventionally acceptable for industrial regulation in UK[4].

Table C.3.10: Total Lifetime Risk for Resident and Farmer Receptors

Receptor Name	Lifetime Risk	
	Adult	Child
Farmer East	**5.51E-06**	**1.19E-06**
Farmer East	1.20E-06	2.58E-07
Farmer South East 1	1.19E-06	2.55E-07
Farmer South East 2	1.12E-06	2.41E-07
Farmer South East 3	2.66E-08	1.38E-08
Resident Abbey Wood 1	1.46E-08	7.68E-09
Resident Abbey Wood 2	2.80E-08	1.45E-08
Resident Belvedere 1	5.00E-08	3.03E-08
Resident Belvedere 2	1.56E-08	8.17E-09
Resident Creekmouth 1	1.27E-08	6.77E-09
Resident Creekmouth 2	2.65E-08	1.39E-08
Resident Dagenham	2.09E-08	1.09E-08
Resident Erith	1.30E-08	6.63E-09
Resident Lessness Heath 1	1.69E-08	8.89E-09

[4] Risk Assessment for Environmental Professionals, CIWEM Publication (December 2001)

Receptor Name	Lifetime Risk	
	Adult	**Child**
Resident Lessness Heath 2	1.47E-08	7.66E-09
Resident Northumberland Heath 1	1.56E-08	8.13E-09
Resident Northumberland Heath 2	1.67E-08	8.77E-09
Resident Northumberland Heath 3	7.39E-08	3.75E-08
Resident Rainham 1	**1.04E-07**	**5.31E-08**
Resident Rainham 2	8.17E-08	4.21E-08
Resident South Hornchurch	5.83E-08	3.00E-08
Resident Thamesmead	1.95E-08	9.99E-09
Resident Wennington	5.51E-06	1.19E-06
Criterion	**7.0×10^{-5}**	

Exposure to Dioxins, Furans and Dioxin-like PCBs

3.5.13 In relation to dioxins/furans, the World Health Organisation (WHO) recommends a tolerable daily intake of 1 to 4 pg I-TEQ kgBW/day (picogrammes as the International Toxic Equivalent per kilogram bodyweight per day). In addition, the Committee on Toxicity (COT) recommends a TDI of 2 pg I-TEQ kgBW/day.

3.5.14 **Table C.3.11** compares the total daily intakes of COPCs with the COT and WHO criteria for the worst affected receptors. For the worst affected farmer receptor, the average daily intake is a maximum of 4.2% of the COT TDI and for the worst affected resident receptor, the average daily intake is a maximum of less than 0.3% of COT TDI.

Table C.3.11: Average and Total Daily Intakes for Dioxins/Furans (pg I-TEQ kgBW/day)

Receptor Name	Average Daily Intake	
	Adult	**Child**
Farmer East	**0.0578132**	**0.0847192**
Farmer South East 1	0.0127681	0.0187322
Farmer South East 2	0.0126049	0.0184930
Farmer South East 3	0.0118904	0.0174440
Resident Abbey Wood 1	0.0004286	0.0013772
Resident Abbey Wood 2	0.0002413	0.0007777
Resident Belvedere 1	0.0004516	0.0014514

Receptor Name	Average Daily Intake	
	Adult	Child
Resident Belvedere 2	0.0010744	0.0034643
Resident Creekmouth 1	0.0002563	0.0008256
Resident Creekmouth 2	**0.0002150**	**0.0006946**
Resident Dagenham	0.0004385	0.0014129
Resident Erith	0.0003375	0.0010846
Resident Lessness Heath 1	0.0002025	0.0006482
Resident Lessness Heath 2	0.0002792	0.0008995
Resident Northumberland Heath 1	0.0002388	0.0007680
Resident Northumberland Heath 2	0.0002543	0.0008184
Resident Northumberland Heath 3	0.0002757	0.0008881
Resident Rainham 1	0.0011455	0.0036642
Resident Rainham 2	0.0016199	0.0051834
Resident South Hornchurch	0.0013020	0.0041790
Resident Thamesmead	0.0009270	0.0029746
Resident Wennington	0.0003070	0.0009841
WHO TDI	**1 to 4 pg I-TEQ kg-BW^{-1} d^{-1}**	
COT TDI	**2 pg I-TEQ kg-BW^{-1} d^{-1}**	

Infant Breast Milk Exposure to Dioxins and Furans

3.5.15 Another exposure pathway of interest is infant exposure to PCDDs and PCDFs via the ingestion of their mother's breast milk. This is because the potential for contamination of breast milk is particularly high for dioxin-like compounds such as these, as they are extremely fat soluble and hence likely to accumulate in breast milk. Further, the infant body weight is smaller and it could be argued that the effect is therefore proportionately greater than in an adult.

3.5.16 This exposure is measured by the Average Daily Dose (ADD) on the basis of averaging time of 1 year. In US, a threshold value of 50 pg/kg.day of 2,3,7,8-TCDD TEQ is cited as being potentially harmful. The IRAP model calculates the ADD that would result from an adult receptor breast feeding an infant. A summary of the ADD for each of the infants of the adult receptors considered for the assessment is presented in Table below.

3.5.17 The calculated ADDs for residential receptors are substantially lower compared to the farmer receptors since the most significant exposure to dioxins/furans is via the food chain, particularly animals and animal products. The farmer receptors are assumed to consume contaminated meat and dairy products. Residential receptors, are however, only assumed to consume vegetable products which are less significant with regards to exposure to dioxins and furans.

Table C.3.12: Assessment of the Average Daily Dose for a Breast-fed infant of an Adult

Receptor Name	Average Daily Dose from Breast Feeding (pg/kg/day of 2,3,7,8-TCDD)
Farmer East	**5.32×10^{-2}**
Farmer South East 1	1.13×10^{-2}
Farmer South East 2	1.12×10^{-2}
Farmer South East 3	1.06×10^{-2}
Resident Abbey Wood 1	2.85×10^{-4}
Resident Abbey Wood 2	1.59×10^{-4}
Resident Belvedere 1	3.00×10^{-4}
Resident Belvedere 2	7.37×10^{-4}
Resident Creekmouth 1	1.69×10^{-4}
Resident Creekmouth 2	1.43×10^{-4}
Resident Dagenham	2.91×10^{-4}
Resident Erith	2.24×10^{-4}
Resident Lessness Heath 1	1.33×10^{-4}
Resident Lessness Heath 2	1.84×10^{-4}
Resident Northumberland Heath 1	1.58×10^{-4}
Resident Northumberland Heath 2	1.68×10^{-4}
Resident Northumberland Heath 3	1.82×10^{-4}
Resident Rainham 1	7.57×10^{-4}
Resident Rainham 2	**1.07×10^{-3}**
Resident South Hornchurch	8.61×10^{-4}
Resident Thamesmead	6.13×10^{-4}
Resident Wennington	2.04×10^{-4}
USEPA	**50**
WHO TDI	**1 to 4**
COT TDI	**2**

3.5.18 The highest intakes for farmer receptor is 0.11% of the US EPA criterion and 0.002% for resident receptor.

C.3.6. Summary and Conclusions

3.6.1 The possible impacts on human health arising from dioxins and furans (PCDD/F), dioxin-like PCBs and trace metals emitted from REP have been assessed under the very worst-case scenario, namely that of an individual exposed for a lifetime to the effects of the highest airborne concentrations and consuming mostly locally grown food. This equates to a hypothetic farmer consuming food grown on limited rural areas within the locality. Therefore, this builds a high degree of conservatism into the assessment. The assessment has also identified more plausible pathways of exposure for the individuals considered (e.g. residents). Deposition and subsequent uptake of COPCs into the locally food chain is likely to be the more numerically significant pathway over direct inhalation.

3.6.2 Values for Hazard Index calculated by IRAP are well below 1.0 and so it is highly unlikely that emissions of COPCs from the facility would cause an adverse non-carcinogenic health risk. The highest HI is predicted for the Farmer East Child which is a factor of around 199 less than unity. As this is 0.5% of the assessment criterion of 1.0, the impacts of the exposure to non-carcinogens is negligible.

3.6.3 The additional, lifetime carcinogenic risk arising from inhalation and ingestion of COPCs were also assessed using US EPA cancer potency factors and unity risk factors and the maximum values for the farmer are 5.51×10^{-6} (1 in 181,333). Expressed as an annual risk, the risk estimates become 12,693,347 assuming a lifetime of 70 years. This assessment indicates that this risk is well within an acceptable level for industrial regulation in UK of 1 in 14,300 (i.e equivalent to an annual risk of 1 in 1,000,000 over a lifetime of 70 years.

3.6.4 The average daily intake of dioxins/furans for the receptors have also been assessed and compared against the COT TDI value of 2 pg I-TEQ $kg\text{-}BW^{-1}d^{-1}$. The highest daily intakes for dioxins/furans is for the farmer east child which is 4.2% of the COT TDI. As for the residential receptor, the highest value is for resident Rainham Child which is around 0.25% and can be considered negligible.