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Consulting Engineers Limited

3R Facility Walsall

BH EnergyGap (Walsall) Limited

Human Health Risk Assessment

ENGINEERING + CONSULTING

Document approval

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Document revision record

Revision no	Date	Details of revisions	Prepared by	Checked by
0	11/09/2019	For Client comment	RDW/SMN	JRS
1	21/10/2019	Updated following Client comments	SMN	JRS

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1 Introduction

BH EnergyGap (Walsall) Limited (BH EnergyGap) were granted an Environmental Permit (EP) for a waste incineration facility (referred to as the 3R Facility), on Fryers Road, Walsall, West Midlands on 22 September 2016. The facility as permitted is referred to as “the Permitted Facility”.

Following further procurement and discussions with technology providers BH EnergyGap is applying for a number of amendments to the EP, including a change in the proposed waste incineration technology and the capacity of the 3R Facility.

Fichtner Consulting Engineers Ltd (Fichtner) has been engaged to undertake a Human Health Risk Assessment (HHRA) to support the Environmental Permit (EP) variation application for the 3R Facility.

As the fuel combusted at the 3R Facility will be sourced from waste, the limits on emissions to air will be based on those outlined in Chapter IV and Annex VI of the Industrial Emissions Directive (IED) (2010/75/EU) for waste incineration and co-incineration plants. This will include limits on emissions of heavy metals and dioxins and furans from the 3R Facility. Within the IED, the requirements of the relevant sector Best Available Techniques Reference document (BREF) become binding as BAT guidance.

The Final Draft Waste incineration BREF was published by the European IPPC Bureau in December 2018. Formal adoption of the BREF is expected in the third quarter of 2019. Upon adoption of the final BREF, the Environment Agency will be required to review and implement conditions within all permits which require operators to comply with the requirements set out in the BREF within four years of adoption. This will apply to the 3R Facility. As currently drafted, the BREF will introduce BAT-Associated Emission Levels (BAT-AELs), some of which are more stringent than the Emission Limit Values (ELVs) currently set out in the IED. It has been assumed that emissions from the 3R Facility will comply with the draft BAT-AELs for new facilities. As the draft BREF had not been published in 2015, the consented impacts of the Permitted Facility are based on emissions at the IED ELVs. As such, a comparison has been made between the impact of the 3R Facility operating at the draft BAT-AELs and the consented impact of the Permitted Facility operating at the IED ELVs.

The advice from health specialists such as the Health Protection Agency that the damage to health from emissions from incineration and co-incineration plants is likely to be very small, and probably not detectable. Nevertheless, the specific effects on human health of the proposed plant have been considered, and are presented in this report.

For most substances released from the 3R Facility, the most significant effects on human health will arise by inhalation. The Air Quality Assessment Levels (AQALs) outlined within the Dispersion Modelling Assessment have been set by the various authorities at a level which is considered to present minimum or zero risk to human health. It is widely accepted that, if the concentrations in the atmosphere are less than the AQALs, then the pollutant is unlikely to have an adverse effect on human health.

For some pollutants which accumulate in the environment, inhalation is only one of the potential exposure routes. Therefore, other exposure routes are considered in this assessment.

2 Issue Identification

2.1 Issue

The key issue for consideration is the release of substances from the 3R Facility to atmosphere which have the potential to harm human health. No other sources will include emissions of either metals or dioxins. The 3R Facility is to be located adjacent to Fryers Road, in Walsall, West Midlands.

The 3R Facility will be designed to meet the draft BAT-AELs outlined in the Draft WI BREF. Limits have been set for pollutants known to be produced during the combustion of municipal waste which have the potential to impact upon the local environment either on human health or ecological receptors. These pollutants include:

- nitrogen dioxide, sulphur dioxide, particulate matter, carbon monoxide, ammonia;
- acid gases - hydrogen chloride, and hydrogen fluoride;
- total organic carbon;
- metals - mercury, cadmium, thallium, antimony, arsenic, lead, cobalt, copper, manganese, nickel and vanadium;
- dioxin and furans;
- dioxin like PCBs; and
- polycyclic aromatic hydrocarbons (PAHs).

For most substances released from the 3R Facility, the most significant effects on human health will arise by inhalation. An Air Quality Assessment has been undertaken to determine the impact of atmospheric concentrations of the pollutants listed above based on the levels transposed under UK Law in the UK Air Quality Strategy and those set by the Environment Agency. These levels have been set at a level which is considered to present minimum or zero risk to human health.

Some pollutants, including dioxins, furans, dioxin-like polychlorinated biphenyls (PCBs) and heavy metals, accumulate in the environment, which means that inhalation is only one of the potential exposure routes. Therefore, impacts cannot be evaluated in terms of their effects on human health by simply reference to ambient air quality standards. An assessment needs to be made of the overall human exposure to the substances by the local population and the risk that this exposure causes.

2.2 Chemicals of Potential Concern (COPC)

The substances which have been considered within this assessment are those which are authorised (as listed above). Although Emission Limit Values (ELVs) for PAHs are not currently set from installations, monitoring is required by legislation in the UK. Therefore, benzo(a)pyrene has been included in the assessment to represent PAH emissions. The following have been considered COPCs for the purpose of this assessment:

- PCDD/Fs (individual congeners) and dioxin like PCBs;
- Benzene;
- Benzo(a)pyrene;
- Mercury (Hg);
- Mercuric chloride;
- Cadmium (Cd);

- Arsenic (As);
- Chromium (Cr), trivalent and hexavalent; and
- Nickel (Ni).

This risk assessment investigates the potential for long term health effect of these COPCs through other routes than just inhalation.

3 Assessment Criteria

A detailed Human Health Risk Assessment has been carried out using the Industrial Risk Assessment Program-Human Health (IRAP-h View – Version 5.0, "IRAP"). IRAP calculates the total exposure through each of the different pathways so that a dose from inhalation and ingestion can be calculated for each receptor. By default, these doses are then used to calculate a cancer risk, using the USEPA's approach. However, the Environment Agency recommends that the results be assessed using the UK's approach, which is explained in the Environment Agency's document "Human Health Toxicological Assessment of Contaminants in Soil", ref SC050021. This approach involves two types of assessment:

- For substances with a threshold level for toxicity, a Tolerable Daily Intake (TDI) is defined. This is "an estimate of the amount of a contaminant, expressed on a bodyweight basis, which can be ingested daily over a lifetime without appreciable health risk." A Mean Daily Intake (MDI) is also defined, which is the typical intake from background sources (including dietary intake) across the UK. In order to assess the impact of the 3R Facility, the predicted intake of a substance due to emissions from the 3R Facility is added to the MDI and compared with the TDI.
- For substances without a threshold level for toxicity, an Index Dose (ID) is defined. This is a level of exposure which is associated with a negligible risk to human health. The predicted intake of a substance due to emissions from the 3R Facility is compared directly with the ID without taking account of background levels.

Substances can reach the body either through inhalation or through ingestion (oral exposure) and the body handles chemicals differently depending on the route of exposure. For this reason, different TDI and IDs are defined for inhalation and oral exposure.

The following table outlines the MDIs (the typical intake from existing background sources) for the pollutants released from the 3R Facility. These figures are defined in the "Contaminants in soil: updated collation of toxicology data and intake values for humans" series of toxicological reports, available from the Environment Agency's website. The values for nickel have been taken from the Environment Agency's August 2015 document following the publication of the new expert opinion by the European Food Safety Authority.

Table 1: Mean Daily Intake of Each Substance

Substance	Mean Daily Intake, 70 kg adult (µg/kg bw/day)		Mean Daily Intake, 20 kg child (µg/kg bw/day)	
	Intake Ingestion	Intake, Inhalation	Intake Ingestion	Intake, Inhalation
Arsenic	0.07	0.0002	0.19	0.0005
Benzene	0.04	2.9	0.11	7.4
Benzene(a)pyrene	-	-	-	-
Cadmium	0.19	0.0003	0.5	0.0007
Chromium	1.81	0.0009	4.70	0.002
Chromium VI	0.18	-	0.47	-
Methyl mercury	0.007	-	0.019	-
Mercuric chloride	0.014	-	0.037	-
Nickel	1.9	0.0037	4.96	0.0096

Substance	Mean Daily Intake, 70 kg adult (µg/kg bw/day)		Mean Daily Intake, 20 kg child (µg/kg bw/day)	
	Intake Ingestion	Intake, Inhalation	Intake Ingestion	Intake, Inhalation
Dioxins and dioxin like PCBs	0.7 pg WHO-TEQ/kg bw/day		1.8 pg WHO-TEQ/kg bw/day	

Table 2: Tolerable Daily Intake of Each Substance (µg/kg bw/day)

Substance	Index dose, Ingestion	Index dose, Inhalation	TDI, Ingestion	TDI, Inhalation
Arsenic	0.3	0.002	-	-
Benzene	0.29	1.4	-	-
Benzene(a)pyrene	0.02	0.00007	-	-
Cadmium	-	-	0.36	0.0014
Chromium	-	0.001	3	-
Chromium VI	-	-	3	-
Methyl mercury	-	-	0.23	0.23
Mercuric chloride	-	-	2	0.06
Nickel	-	-	2.8	0.006
Dioxins and dioxin like PCBs	-	-	2 pg WHO-TEQ/kg bw/day	

To allow comparison with the TDI for dioxins, intake values for each dioxin are multiplied by a factor known as the WHO-TEF. A full list of the WHO-TEF values for each dioxin is provided in Table 10.

The following table presents the MDI for an adult and child as a proportion of the TDI.

Table 3: Mean Daily Intake of Each Substance as a % of the TDI

Substance	Mean Daily Intake, 70 kg adult (µg/kg bw/day)		Mean Daily Intake, 20 kg child (µg/kg bw/day)	
	Intake Ingestion	Intake, Inhalation	Intake Ingestion	Intake, Inhalation
Cadmium	53.2%	20.4%	137.7%	52.9%
Chromium	60.5%	-	156.6%	-
Methyl mercury	3.1%	-	8.0%	-
Mercuric chloride	0.7%	-	1.9%	-
Nickel (screening)	68.4%	61.7%	177.1%	159.7%
Nickel (based on monitoring data)	68.4%	12.9%	177.1%	33.3%

Substance	Mean Daily Intake, 70 kg adult (µg/kg bw/day)		Mean Daily Intake, 20 kg child (µg/kg bw/day)	
	Intake Ingestion	Intake, Inhalation	Intake Ingestion	Intake, Inhalation
Dioxins and dioxin like PCBs	35.0%		90.7%	

The TDI for each pollutant has been set at a level which can be ingested daily over a lifetime without appreciable health risk, and the ID for each pollutant without a toxicity threshold has been set at a level which is associated with a negligible risk to human health. Therefore, if the total exposure is less than the TDI or ID for a pollutant, it can be concluded that the impact of the 3R Facility is negligible and the effect is not significant.

As shown, the MDI of cadmium, chromium and nickel from existing sources exceeds the TDI for children. The implications of the MDI exceeding the TDI for these pollutants are discussed below.

3.1 Chromium

The MDI for chromium is set for chromium III and taken from the DEFRA report "Contaminants in Soil: Collation of Toxicological Data and Intake Values for Humans. Chromium". This states that there are no published reports on the adverse effects in humans resulting from ingested chromium III. Almost all toxicological opinion is that chromium III compounds are of low oral toxicity, and indeed the UK Committee on Medial Aspects of Food Policy recommends chromium III in the diet. The World Health Organisation (WHO) have reviewed the daily intake of chromium from foods and found that existing levels do not represent a toxicity problem. The WHO conclude that "in the form of trivalent compounds, chromium is an essential nutrient and is relatively non-toxic for man and other mammalian species".

The DEFRA report explains that the TDI has been derived from the USEPA's Reference Dose of 3 µg/kg bw/day for chromium VI. This is the only explicitly derived safety limit for oral exposures of chromium. DEFRA recommends that the USEPA Reference Dose is applied to all the chromium content as a starting point. Therefore, the TDI presented in

Table 2 is actually the TDI for chromium VI, not total chromium. Assessing the total dietary intake of chromium against this TDI is highly conservative.

3.2 Cadmium

The key determinant of cadmium's toxicity potential is its chronic accumulation in the kidney The Environment Agency in their toxicology report "Contaminants in Soil: Collation of Toxicological Data and Intake Values for Humans. Cadmium" explains that chronic exposure to levels in excess of the TDI might be associated with an increase in kidney disease in a proportion of those exposed, but (small) exceedances lasting for shorter periods are of less consequence. Therefore, assessing a lifetime exposure is appropriate. If we assess the exposure of a receptor over a lifetime (i.e. a period as a child and adult) the lifetime MDI is below the TDI.

3.3 Nickel

The MDI and TDI (oral) for nickel have been revised following the publication by the European Food Safety Authority of new expert opinion relating to the reproductive and developmental effects in experimental animals. The MDI exceeds the TDI for children for both inhalation and ingestion. The updated MDI for inhalation is 0.259 µg/day for an adult which, assuming an inhalation rate of 20 m^3/day, equates to an atmospheric concentration of 13.0 ng/m^3. A review of local monitoring data of nickel has shown that concentrations at the Walsall Bilston Lane urban industrial site are 2.02 ng/m^3 on average, with a maximum of 2.70 ng/m^3. Applying this maximum background concentration from an urban industrial site of 2.70 ng/m^3, the MDI would be 0.05 µg/day or 12.9% of the inhalation TDI for an adult and 33.3% of the TDI for a child. This has been used as the value of the MDI for inhalation for the remainder of this analysis.

4 Conceptual Site Model

4.1 Conceptual site model

IRAP, created by Lakes Environmental, is based on the United States Environment Protection Agency (USEPA) Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities[1]. This Protocol is a development of the approach defined by Her Majesties Inspectorate on Pollution (HMIP) in the UK in 1996[2], taking account of further research since that date. The exposure pathways included in the IRAP model are shown in Table 4.

Exposure to gaseous contaminants has the potential to occur by direct inhalation or vapour phase transfer to plants. In addition, exposure to particulate phase contaminants may occur via indirect pathways following the deposition of particles to soil. These pathways include:

- ingestion of soil and dust;
- uptake of contaminants from soil into the food-chain (through home-grown produce and crops); and
- direct deposition of particles onto above ground crops.

The pathways through which inhalation and ingestion occur and the receptors that have been considered to be impacted via each pathway are shown in the table below.

Table 4: Pathways Considered

Pathway	Residential	Agricultural
Direct inhalation	Yes	Yes
Ingestion of soil	Yes	Yes
Ingestion of home-grown produce	Yes	Yes
Ingestion of drinking water	Yes	Yes
Ingestion of eggs from home-grown chickens	-	Yes
Ingestion of home-grown poultry	-	Yes
Ingestion of home-grown beef	-	Yes
Ingestion of home-grown pork	-	Yes
Ingestion of home-grown milk	-	Yes
Ingestion of breast milk (infants only)	Infants only	

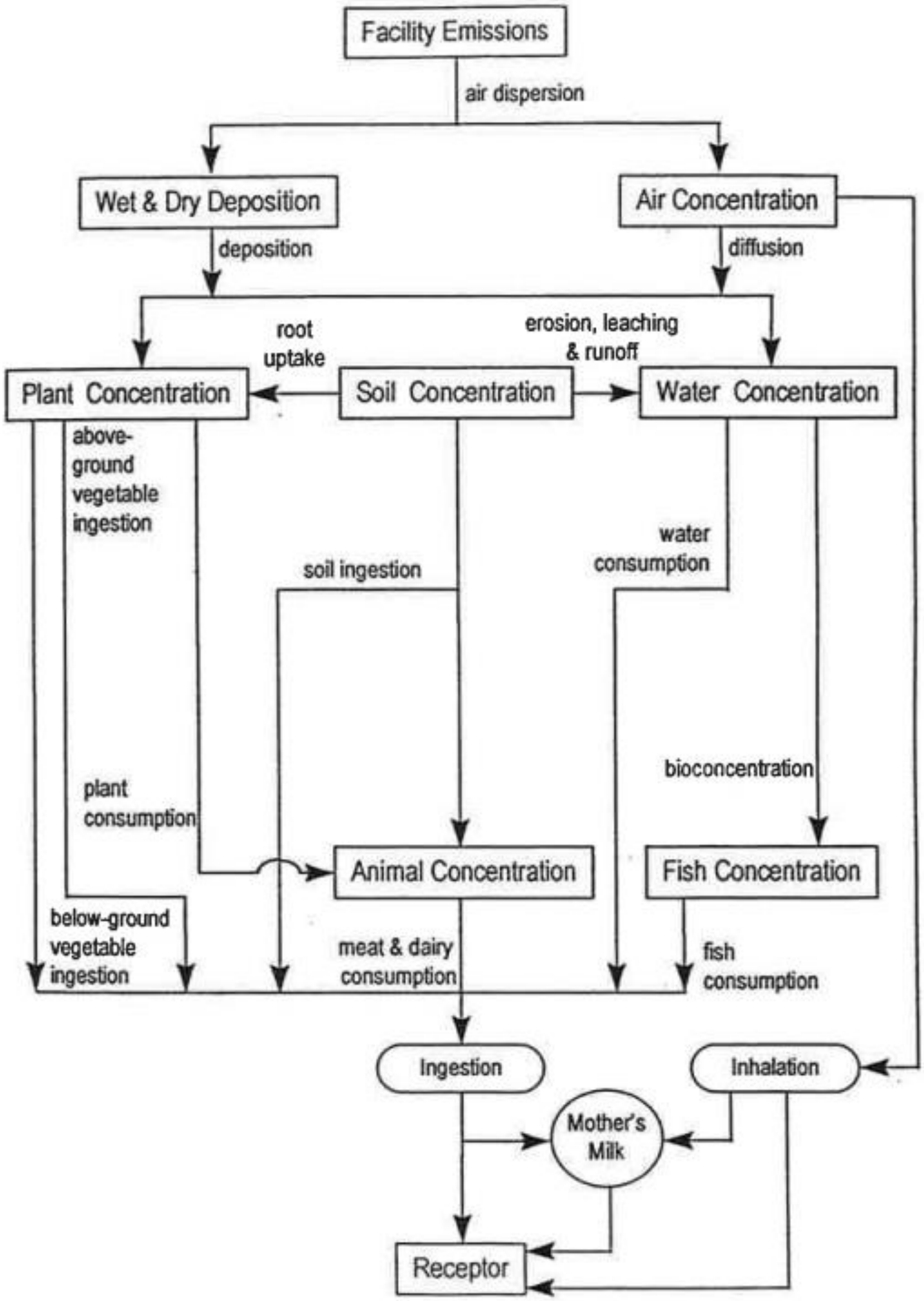
Some households may keep chickens and consume eggs and potentially the birds. The impact on these households is considered to be between the impact at an agricultural receptor and a standard resident receptor. The approach used considers an agricultural receptor at the point of maximum impact as a complete worst case.

As shown in Figure 1, the pathway from the ingestion of mother's milk in infants is considered within the assessment. This considers all dioxins and dioxin-like PCBs. The IRAP model calculates the amount of these COPCs entering the mother's milk and being passed on to the infants. The impacts are then compared against the TDI.

[1] USEPA (2005) Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities.

[2] HMIP (1996) Risk Assessment of Dioxin Releases from Municipal Waste Incineration Processes.

Figure 1: Conceptual Site Model – Exposure Pathways



4.2 Pathways excluded from assessment

The intake of dioxins via dermal absorption, groundwater and surface water exposure pathways is very limited and as such these pathways are excluded from the HHRA. The justification for excluding these pathways is highlighted in the following sections.

4.2.1 Dermal absorption

Both the HMIP and the USEPA note that the contribution from dermal exposure to soils impacted from thermal treatment facilities is typically a very minor pathway and is typically very small relative to contributions resulting from exposures via the food chain.

The USEPA[3] provide an example from the risk assessment conducted for the Waste Technologies, Inc. hazardous thermal treatment in East Liverpool, Ohio. This indicated that for an adult subsidence farmer in a subarea with high exposures, the risk resulting from soil ingestion and dermal contact was 50-fold less than the risk from any other pathway and 300-fold less than the total estimated risk.

The HMIP document[4] provides a screening calculation using conservative assumptions, which states that the intake via dermal absorption is 30 times lower than the intake via inhalation, which is itself a minor contributor to the total risk.

As such the pathway from dermal absorption is deemed to be an insignificant risk and has been excluded from this assessment.

4.2.2 Groundwater

Exposure via groundwater can only occur if the groundwater is contaminated and consumed untreated by an individual.

The USEPA[5] have concluded that the build-up of dioxins in the aquifer over realistic travel times relevant to human exposure was predicted to be so small as to be essentially zero.

As such the pathway from groundwater is deemed to be an insignificant risk and has been excluded from this assessment.

4.2.3 Surface water

A possible pathway is via deposition of emissions directly onto surface water – i.e. local drinking water supplies or rainwater storage tanks.

Surface water generally goes through several treatment steps and as such any contaminants would be removed from the water before consumption. Run off to rainwater tanks may not go through the same treatment. However, rainwater tanks have a very small surface area and as such the potential for deposition and build-up of COPCs is limited. As such, the pathway from contaminated surface water is deemed to be an insignificant risk and has been excluded from this assessment.

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3 USEPA (2005) Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities.

4 HMIP (1996) Risk Assessment of Dioxin Releases from Municipal Waste Incineration Processes.

5 USEPA (2005) Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities.

4.2.4 Fish consumption

The consumption of locally caught fish has been excluded from the assessment. Whilst fish makes up a proportion of the UK diet, it is not likely that this would be sourced wide scale from close proximity to the 3R Facility.

A review of the local waterbodies has been undertaken to see if there are any game fishing lakes in the local area[6]. None have been identified within the modelling domain. The closest game fishing lake is at Gailey Trout Fishery in Stafford, approximately 10 km to the north-west of the 3R Facility. As such, there is no opportunity for individuals to undertake fishing for dietary consumption in close proximity to the Facility. Due to the distance between the Facility and the closest game fishing lake emissions from the 3R Facility would not have a significant impact at this location and as such this pathway has been excluded from this assessment.

[6] Locations Map, http://www.fisharound.net/where-to-fish/locations-map

5 Sensitive Receptors

This assessment considers the possible effects on human health at key receptors, where humans are likely to be exposed to the greatest impact from the 3R Facility, and at the point of maximum impact of annual mean emissions.

For the purposes of this assessment, receptor locations have been categorised as 'residential' or 'agricultural'. Residential receptors represent a known place of residence that is occupied within the study area and agricultural receptors represent a farm holding or area land of horticultural interest. No allotments or fully agricultural areas (i.e. farms) have been identified within the area impacted by the 3R Facility.

A subset of the specific receptors identified in the Air Quality Assessment which are closest to the 3R Facility have been considered in this assessment. In addition, a receptor has been assessed at the point of maximum impact. These sensitive receptors are listed in Table 5. Reference should be made to Appendix B which shows the location of these receptors with respect to the 3R Facility.

Table 5: Sensitive Receptors

ID	Receptor Name	Location		Type of Receptor
		X	Y	
MAX	Point of maximum impact	400240	301510	Agricultural / Residential
R1	Leamore Lane	399136	300941	Residential
R2	Mary Elliot School	399045	301102	Residential
R3	Bloxwich Academy	399025	301291	Residential
R4	Willenhall Lane	399135	301566	Residential
R5	Reeves Street	399556	301680	Residential
R6	Irvine Road	399606	301502	Residential
R7	Blakenall	399593	301183	Residential
R8	Leamore Lane 2	399620	300837	Residential
R9	Bloxwich Hospital	399729	301755	Residential
R10	Castle Business and Enterprise College	399886	301166	Residential
R11	Elmore Green Primary School	399524	302006	Residential
R12	Leamore School	400272	301388	Residential
R13	Christ Church Primary School	400619	301088	Residential
R14	Rough Wood Country Park	400225	301710	Residential
R15	Old Hall School	398447	300222	Residential
R16	Bloxwich West Children School	398878	301856	Residential
R17	Croxstalls Avenue	399301	301802	Residential
R18	Sunshine Infant and Nursery School	400443	301561	Residential

6 IRAP Model Assumptions and Inputs

The following section details the user defined assumptions used within the IRAP model and provides justifications where appropriate.

6.1 Concentrations in soil

The concentration of each chemical in the soil is calculated from the deposition results of the air quality modelling for vapour phase and particle phase deposition. The critical variables in calculating the accumulation of pollutants in the soil are as follows:

- the lifetime of the 3R Facility is taken as 30 years; and
- the soil mixing depth is taken as 2 cm in general and 30 cm for produce.

The split between the solid and vapour phase for the substance considered depends on the specific physical properties of each chemical.

In order to assess the amount of substance which is lost from the soil each year through volatilisation, leaching and surface run-off, a soil loss constant is calculated. The rates for leaching and surface runoff are taken as constant, while the rate for volatilisation is calculated from the physical properties of each substance.

6.2 Concentrations in plants

The concentrations in plants are determined by considering direct deposition and air-to-plant transfer for above ground produce, and root uptake for above ground and below ground produce.

The calculation takes account of the different types of plant. For example, uptake of substances through the roots will differ for below ground and above ground vegetables, and deposition onto plants will be more significant for above ground vegetables.

6.3 Concentrations in animals

The concentrations in animals are calculated from the concentrations in plants, assumed consumption rates and bio-concentration factors. These vary for different animals and different substances, since the transfer of chemicals between the plants consumed and animal tissue varies.

It is also assumed that 100% of the plant material eaten by animals is grown on soil contaminated by emission sources. This is likely to be a highly pessimistic assumption for UK farming practice.

6.4 Concentrations in humans

6.4.1 Intake via inhalation

This is calculated from inhalation rates of typical adults and children and atmospheric concentrations. The inhalation rates used for adults and children are:

- adults - 20m^3/day; and
- children – 7.2m^3/day.

These are as specified within a series of reports published by the Environment Agency titled, “Contaminants in soil: updated collation of toxicology data and intake values for humans”. The calculation also takes account of time spent outside, since most people spend most of their time indoors.

6.4.2 Intake via soil ingestion

This calculation allows for the ingestion of soil and takes account of different exposure frequencies. It allows for ingestion of soil attached to unwashed vegetables, unintended ingestion when farming or gardening and, for children, ingestion of soil when playing.

6.4.3 Ingestion of food

The calculation of exposure due to ingestion of food draws on the calculations of concentrations in animals and plants and takes account of different ingestion rates for the various food groups by different age groups.

For most people, locally produced food is only a fraction of their diet and so exposure factors are applied to allow for this.

6.4.4 Breast milk ingestion

For infants, the primary route of exposure is through breast milk. The calculation draws on the exposure calculation for adults and then allows for the transfer of chemicals in breast milk to an infant who is exclusively breast-fed.

The only pathway considered for dioxins for a breast-feeding infant is through breast milk. The modelled scenario consists of the accumulation of pollutants in the food chain up to an adult receptor, the accumulation of pollutants in breast milk and finally the consumption of breast milk by an infant.

The assumptions used were:

- Exposure duration of infant to breast milk — 1 year
- Proportion of ingested dioxin that is stored in fat — 0.9
- Proportion of mother’s weight that is stored in fat — 0.3
- Fraction of fat in breast milk — 0.04
- Fraction of ingested contaminant that is absorbed — 0.9
- Half-life of dioxins in adults — 2,555 days
- Ingestion rate of breast milk — 0.688kg/day

6.5 Estimation of COPC concentration in media

The IRAP-h model uses a database of physical and chemical parameters to calculate the COPC concentrations through each of the different pathways identified. The base physical and chemical parameters have been used in this assessment.

In order to calculate the COPC concentrations, a number of site specific pieces of information are required.

Weather data was obtained for the period 2014 to 2018 from the Birmingham Airport weather station, as used within the Air Quality Assessment. This provides the annual average precipitation which can be used to calculate the general IRAP-h input parameters, as presented in Table 6.

Table 6: Ground Type Dependent Properties

Input Variable	Assumption	Value (cm/year)
Annual average evapotranspiration	70% of annual average precipitation	45.67
Annual average irrigation	0% of annual average precipitation	0.00
Annual average precipitation	100% of annual average precipitation	65.24
Annual average runoff	10% of annual average precipitation	6.52

The average wind speed was taken as 3.69 m/s, calculated from the average of the five years of weather data.

A number of assumptions have been made with regard to the deposition of the different phases. These are summarised in the following table.

Table 7: Deposition Assumptions

Deposition Phase	Dry Deposition Velocities (m/s)	Ratio Dry deposition to Wet deposition	
		Dry Deposition	Wet Deposition
Vapour	0.005	1.0	2.0
Particle	0.010	1.0	2.0
Bound particle	0.010	1.0	2.0
Mercury vapour	0.029	1.0	0.0
Note: the above deposition velocities have been agreed with the UK Environment Agency for all IRAP based assessments where modelling of specific deposition of pollutants is not undertaken. These are considered to be conservative.			

These deposition assumptions have been applied to the annual mean concentrations predicted using the dispersion modelling which was undertaken as part of the Air Quality Assessment, to generate the inputs needed for the IRAP modelling. For details of the dispersion modelling methodology please refer to the Air Quality Assessment contained as a separate document within the application.

6.6 Modelled emissions

For the purpose of this assessment it is assumed that the 3R Facility operates at the draft BAT-AELs prescribed by the Draft WI BREF for its entire operational life, and the Permitted Facility operates at the ELVs prescribed by the Industrial Emissions Directive (IED). In reality the 3R Facility and Permitted Facility will be shut down for periods of maintenance and monitoring of similar facilities in the UK shows that they operate below the emission limits prescribed in their permits.

The emissions of each of the metals in the third group have been taken as no worse than a currently operating facility as detailed in Table A1 of the Environment Agency "Guidance on assessing group 3 metals stack emissions from incinerators – v4", which is reproduced in Table 8. This data is based on monitoring at 18 MWI and Waste Wood Co-Incinerators between 2007 and 2015 operating under the IED in the UK.

Table 8: Monitoring Data from Municipal Waste Incinerators

Pollutant	Measured Concentration as % of IED Group 3 ELV (i.e. Draft BAT-AEL)		
	Mean	Max	Min
Arsenic	0.33%	8.33%	0.07%
Chromium	2.80%	30.67%	0.07%
Chromium VI	0.012%	0.043%	0.0008%
Nickel	5.00%	73.33%	0.83%
Note: The two highest nickel concentrations are outliers being 73%, as above, and 27% of the draft BAT-AEL. The third highest concentration is 0.053 mg/Nm³ or 18% of the draft BAT-AEL.			

The following tables present the emissions rates of each COPC modelled and the associated emission concentrations which have been used to derive the emission rate.

Table 9: COPC Emissions Modelled – 3R Facility

COPC	Emission Limit Value (mg/Nm³)	Emission rate	Units
Benzene	10	857.20	mg/s
PAHs (Benzo(a)pyrene)	0.0001	9.00	µg/s
Elemental mercury	0.0001	3.43	µg/s
Mercuric chloride	0.010	0.82	mg/s
Cadmium	0.010	0.857	mg/s
Arsenic	0.025	2.14	mg/s
Chromium	0.092	7.89	mg/s
Chromium VI	0.00013	11.14	µg/s
Nickel	0.220	18.86	mg/s
Dioxin like PCBs	0.0092	0.789	ng/s

Table 10: Emission Rates of Dioxins and Furans- 3R Facility

Dioxin / furan	Split of Congeners for a release of 1 ng I-TEQ/Nm³	I-TEFs for the congeners	Emission concentration (ng/Nm³)	Emission rate (ng/s)
2,3,7,8-TCDD	0.031	1	0.002	0.159
1,2,3,7,8-PeCDD	0.245	0.5	0.015	1.260
1,2,3,4,7,8-HxCDD	0.287	0.1	0.017	1.476
1,2,3,6,7,8-HxCDD	0.258	0.1	0.015	1.326
1,2,3,7,8,9-HxCDD	0.205	0.1	0.012	1.054
1,2,3,4,6,7,8-HpCDD	1.704	0.01	0.102	8.761
1,2,3,4,6,7,8,9-OctaCDD	4.042	0.001	0.242	20.782

Dioxin / furan	Split of Congeners for a release of 1 ng I-TEQ/Nm³	I-TEFs for the congeners	Emission concentration (ng/Nm³)	Emission rate (ng/s)
2,3,7,8-TCDF	0.277	0.1	0.017	1.424
1,2,3,7,8-PCDF	0.277	0.05	0.017	1.424
2,3,4,7,8-PCDF	0.535	0.5	0.032	2.751
1,2,3,4,7,8-HxCDD	2.179	0.1	0.131	11.203
1,2,3,6,7,8-HxCDF	0.807	0.1	0.048	4.149
1,2,3,7,8,9-HxCDF	0.042	0.1	0.003	0.216
2,3,4,6,7,8-HxCDF	0.871	0.1	0.052	4.478
1,2,3,4,6,7,8-HpCDF	4.395	0.01	0.264	22.597
1,2,3,4,7,8,9-HpCDF	0.429	0.01	0.026	2.206
1,2,3,4,6,7,8,9-OctaCDF	3.566	0.001	0.214	18.334
Total (I-TEQ)	20.150	-	1.209	103.600
Notes: Split of the Congener taken from Table 7.2a from the HMIP document and factored by the ELV to determine the split for the proposed ELV. This has then been multiplied by the Normalised Volumetric Flow rate to determine the release rate in g/s.				

Table 11: COPC Emissions Modelled – Permitted Facility

COPC	Emission Limit Value (mg/Nm³)	Emission rate	Units
Benzene	10	521.70	mg/s
PAHs (Benzo(a)pyrene)	0.0001	5.48	µg/s
Elemental mercury	0.0001	5.22	µg/s
Mercuric chloride	0.024	1.25	mg/s
Cadmium	0.025	1.30	mg/s
Arsenic	0.025	1.30	mg/s
Chromium	0.092	4.80	mg/s
Chromium VI	0.00013	6.78	µg/s
Nickel	0.220	11.47	mg/s
Dioxin like PCBs	0.0092	0.480	ng/s

Table 12: Emission Rates of Dioxins and Furans– Permitted Facility

Dioxin / furan	Split of Congeners for a release of 1 ng I-TEQ/Nm³	I-TEFs for the congeners	Emission concentration (ng/Nm³)	Emission rate (ng/s)
2,3,7,8-TCDD	0.031	1	0.003	0.162

Dioxin / furan	Split of Congeners for a release of 1 ng I-TEQ/Nm³	I-TEFs for the congeners	Emission concentration (ng/Nm³)	Emission rate (ng/s)
1,2,3,7,8-PeCDD	0.245	0.5	0.024	1.278
1,2,3,4,7,8-HxCDD	0.287	0.1	0.029	1.497
1,2,3,6,7,8-HxCDD	0.258	0.1	0.026	1.346
1,2,3,7,8,9-HxCDD	0.205	0.1	0.020	1.069
1,2,3,4,6,7,8-HpCDD	1.704	0.01	0.170	8.887
1,2,3,4,6,7,8,9-OctaCDD	4.042	0.001	0.404	21.080
2,3,7,8-TCDF	0.277	0.1	0.028	1.445
1,2,3,7,8-PCDF	0.277	0.05	0.028	1.445
2,3,4,7,8-PCDF	0.535	0.5	0.053	2.790
1,2,3,4,7,8-HxCDD	2.179	0.1	0.218	11.364
1,2,3,6,7,8-HxCDF	0.807	0.1	0.081	4.209
1,2,3,7,8,9-HxCDF	0.042	0.1	0.004	0.219
2,3,4,6,7,8-HxCDF	0.871	0.1	0.087	4.542
1,2,3,4,6,7,8-HpCDF	4.395	0.01	0.439	22.921
1,2,3,4,7,8,9-HpCDF	0.429	0.01	0.043	2.237
1,2,3,4,6,7,8,9-OctaCDF	3.566	0.001	0.356	18.598
Total (I-TEQ)	20.150	-	2.014	105.087

Notes:
Split of the Congener taken from Table 7.2a from the HMIP document and factored by the ELV to determine the split for the proposed ELV. This has then been multiplied by the Normalised Volumetric Flow rate to determine the release rate in g/s.

A number of points should be noted for each group of COPCs:

1. **Benzene (Table 9 and Table 11).**
   a. It has been assumed that the entire TOC emissions consist of only benzene.
   b. It has been assumed that TOC emissions are emitted at the daily ELV.
2. **PAHs (Table 9 and Table 11).**
   a. It has been assumed that the entire PAH emissions consist of only benzo(a)pyrene.
   b. Benzo(a)pyrene is not a regulated pollutant within the IED. The highest recorded emission concentration of Benzo(a)pyrene from the UK Environment Agency's public register was 0.105ug/m³, or 0.000105mg/m³ (dry, 11% oxygen, 273K). As this is not a regulated pollutant and only monitored periodically we have applied a safety factor of 2.
3. **Group 1 metals - mercury and compounds (Table 9 and Table 11).**
   a. It has been assumed that the ELV of total mercury is 0.02 mg/Nm³ for the 3R Facility and 0.05 mg/Nm³ for the Permitted Facility.
   b. The concentration of elemental mercury has been taken as 0.2% of the total mercury and compounds ELV for the 3R Facility and the Permitted Facility.

c. The concentration of mercury chloride has been taken as 48% of the total mercury and compounds ELV for the 3R Facility and the Permitted Facility.

d. The losses to the global cycle have been taken as 51.8% of the total mercury and compounds ELV for the 3R Facility and the Permitted Facility.

4. Group 2 metals – cadmium and compounds (Table 9 and Table 11).

a. The assessment is based on the ELV of 0.02 mg/Nm³ for cadmium and compounds for the 3R Facility and 0.05 mg/Nm³ for the Permitted Facility.

b. It is assumed that the emissions of cadmium and thallium are each half of the combined ELV.

5. Group 3 metals – arsenic, chromium, and nickel (Table 9 and Table 11).

The emissions of each of the metals in the third group have been taken as no worse than a currently operating facility as detailed in Table A1 of the Environment Agency "Guidance on assessing group 3 metals stack emissions from incinerators – v4", which is reproduced in Table 8. This data is based on monitoring at 18 MWI and Waste Wood Co-Incinerators between 2007 and 2015 operating under the IED in the UK

6. Dioxin like PCBs (Table 9 and Table 11).

There are a total of 209 PCBs, which act in a similar manner to dioxins, are generally found in complex mixtures and also have TEFs.

The UK Environment Agency has advised that 44 measurements of dioxin like PCBs have been taken at 24 MWIs between 2008 and 2010. The following data summarises the measurements, all at 11% reference oxygen content:

- Maximum = 9.2×10^{-3} ng[TEQ]/m³
- Mean = 2.6×10^{-3} ng[TEQ]/m³
- Minimum = 5.6×10^{-5} ng[TEQ]/m³

For the purpose of this assessment, as a conservative assumption, the maximum monitored PCB concentration has been used which has been converted to an emission rate using the volumetric flow rate at reference conditions.

The IRAP software, and the HHRAP database which underpins it, does not include any data on individual PCBs, but it does include data for take-up and accumulation rates within the food chain for two groups of PCBs, known as Aroclor 1254 and Aroclor 1016. Each Aroclor is based on a fixed composition of PCBs. Since we are not aware of any data on the speciation of PCBs within incinerator emissions, as a worst-case assumption we have assumed that the PCBs are released in each of the two Aroclor compositions.

7. Dioxins and furans (Table 11 and Table 12).

These are a group of similar halogenated organic compounds, which are generally found as a complex mixture. The toxicity of each compound is different and is generally expressed as a Toxic Equivalent Factor (TEF), which relates the toxicity of each individual compound to the toxicity of 2,3,7,8-TCDD, the most toxic dioxin. A full list of the TEF values for each dioxin is provided in Table 10. The total concentration is then expressed as a Toxic Equivalent (TEQ).

The split of the different dioxins and furans is based on split of congeners for a release of 1 ng I-TEQ/Nm³ as presented in Table 10 and Table 12. To determine the Emission Rates, the split of the different dioxins for a 0.06 ng I-TEQ/Nm³ (3R Facility) and 0.10 ng I-TEQ/Nm³ (Permitted Facility) has been multiplied by the normalised volumetric flow rate to determine the release rate of each congener. The output of the IRAP model is then multiplied by the TEFs to determine the total intake TEQ for comparison with the TDI.

7 Results

7.1 Assessment against TDI - point of maximum impact

The following tables present the impact of emissions from the 3R Facility at the point of maximum impact for an 'Agricultural' receptor. As explained in section 3, this receptor type assumes the direct inhalation, and ingestion from soil, drinking water, and home-grown eggs and meat, beef, pork, and milk. This assumes that the person lives at the point of maximum impact and consumes home-grown produce etc. This is considered to be a very worst-case scenario, especially given the industrial nature of the area where this impact is predicted to occur. Reference should be made to Appendix B for the location of the point in relation to the 3R Facility.

Where appropriate a comparison has been made to the TDI or ID.

Table 13: Impact Analysis – TDI – Point of Maximum Impact - Adult

Substance	MDI (% of TDI)		Process Contribution (% of TDI)		Overall (% of TDI)	
	Inhalation	Ingestion	Inhalation	Ingestion	Inhalation	Ingestion
Agricultural						
Cadmium	20.41%	53.17%	0.83%	0.02%	21.24%	53.20%
Chromium	-	60.48%	-	0.24%	-	60.71%
Chromium VI	-	6.05%	-	0.0003%	-	6.05%
Methyl mercury	-	3.11%	-	0.01%	-	3.11%
Mercuric chloride	-	0.71%	-	0.03%	-	0.75%
Mercury	1.19%	-	0.0001%	-	1.19%	-
Nickel	12.86%	68.37%	4.25%	0.44%	17.11%	68.81%
Dioxins and dioxin like PCBs	35.00%		1.51%		36.51%	
Residential						
Cadmium	20.41%	53.17%	0.83%	0.01%	21.24%	53.19%
Chromium	-	60.48%	-	0.02%	-	60.50%
Chromium VI	-	6.05%	-	0.00003%	-	6.05%
Methyl mercury	-	3.11%	-	0.00%	-	3.11%
Mercuric chloride	-	0.71%	-	0.00%	-	0.72%
Mercury	1.19%	-	0.0001%	-	1.19%	-
Nickel	12.86%	68.37%	4.25%	0.04%	17.11%	68.41%
Dioxins and dioxin like PCBs	35.00%		0.03%		35.03%	

Table 14: Impact Analysis – TDI – Point of Maximum Impact - Child

Substance	MDI (% of TDI)		Process Contribution (% of TDI)		Overall (% of TDI)	
	Inhalation	Ingestion	Inhalation	Ingestion	Inhalation	Ingestion
Agricultural						
Cadmium	52.86%	**137.72%**	1.04%	0.05%	53.90%	**137.78%**
Chromium	-	**156.63%**	-	0.38%	-	**157.02%**
Chromium VI	-	15.66%	-	0.0005%	-	15.66%
Methyl mercury	-	8.04%	-	0.02%	-	8.06%
Mercuric chloride	-	1.85%	-	0.05%	-	1.90%
Mercury	3.08%	-	0.0001%	-	3.08%	-
Nickel	33.30%	**177.07%**	5.36%	0.67%	38.66%	**177.74%**
Dioxins and dioxin like PCBs	90.65%		2.13%		92.78%	
Residential						
Cadmium	52.86%	**137.72%**	1.04%	0.04%	53.90%	**137.76%**
Chromium	-	**156.63%**	-	0.05%	-	**156.69%**
Chromium VI	-	15.66%	-	0.0001%	-	15.66%
Methyl mercury	-	8.04%	-	0.01%	-	8.05%
Mercuric chloride	-	1.85%	-	0.01%	-	1.86%
Mercury	3.08%	-	0.0001%	-	3.08%	-
Nickel	33.30%	**177.07%**	5.36%	0.10%	38.66%	**177.17%**
Dioxins and dioxin like PCBs	90.65%		0.11%		90.76%	

The TDI is an estimate of the amount of a contaminant, expressed on a bodyweight basis, which can be ingested daily over a lifetime without appreciable health risk. As shown in Table 13 and Table 14, for the worst-case receptor the overall impact (including the contribution from existing dietary intakes) is less than the TDI for chromium VI, mercury (including compounds) and dioxins. Therefore, there would not be an appreciable health risk based on the emission of these pollutants.

For a child receptor the cadmium, chromium and nickel MDI (that sourced from existing dietary intake) exceeds the TDI. However, the process contribution is exceptionally small and the exceedance is a reflection of the fact the MDI is over 100% of the TDI. On this basis it is not considered that the 3R Facility would increase the health risks from cadmium, chromium or nickel for children significantly. A discussion of the impact from each of these pollutants is provided below.

7.1.1 Cadmium

For cadmium, the MDI for ingestion exceeds the TDI for the child receptor. However, this is a reflection of the fact the MDI is over 100% of the TDI. The process contribution is exceptionally small at only 0.05% of the ingestion TDI for an agricultural child at the point of maximum impact.

As noted in Section 3.2, the key determinant of cadmium's toxicity potential is its chronic accumulation in the kidney. The Environment Agency explains that chronic exposure to levels in excess of the TDI might be associated with an increase in kidney disease in a proportion of those exposed, but (small) exceedances lasting for shorter periods are of less consequence. When lifetime exposure is assessed (i.e. a period being a child and an adult) the overall impact is well below the TDI. Therefore, there would not be an appreciable health risk based on the emission of cadmium over a lifetime of an individual.

7.1.2 Chromium

As shown in Table 8, concentrations of total chromium in emissions from municipal waste incineration processes are typically 2.80% of the draft BAT-AEL, with only a fraction of this being in the hexavalent form. Even using the worst-case assumption that emissions of chromium are the maximum monitored from an existing waste incineration 3R Facility (30.67% of the draft BAT-AEL), the process contribution is only 0.38% of the TDI for an agricultural child at the point of maximum impact. Almost all toxicological opinion is that chromium III compounds are of low oral toxicity and the WHO state that "in the form of trivalent compounds, chromium is an essential nutrient and is relatively non-toxic for man and other mammalian species". Although the TDI is predicted to be exceeded, this is due to existing dietary intake.

The TDI is based on the USEPA's Reference Dose for chromium VI. Assessing the total dietary intake of chromium against this TDI is highly conservative. As the process contribution is small, the existing levels of chromium do not represent a toxicity problem and the TDI is highly conservative, there would not be an appreciable health risk based on the emissions of chromium over the lifetime of an individual.

7.1.3 Nickel

For nickel, the MDI for ingestion exceeds the TDI for the child receptor. However, this is a reflection of the fact the MDI is over 100% of the TDI. The process contribution is exceedingly small at 0.67% of the TDI. This is based on the conservative assumption that the process contribution is based on emissions of nickel at 73.3% of the draft Group 3 metals draft BAT-AEL. As outlined in Table 8, this is the maximum of the monitoring data and is an outlier. The third highest concentration was 18% and the mean 5% of the draft Group 3 metals draft BAT-AEL. If we assume the 3R Facility operates as per the 3rd highest – i.e. 18% of the draft Group 3 metals draft BAT-AEL - the process contribution would be 0.17% of the ingestion TDI at the point of maximum impact for the agricultural child receptor. On this basis, it is not considered that the 3R Facility would increase the health risks from nickel for children significantly.

7.2 Breast milk exposure

The total accumulation of dioxins in an infant, considering the breast milk pathway and based on an adult agricultural receptor at the point of maximum impact feeding an infant, is 0.234 pg WHO-TEQ / kg-bw / day which is 11.71% of the TDI. For a residential type receptor this is only 0.22% of the TDI. There are no ingestion pathways besides breast milk ingestion for an infant receptor. As the process contribution is less than the TDI, it is considered that the 3R Facility will not increase the health risks from the accumulation of dioxins in infants.

7.3 Assessment against ID - point of maximum impact

Table 15 and Table 16 outline the impact of emissions from the 3R Facility for an 'agricultural' and a 'residential' receptor located at the point of maximum impact as a percentage of the ID.

Table 15: Impact Analysis – ID – Point of Maximum Impact - Adult

Substance	Inhalation (% of ID)	Ingestion (% of ID)
Agricultural		
Arsenic	1.45%	0.12%
Benzene	0.83%	0.19%
Benzo[a]pyrene	0.17%	0.36%
Chromium	10.67%	-
Residential		
Arsenic	1.45%	0.04%
Benzene	0.83%	0.20%
Benzo[a]pyrene	0.17%	0.004%
Chromium	10.67%	-

Table 16: Impact Analysis – ID – Point of Maximum Impact - Child

Substance	Inhalation (% of ID)	Ingestion (% of ID)
Agricultural		
Arsenic	1.83%	0.20%
Benzene	1.04%	0.45%
Benzo[a]pyrene	0.22%	0.53%
Chromium	13.44%	-
Residential		
Arsenic	1.83%	0.10%
Benzene	1.04%	0.36%
Benzo[a]pyrene	0.22%	0.01%
Chromium	13.44%	-

The ID is the level of exposure which is associated with a negligible risk to human health. As shown, for this worst-case receptor the process contribution is well below the ID. Therefore, emissions from the 3R Facility are considered to have a negligible impact on human health.

7.4 Maximum impact at a receptor

The following tables outline the impact of emissions from the 3R Facility at the most affected receptor (i.e. the receptor with the greatest impact from ingestion and inhalation of emissions) (R18 – Sunshine Infant and Nursery School). Where appropriate a comparison has been made to the TDI or ID.

Table 17: Impact Analysis – TDI –Maximum Impacted Receptor

Substance	MDI (% of TDI)		Process Contribution (% of TDI)		Overall (% of TDI)	
	Inhalation	Ingestion	Inhalation	Ingestion	Inhalation	Ingestion
Adult						
Cadmium	20.41%	53.17%	0.77%	0.01%	21.18%	53.19%
Chromium	-	60.48%	-	0.018%	-	60.49%
Chromium VI	-	6.05%	-	0.0000%	-	6.05%
Methyl mercury	-	3.11%	-	0.003%	-	3.11%
Mercuric chloride	-	0.71%	-	0.003%	-	0.72%
Mercury	1.19%	-	0.0001%	-	1.19%	-
Nickel	12.86%	68.37%	3.97%	0.04%	16.83%	68.41%
Dioxins and dioxin like PCBs	35.00%		0.03%		35.03%	
Child						
Cadmium	52.86%	**137.72%**	0.98%	0.03%	53.83%	**137.76%**
Chromium	-	**156.63%**	-	0.05%	-	**156.68%**
Chromium VI	-	15.66%	-	0.0001%	-	15.66%
Methyl mercury	-	8.04%	-	0.01%	-	8.05%
Mercuric chloride	-	1.85%	-	0.01%	-	1.86%
Mercury	3.08%	-	0.0001%	-	3.08%	-
Nickel	33.30%	**177.07%**	5.01%	0.09%	38.31%	**177.16%**
Dioxins and dioxin like PCBs	90.65%		0.10%		90.75%	

As shown, for the most impacted receptor the overall impact (including the contribution from existing dietary intakes) is less than the TDI for chromium VI, mercury (including compounds) and dioxins. Therefore, emissions of these pollutants would not have an appreciable health risk.

For a child receptor the cadmium, chromium and nickel MDI (that sourced from existing dietary intake) exceeds the TDI for ingestion. However, the process contribution is exceptionally small and the exceedance is a reflection of the fact the MDI is over 100% of the TDI. On this basis, it is considered that emissions of cadmium, chromium or nickel the 3R Facility would not increase the health risks for children.

The total accumulation of dioxins in an infant, considering the breast milk pathway and based on the adult residential receptor at R18 feeding an infant, is 0.004 pg WHO-TEQ / kg bw / day which is 0.20% of the TDI. As the process contribution is less than the TDI, it is considered that the 3R Facility will not increase the health risks from the accumulation of dioxins in infants.

Table 18: Impact Analysis – ID – Maximum Impacted Receptor

Substance	Inhalation (% of ID)	Ingestion (% of ID)
Adult – Agricultural		
Arsenic	1.36%	0.04%
Benzene	0.78%	0.19%
Benzo[a]pyrene	0.16%	0.003%
Chromium VI	9.97%	-
Child – Agricultural		
Arsenic	1.71%	0.10%
Benzene	0.98%	0.34%
Benzo[a]pyrene	0.20%	0.01%
Chromium VI	12.57%	-

As shown, for the maximum impacted receptor the process contribution is well below the ID. Therefore, emissions from the 3R Facility are considered to have a negligible impact on human health.

7.5 Comparison of the assessment against TDI for the 3R Facility and the Permitted Facility

The overall impact for the hypothetical worst-case receptor (including the contribution from existing dietary intakes) from the 3R Facility is less than the TDI for chromium VI, mercury (including compounds) and dioxins, and less than the ID for all pollutants considered. Therefore, there would not be an appreciable health risk based on the emission of these pollutants and a comparison between the impacts from the Permitted Facility is not required.

For a child receptor the cadmium, chromium and nickel MDI (that sourced from existing dietary intake) exceeds the TDI for the 3R Facility. The process contribution is exceptionally small and the exceedance is a reflection of the fact the MDI (i.e. existing exposure) is over 100% of the TDI. A discussion of the comparisons between the impacts from the 3R Facility and the Permitted Facility for each of these pollutants is provided below.

7.5.1 Cadmium

The process contribution from the 3R Facility is very small at only 0.054% of the ingestion TDI for an agricultural child at the point of maximum impact. The process contribution from the Permitted Facility is slightly less than the 3R Facility at 0.052% of the ingestion TDI for an agricultural child at the point of maximum impact. As shown, the change in impact is exceptionally small and when lifetime exposure is assessed (i.e. a period being a child and an adult) the overall impact from both the 3R Facility and the Permitted Facility is well below the TDI. Therefore, there would not be an appreciable health risk based on the emission of cadmium from the 3R Facility compared to the Permitted Facility over a lifetime of an individual.

7.5.2 Chromium

The process contribution from the 3R Facility is very small at only 0.384% of the ingestion TDI for an agricultural child at the point of maximum impact. The process contribution from the Permitted Facility is slightly less than the 3R Facility at 0.376% of the ingestion TDI for an agricultural child at the point of maximum impact. The change in impact is exceptionally small, and the existing levels of chromium do not represent a toxicity problem and the TDI is highly conservative. Therefore, there would not be an appreciable health risk based on the emissions of chromium from the 3R Facility compared to the Permitted Facility over the lifetime of an individual.

7.5.3 Nickel

The process contribution from the 3R Facility is small at only 0.672% of the ingestion TDI for an agricultural child at the point of maximum impact. The process contribution from the Permitted Facility is slightly less than the 3R Facility at 0.658% of the ingestion TDI for an agricultural child at the point of maximum impact. The change in impact is exceptionally small. On this basis the impact from the 3R Facility compared to the Permitted Facility would not increase the health risks from nickel for children significantly.

7.6 Uncertainty and sensitivity analysis

To account for uncertainty in the modelling the impact on human health was assessed for a receptor at the point of maximum impact.

To account for uncertainty in the dietary intake of a person, both residential and agricultural receptors have been assessed. The agricultural receptor is assumed to consume a greater proportion of home grown produce, which has the potential to be contaminated by the COPCs released, than for a residential receptor. In addition, the agricultural receptor includes the pathway from consuming animals grazed on land contaminated by the emission source. This assumes that 100% of the plant materials eaten by the animals is grown on soil contaminated by emission sources.

The agricultural receptor at the point of maximum impact is considered the upper maximum of the impact of the 3R Facility.

7.7 Upset process conditions

Article 46(6) of the IED (Directive 2010/75/EU) states that:

> *"… the waste incineration plant … shall under no circumstances continue to incinerate waste for a period of more than 4 hours uninterrupted where emission limit values are exceeded.*
>
> *The cumulative duration or operation in such conditions over 1 year shall not exceed 60 hours."*

Article 47 continues with:

> *"In the case of a breakdown, the operator shall reduce or close down operations as soon as practicable until normal operations can be restored."*

In addition Annex VI, Part 3, 2 of the IED states the emission limit values applicable in the circumstances described in Article 46(6) and Article 47:

> *"The total dust concentration in the emissions into the air of a waste incineration plant shall under no circumstances exceed 150 mg/Nm³ expressed as a half-hourly average. The air emission limit values for TOC and CO set out in points 1.2 and 1.5(b) shall not be exceeded."*

The conditions detailed in Article 46(6) are considered to be "Upset Operating Conditions". As identified these periods are short term events which can only occur for a maximum of 60 hours per year.

Start-up of the 3R Facility from cold will be conducted with clean support fuel (low sulphur light fuel oil). During start-up waste will not be introduced onto the grate unless the temperature within the oxidation zone is above the 850^{o}C as required by Article 50, paragraph 4(a) of the IED. During start-up, the flue gas treatment plant will be operational as will be the combustion control systems and emissions monitoring equipment.

The same is true during plant shutdown where waste will cease to be introduced to the grate. The waste remaining on the grate will be combusted, the temperature not being permitted to drop below 850^{o}C through the combustion of clean support auxiliary fuel. During this period the flue gas treatment equipment is fully operational, as will be the control systems and monitoring equipment. After complete combustion of the waste, the auxiliary burners will be turned off and the plant will be allowed to cool.

Start-up and shutdown are infrequent events. The 3R Facility is designed to operate continuously, and ideally only shutdown for its annual maintenance programme.

In relation to the magnitude of dioxin emissions during plant start-up and shutdown, research has been undertaken by AEA Technology on behalf of the Environment Agency[7]. Whilst elevated emissions of dioxins (within one order of magnitude) were found during shutdown and start-up phases where the fuel was not fully established in the combustion chamber, the report concluded that:

> *"The mass of dioxin emitted during start-up and shutdown for a 4-5 day planned outage was similar to the emission which would have occurred during normal operation in the same period. The emission during the shutdown and restart is equivalent to less than 1 % of the estimated annual emission (if operating normally all year)."*

There is therefore no reason why such start-up and shutdown operations or upset operating conditions will affect the long-term impact of the 3R Facility.

[7] AEA Technology (2012) Review of research into health effects of Energy from Waste facilities.

8 Conclusions

This HHRA has been undertaken based on the following conservative assumptions:

- the 3R Facility will operate continually at the draft BAT-AELs for a 'new facility', i.e. at the maximum concentrations which it is expected that the 3R Facility will be permitted to operate at; where this assumption results in unrealistic impacts, further analysis has been undertaken; and
- the hypothetical maximum impacted receptor (an agricultural receptor at the point of maximum impact) only ingests food and drink sourced from the area with the maximum contribution from the 3R Facility.

The results of the assessment show that, for an agricultural child receptor at the point of maximum impact, the total ingestion of cadmium, chromium and nickel exceeds the TDIs. For all other pollutants and intake pathways, the combined intake from the 3R Facility plus the existing MDI is below the TDI, and the impact of the 3R Facility is below the ID. Therefore, there would not be an appreciable health risk based on the emission of these pollutants.

Further analysis of the impact of the ingestion of cadmium, chromium and nickel has been undertaken, with the following conclusions:

1. For the ingestion of cadmium and chromium, the maximum process contribution is small at 0.05% and 0.38% of the TDIs respectively, and lower at identified receptors. In addition, when lifetime exposure is assessed (i.e. a period being a child and an adult) the overall intake is well below the TDI. Therefore, there would not be an appreciable health risk over a lifetime of an individual.
2. For nickel, if it is assumed that emissions from the 3R Facility are as the third highest concentration from the available monitoring data, the maximum process contribution for ingestion is small at 0.67% of the TDI, and lower at identified receptors. Therefore, it is considered that the 3R Facility would not significantly increase the health risks for children from the ingestion of nickel.

Based on the above, it is concluded that the operation of the 3R Facility will not result in an appreciable increase in health impacts. In addition, a comparison has been made between the impacts from the 3R Facility and the Permitted Facility. This has shown that the impacts from the 3R Facility are predicted to be very similar to those of the Permitted Facility.

Appendices

A Detailed Results Tables

A.1 3R Facility

Table 19: Comparison with ID Limits for Adult Receptors

Receptor	Ingestion (% of ID)			Inhalation (% of ID)			
	Arsenic	Benzene	Benzo(a)pyrene	Arsenic	Benzene	Benzo(a)pyrene	Chromium VI
Point of maximum impact - agricultural	0.117%	0.191%	0.365%	1.449%	0.829%	0.174%	10.667%
Point of maximum impact - residential	0.043%	0.202%	0.004%	1.449%	0.829%	0.174%	10.667%
R1	0.008%	0.038%	0.001%	0.273%	0.156%	0.033%	2.008%
R2	0.006%	0.026%	0.000%	0.186%	0.106%	0.022%	1.365%
R3	0.004%	0.018%	0.000%	0.130%	0.074%	0.016%	0.953%
R4	0.003%	0.016%	0.000%	0.112%	0.064%	0.013%	0.822%
R5	0.005%	0.021%	0.000%	0.152%	0.087%	0.018%	1.115%
R6	0.002%	0.007%	0.000%	0.053%	0.030%	0.006%	0.392%
R7	0.001%	0.004%	0.000%	0.031%	0.017%	0.004%	0.225%
R8	0.009%	0.041%	0.001%	0.290%	0.166%	0.035%	2.136%
R9	0.015%	0.069%	0.001%	0.495%	0.283%	0.059%	3.641%
R10	0.012%	0.057%	0.001%	0.406%	0.232%	0.049%	2.990%
R11	0.021%	0.097%	0.002%	0.696%	0.398%	0.084%	5.126%
R12	0.038%	0.178%	0.003%	1.274%	0.729%	0.153%	9.376%
R13	0.021%	0.099%	0.002%	0.707%	0.404%	0.085%	5.203%
R14	0.039%	0.184%	0.003%	1.316%	0.753%	0.158%	9.682%
R15	0.018%	0.084%	0.001%	0.602%	0.344%	0.072%	4.428%

Receptor	Ingestion (% of ID)			Inhalation (% of ID)			
	Arsenic	Benzene	Benzo(a)pyrene	Arsenic	Benzene	Benzo(a)pyrene	Chromium VI
R16	0.013%	0.063%	0.001%	0.449%	0.257%	0.054%	3.308%
R17	0.007%	0.031%	0.001%	0.222%	0.127%	0.027%	1.636%
R18	0.041%	0.189%	0.003%	1.355%	0.775%	0.163%	9.973%

Table 20: Comparison with ID Limits for Child Receptors

Receptor	Ingestion (% of ID)			Inhalation (% of ID)			
	Arsenic	Benzene	Benzo(a)pyrene	Arsenic	Benzene	Benzo(a)pyrene	Chromium VI
Point of maximum impact - agricultural	0.205%	0.448%	0.527%	1.826%	1.045%	0.219%	13.440%
Point of maximum impact - residential	0.104%	0.359%	0.009%	1.826%	1.045%	0.219%	13.440%
R1	0.020%	0.068%	0.002%	0.344%	0.197%	0.041%	2.530%
R2	0.013%	0.046%	0.001%	0.234%	0.134%	0.028%	1.720%
R3	0.009%	0.032%	0.001%	0.163%	0.093%	0.020%	1.201%
R4	0.008%	0.028%	0.001%	0.141%	0.081%	0.017%	1.036%
R5	0.011%	0.037%	0.001%	0.191%	0.109%	0.023%	1.405%
R6	0.004%	0.013%	0.000%	0.067%	0.038%	0.008%	0.494%
R7	0.002%	0.008%	0.000%	0.039%	0.022%	0.005%	0.284%
R8	0.021%	0.072%	0.002%	0.366%	0.209%	0.044%	2.691%
R9	0.036%	0.122%	0.003%	0.623%	0.356%	0.075%	4.588%
R10	0.029%	0.101%	0.003%	0.512%	0.293%	0.061%	3.767%
R11	0.050%	0.172%	0.004%	0.878%	0.502%	0.105%	6.459%
R12	0.092%	0.316%	0.008%	1.605%	0.918%	0.193%	11.813%
R13	0.051%	0.175%	0.004%	0.891%	0.510%	0.107%	6.556%
R14	0.095%	0.326%	0.008%	1.658%	0.948%	0.199%	12.200%
R15	0.043%	0.149%	0.004%	0.758%	0.434%	0.091%	5.579%
R16	0.032%	0.111%	0.003%	0.566%	0.324%	0.068%	4.168%
R17	0.016%	0.055%	0.001%	0.280%	0.160%	0.034%	2.061%
R18	0.098%	0.336%	0.009%	1.707%	0.977%	0.205%	12.566%

Table 21: Comparison with TDI Limits for Adult Receptors

Receptor	Ingestion (% of ID)						Inhalation (% of ID)		
	Cadmium	Chromium	Chromium VI	Methyl Mercury	Mercuric Chloride	Nickel	Cadmium	Mercury	Nickel
MDI of TDI (%)	53.175%	60.476%	6.048%	3.106%	0.714%	68.367%	20.408%	1.190%	12.857%
Point of maximum impact - agricultural	53.198%	60.715%	6.0480%	3.114%	0.746%	68.808%	21.236%	1.191%	17.108%
Point of maximum impact - residential	53.189%	60.495%	6.0476%	3.109%	0.718%	68.408%	21.236%	1.191%	17.108%
R1	53.177%	60.480%	6.0476%	3.106%	0.715%	68.375%	20.564%	1.190%	13.657%
R2	53.176%	60.479%	6.0476%	3.106%	0.715%	68.373%	20.514%	1.190%	13.401%
R3	53.176%	60.478%	6.0476%	3.106%	0.715%	68.371%	20.482%	1.190%	13.237%
R4	53.176%	60.478%	6.0476%	3.106%	0.715%	68.370%	20.472%	1.190%	13.185%
R5	53.176%	60.478%	6.0476%	3.106%	0.715%	68.372%	20.495%	1.190%	13.302%
R6	53.175%	60.477%	6.0476%	3.106%	0.714%	68.369%	20.439%	1.190%	13.013%
R7	53.175%	60.477%	6.0476%	3.106%	0.714%	68.368%	20.426%	1.190%	12.947%
R8	53.178%	60.480%	6.0476%	3.106%	0.715%	68.376%	20.574%	1.190%	13.708%
R9	53.180%	60.483%	6.0476%	3.107%	0.715%	68.381%	20.691%	1.191%	14.308%
R10	53.179%	60.482%	6.0476%	3.107%	0.715%	68.379%	20.640%	1.190%	14.049%
R11	53.182%	60.485%	6.0476%	3.107%	0.716%	68.387%	20.806%	1.191%	14.900%
R12	53.188%	60.493%	6.0476%	3.108%	0.717%	68.403%	21.136%	1.191%	16.594%
R13	53.182%	60.485%	6.048%	3.107%	0.716%	68.387%	20.812%	1.191%	14.931%
R14	53.188%	60.493%	6.048%	3.109%	0.717%	68.404%	21.160%	1.191%	16.716%
R15	53.181%	60.484%	6.048%	3.107%	0.716%	68.384%	20.752%	1.191%	14.622%
R16	53.179%	60.482%	6.048%	3.107%	0.715%	68.380%	20.665%	1.191%	14.175%

Receptor	Ingestion (% of ID)						Inhalation (% of ID)		
	Cadmium	Chromium	Chromium VI	Methyl Mercury	Mercuric Chloride	Nickel	Cadmium	Mercury	Nickel
R17	53.177%	60.479%	6.048%	3.106%	0.715%	68.374%	20.535%	1.190%	13.509%
R18	53.188%	60.494%	6.048%	3.109%	0.717%	68.406%	21.182%	1.191%	16.832%

Table 22: Comparison with TDI Limits for Child Receptors

Receptor	Ingestion (% of ID)						Inhalation (% of ID)		
	Cadmium	Chromium	Chromium VI	Methyl Mercury	Mercuric Chloride	Nickel	Cadmium	Mercury	Nickel
MDI of TDI (%)	137.722%	156.633%	15.663%	8.043%	1.850%	177.071%	52.857%	3.083%	33.300%
Point of maximum impact - agricultural	137.776%	157.017%	15.664%	8.061%	1.900%	177.744%	53.901%	3.083%	38.657%
Point of maximum impact - residential	137.758%	156.686%	15.663%	8.052%	1.864%	177.170%	53.901%	3.083%	38.657%
R1	137.729%	156.643%	15.663%	8.045%	1.853%	177.090%	53.054%	3.083%	34.308%
R2	137.727%	156.640%	15.663%	8.045%	1.852%	177.084%	52.991%	3.083%	33.986%
R3	137.725%	156.638%	15.663%	8.044%	1.851%	177.080%	52.950%	3.083%	33.779%
R4	137.725%	156.637%	15.663%	8.044%	1.851%	177.079%	52.938%	3.083%	33.713%
R5	137.726%	156.639%	15.663%	8.044%	1.851%	177.082%	52.966%	3.083%	33.860%
R6	137.724%	156.635%	15.663%	8.044%	1.851%	177.075%	52.895%	3.083%	33.497%
R7	137.723%	156.634%	15.663%	8.044%	1.850%	177.074%	52.879%	3.083%	33.413%
R8	137.729%	156.644%	15.663%	8.045%	1.853%	177.091%	53.066%	3.083%	34.373%
R9	137.734%	156.651%	15.663%	8.047%	1.855%	177.105%	53.213%	3.083%	35.129%
R10	137.732%	156.648%	15.663%	8.046%	1.854%	177.099%	53.150%	3.083%	34.802%
R11	137.739%	156.659%	15.663%	8.048%	1.857%	177.119%	53.359%	3.083%	35.874%
R12	137.754%	156.679%	15.663%	8.051%	1.862%	177.158%	53.774%	3.083%	38.008%
R13	137.740%	156.659%	15.663%	8.048%	1.857%	177.119%	53.366%	3.083%	35.913%
R14	137.755%	156.681%	15.663%	8.052%	1.863%	177.161%	53.804%	3.083%	38.162%
R15	137.737%	156.655%	15.663%	8.047%	1.856%	177.112%	53.290%	3.083%	35.523%
R16	137.733%	156.650%	15.663%	8.046%	1.854%	177.102%	53.181%	3.083%	34.961%

Receptor	Ingestion (% of ID)						Inhalation (% of ID)		
	Cadmium	Chromium	Chromium VI	Methyl Mercury	Mercuric Chloride	Nickel	Cadmium	Mercury	Nickel
R17	137.728%	156.641%	15.663%	8.045%	1.852%	177.087%	53.017%	3.083%	34.121%
R18	137.756%	156.682%	15.663%	8.052%	1.863%	177.163%	53.833%	3.083%	38.308%

Table 23: Comparison with Total Dioxin TDI Limits for Adult Receptors

Receptor	Total Inhalation, (pg WHO-TEQ kg-1 bw day -1)	Total Ingestion, (pg WHO-TEQ kg-1 bw day -1)	Total uptake, (pg WHO-TEQ kg-1 bw day -1)	Comparison (% of limit)
MDI (% of TDI)				**35.00%**
Point of maximum impact - agricultural	0.008%	3.011%	3.019%	36.509%
Point of maximum impact - residential	0.008%	0.060%	0.068%	35.034%
R1	0.002%	0.011%	0.013%	35.006%
R2	0.001%	0.008%	0.009%	35.004%
R3	0.001%	0.005%	0.006%	35.003%
R4	0.001%	0.005%	0.005%	35.003%
R5	0.001%	0.006%	0.007%	35.004%
R6	0.0003%	0.002%	0.002%	35.001%
R7	0.0002%	0.001%	0.001%	35.001%
R8	0.002%	0.012%	0.014%	35.007%
R9	0.003%	0.020%	0.023%	35.012%
R10	0.002%	0.017%	0.019%	35.009%
R11	0.004%	0.029%	0.033%	35.016%
R12	0.007%	0.052%	0.059%	35.030%
R13	0.004%	0.029%	0.033%	35.017%
R14	0.007%	0.054%	0.061%	35.031%
R15	0.003%	0.025%	0.028%	35.014%
R16	0.003%	0.018%	0.021%	35.010%

Receptor	Total Inhalation, (pg WHO-TEQ kg-1 bw day -1)	Total Ingestion, (pg WHO-TEQ kg-1 bw day -1)	Total uptake, (pg WHO-TEQ kg-1 bw day -1)	Comparison (% of limit)
R17	0.001%	0.009%	0.010%	35.005%
R18	0.008%	0.056%	0.063%	35.032%

Table 24: Comparison with Total Dioxin TDI Limits for Child Receptors

Receptor	Total Inhalation, (pg WHO-TEQ kg-1 bw day -1)	Total Ingestion, (pg WHO-TEQ kg-1 bw day -1)	Total uptake, (pg WHO-TEQ kg-1 bw day -1)	Comparison (% of limit)
MDI (% of TDI)				**90.65%**
Point of maximum impact - agricultural	0.010%	4.257%	4.267%	92.783%
Point of maximum impact - residential	0.010%	0.200%	0.210%	90.755%
R1	0.002%	0.038%	0.04%	90.670%
R2	0.001%	0.026%	0.03%	90.663%
R3	0.001%	0.018%	0.02%	90.659%
R4	0.001%	0.015%	0.02%	90.658%
R5	0.001%	0.021%	0.02%	90.661%
R6	0.0004%	0.007%	0.01%	90.654%
R7	0.0002%	0.004%	0.00%	90.652%
R8	0.002%	0.040%	0.04%	90.671%
R9	0.003%	0.068%	0.07%	90.686%
R10	0.003%	0.056%	0.06%	90.679%
R11	0.005%	0.096%	0.10%	90.701%
R12	0.009%	0.176%	0.18%	90.742%
R13	0.005%	0.098%	0.10%	90.701%
R14	0.009%	0.182%	0.19%	90.745%
R15	0.004%	0.083%	0.09%	90.694%
R16	0.003%	0.062%	0.07%	90.683%

Receptor	Total Inhalation, (pg WHO-TEQ kg-1 bw day -1)	Total Ingestion, (pg WHO-TEQ kg-1 bw day -1)	Total uptake, (pg WHO-TEQ kg-1 bw day -1)	Comparison (% of limit)
R17	0.002%	0.031%	0.03%	90.666%
R18	0.010%	0.187%	0.20%	90.748%

A.2 Permitted Facility

Table 25: Comparison with ID Limits for Adult Receptors

Receptor	Ingestion (% of ID)			Inhalation (% of ID)			
	Arsenic	Benzene	Benzo(a)pyrene	Arsenic	Benzene	Benzo(a)pyrene	Chromium VI
Point of maximum impact - agricultural	0.115%	0.187%	0.357%	1.419%	0.811%	0.170%	10.446%
Point of maximum impact - residential	0.042%	0.198%	0.003%	1.419%	0.811%	0.170%	10.446%
R1	0.011%	0.052%	0.001%	0.372%	0.212%	0.045%	2.735%
R2	0.007%	0.032%	0.001%	0.233%	0.133%	0.028%	1.712%
R3	0.004%	0.020%	0.000%	0.142%	0.081%	0.017%	1.043%
R4	0.005%	0.024%	0.000%	0.171%	0.098%	0.021%	1.260%
R5	0.007%	0.031%	0.001%	0.221%	0.126%	0.026%	1.625%
R6	0.003%	0.013%	0.000%	0.090%	0.052%	0.011%	0.665%
R7	0.003%	0.014%	0.000%	0.099%	0.057%	0.012%	0.730%
R8	0.015%	0.070%	0.001%	0.505%	0.289%	0.061%	3.718%
R9	0.017%	0.079%	0.001%	0.567%	0.324%	0.068%	4.175%
R10	0.018%	0.082%	0.001%	0.591%	0.337%	0.071%	4.347%
R11	0.029%	0.133%	0.002%	0.955%	0.546%	0.115%	7.032%
R12	0.035%	0.163%	0.003%	1.166%	0.666%	0.140%	8.580%
R13	0.024%	0.113%	0.002%	0.812%	0.464%	0.097%	5.975%
R14	0.037%	0.174%	0.003%	1.251%	0.715%	0.150%	9.209%
R15	0.020%	0.092%	0.002%	0.657%	0.375%	0.079%	4.833%

Receptor	Ingestion (% of ID)			Inhalation (% of ID)			
	Arsenic	Benzene	Benzo(a)pyrene	Arsenic	Benzene	Benzo(a)pyrene	Chromium VI
R16	0.017%	0.080%	0.001%	0.575%	0.329%	0.069%	4.234%
R17	0.010%	0.045%	0.001%	0.321%	0.183%	0.038%	2.359%
R18	0.038%	0.175%	0.003%	1.257%	0.718%	0.151%	9.249%

Table 26: Comparison with ID Limits for Child Receptors

Receptor	Ingestion (% of ID)			Inhalation (% of ID)			
	Arsenic	Benzene	Benzo(a)pyrene	Arsenic	Benzene	Benzo(a)pyrene	Chromium VI
Point of maximum impact - agricultural	0.200%	0.438%	0.516%	1.788%	1.022%	0.215%	13.162%
Point of maximum impact - residential	0.102%	0.351%	0.009%	1.788%	1.022%	0.215%	13.162%
R1	0.027%	0.092%	0.002%	0.468%	0.268%	0.056%	3.447%
R2	0.017%	0.058%	0.001%	0.293%	0.168%	0.035%	2.158%
R3	0.010%	0.035%	0.001%	0.179%	0.102%	0.021%	1.314%
R4	0.012%	0.042%	0.001%	0.216%	0.123%	0.026%	1.587%
R5	0.016%	0.055%	0.001%	0.278%	0.159%	0.033%	2.047%
R6	0.006%	0.022%	0.001%	0.114%	0.065%	0.014%	0.838%
R7	0.007%	0.024%	0.001%	0.125%	0.071%	0.015%	0.920%
R8	0.036%	0.125%	0.003%	0.636%	0.364%	0.076%	4.684%
R9	0.041%	0.140%	0.004%	0.715%	0.408%	0.086%	5.261%
R10	0.043%	0.146%	0.004%	0.744%	0.425%	0.089%	5.477%
R11	0.069%	0.236%	0.006%	1.204%	0.688%	0.144%	8.861%
R12	0.084%	0.288%	0.007%	1.469%	0.839%	0.176%	10.811%
R13	0.058%	0.201%	0.005%	1.023%	0.585%	0.123%	7.529%
R14	0.090%	0.309%	0.008%	1.577%	0.901%	0.189%	11.603%
R15	0.047%	0.162%	0.004%	0.827%	0.473%	0.099%	6.090%
R16	0.041%	0.142%	0.004%	0.725%	0.414%	0.087%	5.334%
R17	0.023%	0.079%	0.002%	0.404%	0.231%	0.048%	2.972%
R18	0.090%	0.311%	0.008%	1.583%	0.905%	0.190%	11.654%

Table 27: Comparison with TDI Limits for Adult Receptors

Receptor	Ingestion (% of ID)						Inhalation (% of ID)		
	Cadmium	Chromium	Chromium VI	Methyl Mercury	Mercuric Chloride	Nickel	Cadmium	Mercury	Nickel
MDI of TDI (%)	53.175%	60.476%	6.048%	3.106%	0.714%	68.367%	20.408%	1.190%	12.857%
Point of maximum impact - agricultural	53.197%	60.710%	6.048%	3.114%	0.746%	68.799%	21.219%	1.191%	17.020%
Point of maximum impact - residential	53.189%	60.495%	6.048%	3.109%	0.718%	68.407%	21.219%	1.191%	17.020%
R1	53.178%	60.481%	6.048%	3.106%	0.715%	68.378%	20.621%	1.190%	13.947%
R2	53.177%	60.479%	6.048%	3.106%	0.715%	68.374%	20.541%	1.190%	13.540%
R3	53.176%	60.478%	6.048%	3.106%	0.715%	68.371%	20.489%	1.190%	13.273%
R4	53.176%	60.478%	6.048%	3.106%	0.715%	68.372%	20.506%	1.190%	13.359%
R5	53.177%	60.479%	6.048%	3.106%	0.715%	68.374%	20.534%	1.190%	13.505%
R6	53.176%	60.477%	6.048%	3.106%	0.714%	68.370%	20.460%	1.190%	13.122%
R7	53.176%	60.477%	6.048%	3.106%	0.715%	68.370%	20.465%	1.190%	13.148%
R8	53.180%	60.483%	6.048%	3.107%	0.715%	68.382%	20.697%	1.191%	14.339%
R9	53.180%	60.484%	6.048%	3.107%	0.716%	68.383%	20.732%	1.191%	14.521%
R10	53.181%	60.484%	6.048%	3.107%	0.716%	68.384%	20.746%	1.191%	14.589%
R11	53.184%	60.489%	6.048%	3.108%	0.717%	68.394%	20.954%	1.191%	15.660%
R12	53.187%	60.491%	6.048%	3.108%	0.717%	68.400%	21.074%	1.191%	16.277%
R13	53.183%	60.487%	6.048%	3.107%	0.716%	68.390%	20.872%	1.191%	15.239%
R14	53.187%	60.493%	6.048%	3.108%	0.717%	68.403%	21.123%	1.191%	16.527%
R15	53.181%	60.485%	6.048%	3.107%	0.716%	68.386%	20.783%	1.191%	14.783%
R16	53.180%	60.484%	6.048%	3.107%	0.716%	68.384%	20.737%	1.191%	14.545%

Receptor	Ingestion (% of ID)						Inhalation (% of ID)		
	Cadmium	Chromium	Chromium VI	Methyl Mercury	Mercuric Chloride	Nickel	Cadmium	Mercury	Nickel
R17	53.178%	60.480%	6.048%	3.106%	0.715%	68.376%	20.591%	1.190%	13.797%
R18	53.187%	60.493%	6.048%	3.108%	0.717%	68.403%	21.126%	1.191%	16.544%

Table 28: Comparison with TDI Limits for Child Receptors

Receptor	Ingestion (% of ID)						Inhalation (% of ID)		
	Cadmium	Chromium	Chromium VI	Methyl Mercury	Mercuric Chloride	Nickel	Cadmium	Mercury	Nickel
MDI of TDI (%)	137.722%	156.633%	15.663%	8.043%	1.850%	177.071%	52.857%	3.083%	33.300%
Point of maximum impact - agricultural	137.775%	157.009%	15.664%	8.061%	1.899%	177.730%	53.879%	3.083%	38.546%
Point of maximum impact - residential	137.757%	156.685%	15.663%	8.052%	1.863%	177.168%	53.879%	3.083%	38.546%
R1	137.731%	156.647%	15.663%	8.046%	1.854%	177.097%	53.125%	3.083%	34.674%
R2	137.728%	156.642%	15.663%	8.045%	1.852%	177.087%	53.025%	3.083%	34.160%
R3	137.726%	156.638%	15.663%	8.044%	1.851%	177.081%	52.959%	3.083%	33.824%
R4	137.726%	156.640%	15.663%	8.045%	1.852%	177.083%	52.980%	3.083%	33.933%
R5	137.728%	156.641%	15.663%	8.045%	1.852%	177.086%	53.016%	3.083%	34.116%
R6	137.724%	156.637%	15.663%	8.044%	1.851%	177.078%	52.922%	3.083%	33.634%
R7	137.725%	156.637%	15.663%	8.044%	1.851%	177.078%	52.929%	3.083%	33.667%
R8	137.735%	156.652%	15.663%	8.047%	1.855%	177.106%	53.221%	3.083%	35.167%
R9	137.736%	156.654%	15.663%	8.047%	1.855%	177.110%	53.266%	3.083%	35.397%
R10	137.737%	156.655%	15.663%	8.047%	1.856%	177.111%	53.282%	3.083%	35.483%
R11	137.746%	156.668%	15.663%	8.049%	1.859%	177.136%	53.545%	3.083%	36.831%
R12	137.751%	156.676%	15.663%	8.051%	1.861%	177.151%	53.697%	3.083%	37.609%
R13	137.742%	156.663%	15.663%	8.048%	1.858%	177.126%	53.442%	3.083%	36.301%
R14	137.753%	156.679%	15.663%	8.051%	1.862%	177.156%	53.758%	3.083%	37.924%
R15	137.738%	156.657%	15.663%	8.047%	1.856%	177.116%	53.330%	3.083%	35.727%
R16	137.736%	156.654%	15.663%	8.047%	1.855%	177.110%	53.271%	3.083%	35.426%

Receptor	Ingestion (% of ID)						Inhalation (% of ID)		
	Cadmium	Chromium	Chromium VI	Methyl Mercury	Mercuric Chloride	Nickel	Cadmium	Mercury	Nickel
R17	137.730%	156.645%	15.663%	8.045%	1.853%	177.093%	53.088%	3.083%	34.485%
R18	137.753%	156.679%	15.663%	8.051%	1.862%	177.157%	53.762%	3.083%	37.945%

Table 29: Comparison with Total Dioxin TDI Limits for Adult Receptors

Receptor	Total Inhalation, (pg WHO-TEQ kg-1 bw day -1)	Total Ingestion, (pg WHO-TEQ kg-1 bw day -1)	Total uptake, (pg WHO-TEQ kg-1 bw day -1)	Comparison (% of limit)
MDI (% of TDI)				**35.00%**
Point of maximum impact - agricultural	0.008%	2.947%	2.955%	36.478%
Point of maximum impact - residential	0.008%	0.058%	0.066%	35.033%
R1	0.002%	0.015%	0.017%	35.009%
R2	0.001%	0.010%	0.011%	35.005%
R3	0.001%	0.006%	0.007%	35.003%
R4	0.001%	0.007%	0.008%	35.004%
R5	0.001%	0.009%	0.010%	35.005%
R6	0.001%	0.004%	0.004%	35.002%
R7	0.001%	0.004%	0.005%	35.002%
R8	0.003%	0.021%	0.024%	35.012%
R9	0.003%	0.023%	0.026%	35.013%
R10	0.003%	0.024%	0.028%	35.014%
R11	0.005%	0.039%	0.045%	35.022%
R12	0.007%	0.048%	0.054%	35.027%
R13	0.005%	0.033%	0.038%	35.019%
R14	0.007%	0.051%	0.058%	35.029%
R15	0.004%	0.027%	0.031%	35.015%
R16	0.003%	0.024%	0.027%	35.013%
R17	0.002%	0.013%	0.015%	35.007%

Receptor	Total Inhalation, (pg WHO-TEQ kg-1 bw day -1)	Total Ingestion, (pg WHO-TEQ kg-1 bw day -1)	Total uptake, (pg WHO-TEQ kg-1 bw day -1)	Comparison (% of limit)
R18	0.007%	0.052%	0.059%	35.029%

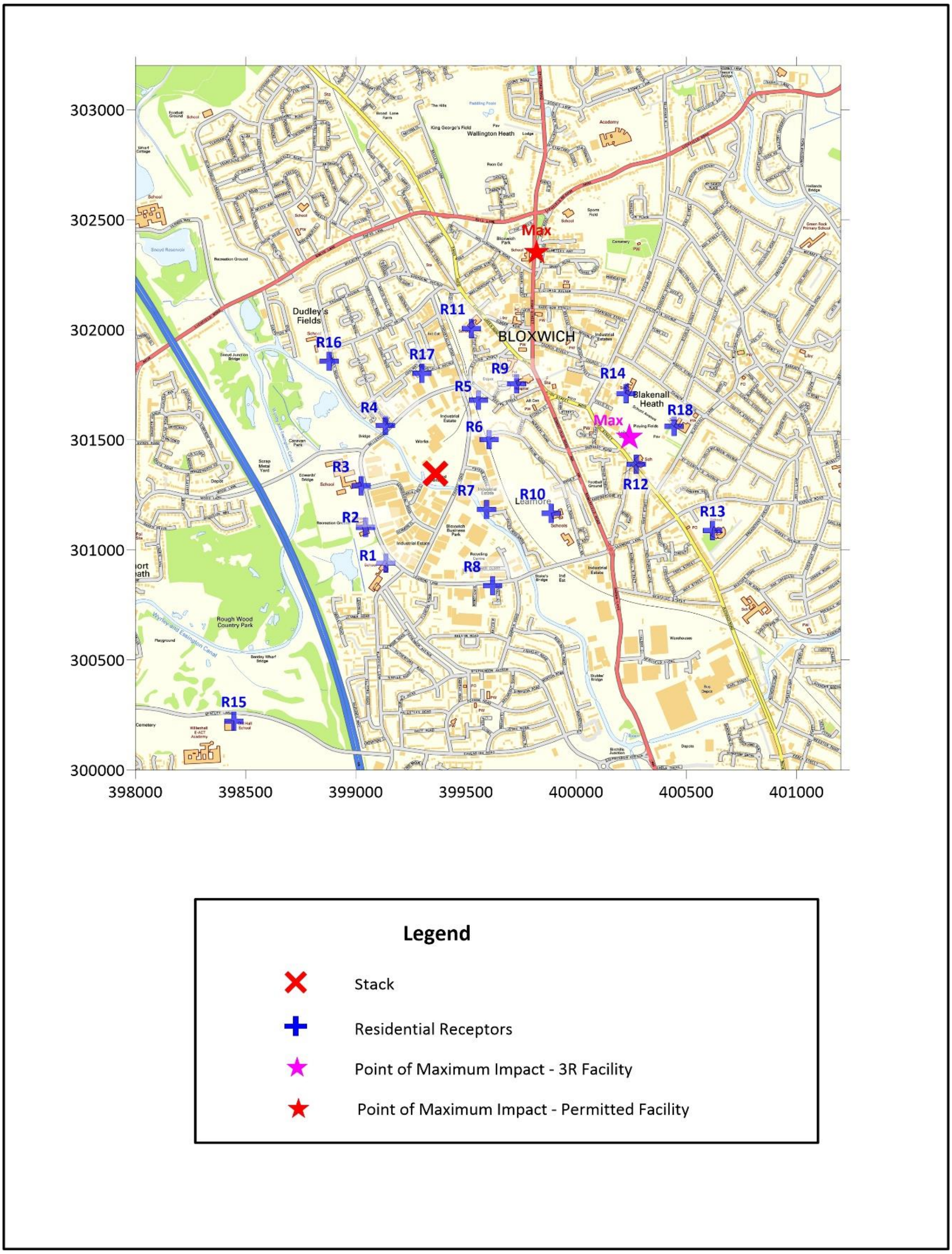
Table 30: Comparison with Total Dioxin TDI Limits for Child Receptors

Receptor	Total Inhalation, (pg WHO-TEQ kg-1 bw day -1)	Total Ingestion, (pg WHO-TEQ kg-1 bw day -1)	Total uptake, (pg WHO-TEQ kg-1 bw day -1)	Comparison (% of limit)
MDI (% of TDI)				**90.65%**
Point of maximum impact - agricultural	0.010%	4.167%	4.177%	92.739%
Point of maximum impact - residential	0.010%	0.196%	0.206%	90.753%
R1	0.003%	0.051%	0.054%	90.677%
R2	0.002%	0.032%	0.034%	90.667%
R3	0.001%	0.020%	0.021%	90.660%
R4	0.001%	0.024%	0.025%	90.662%
R5	0.002%	0.030%	0.032%	90.666%
R6	0.001%	0.012%	0.013%	90.657%
R7	0.001%	0.014%	0.014%	90.657%
R8	0.004%	0.070%	0.073%	90.687%
R9	0.004%	0.078%	0.082%	90.691%
R10	0.004%	0.082%	0.086%	90.693%
R11	0.007%	0.132%	0.139%	90.719%
R12	0.008%	0.161%	0.169%	90.735%
R13	0.006%	0.112%	0.118%	90.709%
R14	0.009%	0.173%	0.182%	90.741%
R15	0.005%	0.091%	0.095%	90.698%
R16	0.004%	0.079%	0.083%	90.692%

Receptor	Total Inhalation, (pg WHO-TEQ kg-1 bw day -1)	Total Ingestion, (pg WHO-TEQ kg-1 bw day -1)	Total uptake, (pg WHO-TEQ kg-1 bw day -1)	Comparison (% of limit)
R17	0.002%	0.044%	0.046%	90.673%
R18	0.009%	0.174%	0.182%	90.741%

B Location of Sensitive Receptors

Figure 2: Location of Sensitive Receptors



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