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Consulting Engineers Limited

GENT FAIRHEAD & CO
RIVENHALL
HUMAN HEALTH RISK ASSESSMENT

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1 INTRODUCTION

Fichtner Consulting Engineers Ltd ("Fichtner") has been engaged to undertake a Human Health Risk Assessment (HHRA) to support the planning and Environmental Permit application for the proposed Rivenhall Integrated Waste Management Facility (IWMF). The Facility will include a Combined Heat and Power (CHP) plant consisting of 2 streams to process up to 595,000 tonnes per annum of non-hazardous Solid Recovered Fuel (SRF) and Refuse Derived Fuel (RDF). Due to the recycled nature of some of the fuel, 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.

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 Facility, the most significant effects on human health will arise by inhalation. The air quality objectives (AQOs) outlined within the air quality 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 AQOs, 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.

The Facility is located in a sparsely populated area, and areas in the direction of the maximum impact have either been subject to quarrying (the former Coggeshall Pit) or will be subject to quarrying operations (by Blackwater Aggregates adjacent to the Facility); and future residential development and/or habitation is therefore unlikely.

A number of agricultural and residential receptors have been identified and the impact of the Facility on those receptors considered. The point of maximum impact is located in an uninhabited site in the adjacent quarry.

2 Issue Identification

2.1 Issue

The key issue is the release of substances from the proposed CHP to atmosphere which have the potential to harm human health. No other sources will include emissions of either metals or dioxins. The Facility is to be located to the south-east of the disused airfield known as Rivenhall airfield, in rural Essex approximately 3.4km south east of Kelvedon. The closest residential properties are Allshots Farmhouse and The Lodge approximately 450m to the north east of the Facility.

The Facility will be designed to meet the emission limits outlined in the IED (2010/75/EU). Limits have been set for pollutants known to be produced during the combustion of 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 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;
- Hydrogen chloride
- Benzene
- Benzo(a)pyrene
- Mercury (Hg)
- Mercuric chloride
- Cadmium (Cd)
- Thallium (Tl)

- Antimony (Sb)
- Arsenic (As)
- Chromium (Cr), trivalent and hexavalent
- Lead (Pb); 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

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 recommend 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 those 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 Facility, the predicted intake of a substance due to emissions from the 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 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 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.

Table 3.1: 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	3.94	0.0011
Chromium (VI)	0.18	-	0.39	-
Methyl mercury	0.007	-	0.019	-
Mercuric chloride	0.014	-	0.037	-
Nickel	1.9	0.0009	4.8	0.002
Dioxins and dioxin like PCBs	0.7		1.8	

Table 3.2: 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)	-	-	-	-
Methyl mercury	-	-	0.23	0.23
Mercuric chloride	-	-	2	0.06
Nickel	-	-	12	0.006
Dioxins and dioxin like PCBs (pg WHO-TEQ kg-bw^{-1} day $^{-1}$)	-	-	2	

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 Appendix A.

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

Table 3.3: 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	52.78%	21.43%	138.89%	50.00%
Chromium	60.33%	-	131.33%	-
Methyl mercury	3.04%	-	8.26%	-
Mercuric chloride	0.70%	-	1.85%	-
Nickel	15.83%	15.00%	40.00%	33.33%
Dioxins and dioxin like PCBs	35.00%		90.00%	

As shown, the cadmium and chromium from existing sources exceeds the MDI. 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 3.2 is actually the TDI for chromium VI not chromium. Assessing the total dietary intake of chromium against this TDI is highly conservative.

The key determinant of cadmium's toxicity potential is its chronic accumulation in the kidney. The Environment Agency in their toxicology report "SC050021/TOx 3) explain 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.

4 Conceptual Site Model

4.1 Conceptual site model

A detailed Human Health Risk Assessment has been carried out using the Industrial Risk Assessment Program-Human Health (IRAP-h View – Version 4.0). The programme, 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 Figure 1.

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:

• Direct inhalation	All receptors
• Ingestion of soil	All receptors
• Ingestion of home-grown produce	All receptors
• Ingestion of drinking water	All receptors
• Ingestion of eggs from home-grown chickens	Agricultural receptors
• Ingestion of home-grown chickens	Agricultural receptors
• Ingestion of home-grown beef	Agricultural receptors
• Ingestion of home-grown pork	Agricultural receptors
• Ingestion of home-grown milk	Agricultural receptors
• Ingestion of breast milk	Infants only

It is noted that 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.

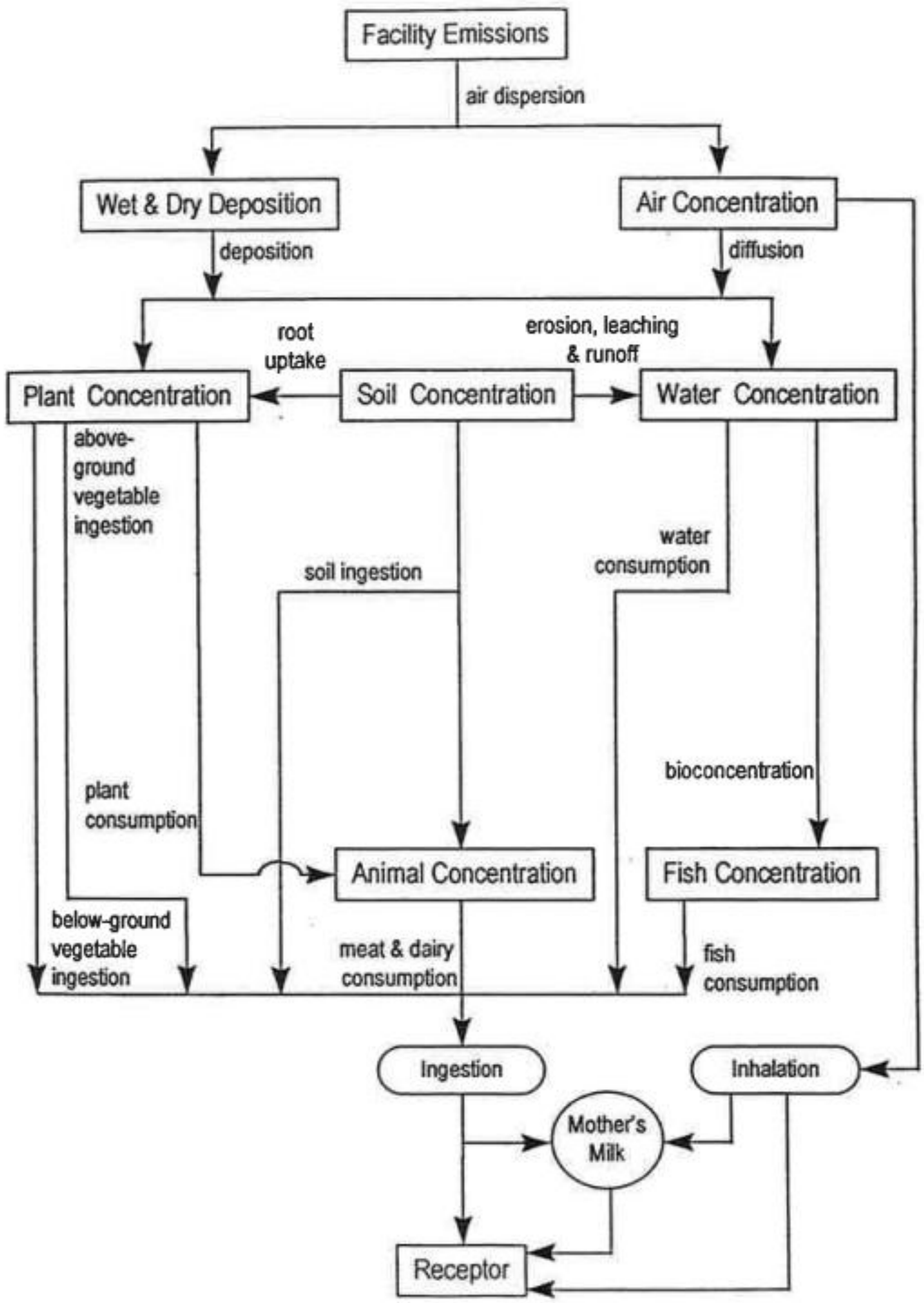

Figure 1: Conceptual Site Model – Exposure Pathways

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 waste combustion 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 waste incinerator 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 for a 1 pg I-TEQ/m^3 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

It is noted that 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. It is noted that run off to rainwater tanks may not go through the same treatment. However, rain water 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 it is noted that 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 Facility as the majority of UK dietary fish comes from marine habitats, not inland waterways.

A review of the local waterbodies has been undertaken to see if there are any game fishing lakes in the local area (http://www.fisharound.net/where-to-fish/locations-map). This has shown that the local waterbodies are all coarse fishing lakes which are not routinely used for human consumption. The closest lake which both game and course fishing takes place is Chigboro Fisheries which is approximately 9km to the south east of the Facility. Whilst fish caught in this lake may be used for human consumption, due to the distance from the facility this source has been excluded from the analysis. No other game fishing lakes have been identified within 10km of the Facility.

It is noted that the Bradwell Trout Farm is located approximately 1.5km to the north of the Facility. The Bradwell Trout Farm website explains that they produce rainbow trout exclusively for the restaurant and catering trade and that the supply is limited. It is highly unlikely that any fish caught would make up a significant proportion of the local community’s diet. Therefore this pathway has been excluded from this assessment, based on professional judgement.

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 Facility, and at the point of maximum impact of annual mean emissions.

For the purposes of this assessment, 'Residential' and 'Agricultural' receptors have been identified and can be defined as follows:

Residential: A known place of residence that is occupied within the study area;

Agricultural: A farm holding or area land of horticultural interest.

The emissions from the Facility are expected to be significant only in the locality of the plant. The specific receptors identified in the Air Quality Assessment have been considered in this Assessment. In addition a 'Point of maximum impact' receptor has been selected at the point of maximum impact within fields close to the Facility (and within the adjacent quarry) from annual mean process emissions, although it should be noted that this point is actually uninhabited.

These sensitive receptors are listed in Table 5.1 and displayed in Figure 2, which also contains the receptor designation considered most appropriate for each receptor.

Table 5.1: Sensitive Receptors

ID	Receptor Name	Location		Type of Receptor
		X	Y	
MAX	Point of maximum impact	582824	220771	Agricultural
HH1	Sheepcotes Farm (Hanger No.1)	581565	220328	Resident
HH2	Allshot's Farm (Scrap Yard)	582893	220458	Resident
HH3	Haywards	583236	221163	Resident
HH4	Herons Farm	582443	221378	Resident
HH5	Gosling's Farm	581427	221381	Resident
HH6	Curd Hall Farm	583262	221708	Resident
HH7	Church (adjacent to Bradwell Hall)	581832	222158	Resident
HH8	Bradwell Hall	581838	222319	Agricultural
HH9	Rolphs Farmhouse	580676	220513	Agricultural
HH10	Silver End / Bower Hall / Fossil Hall	581287	219731	Agricultural
HH11	Rivenhall Pl/Hall	581861	219104	Agricultural
HH12	Parkgate Farm / Watchpall Cottages	582337	219195	Agricultural
HH13	Ford Farm / Rivenhall Cottage	582698	218598	Agricultural
HH14	Porter's Farm	583391.6	219242	Agricultural
HH15	Unknown Building 1	583131.7	219462.9	Resident
HH16	Bumby Hall / The Lodge / Polish Site (Light Industry)	582947.2	220115.2	Resident
HH17	Green Pastures Bungalow	581249.9	221176.1	Resident
HH18	Deeks Cottage	582873.4	221255.1	Resident
HH19	Gosling Cottage / Barn	581508.4	221305.5	Resident

Table 5.1: Sensitive Receptors				
ID	**Receptor Name**	**Location**		**Type of**
HH20	Felix Hall / The Clock House / Park Farm	584578.8	219574.9	Agricultural
HH21	Glazenwood House	579980.5	222134.8	Resident
HH22	Bradwell Hall	580570.6	222802.9	Agricultural
HH23	Perry Green Farm	580899.7	221973.3	Agricultural
HH24	The Granary / Porter Farm / Rook Hall	584106.2	218964.5	Agricultural
HH25	Grange Farm	584888	222222	Agricultural
HH26	Coggeshall	585070	222839	Agricultural

It is noted that a number of additional receptors were included in the original HHRA, However on reviewing the status of these properties these were identified to be industrial units. These have therefore been excluded from this assessment.

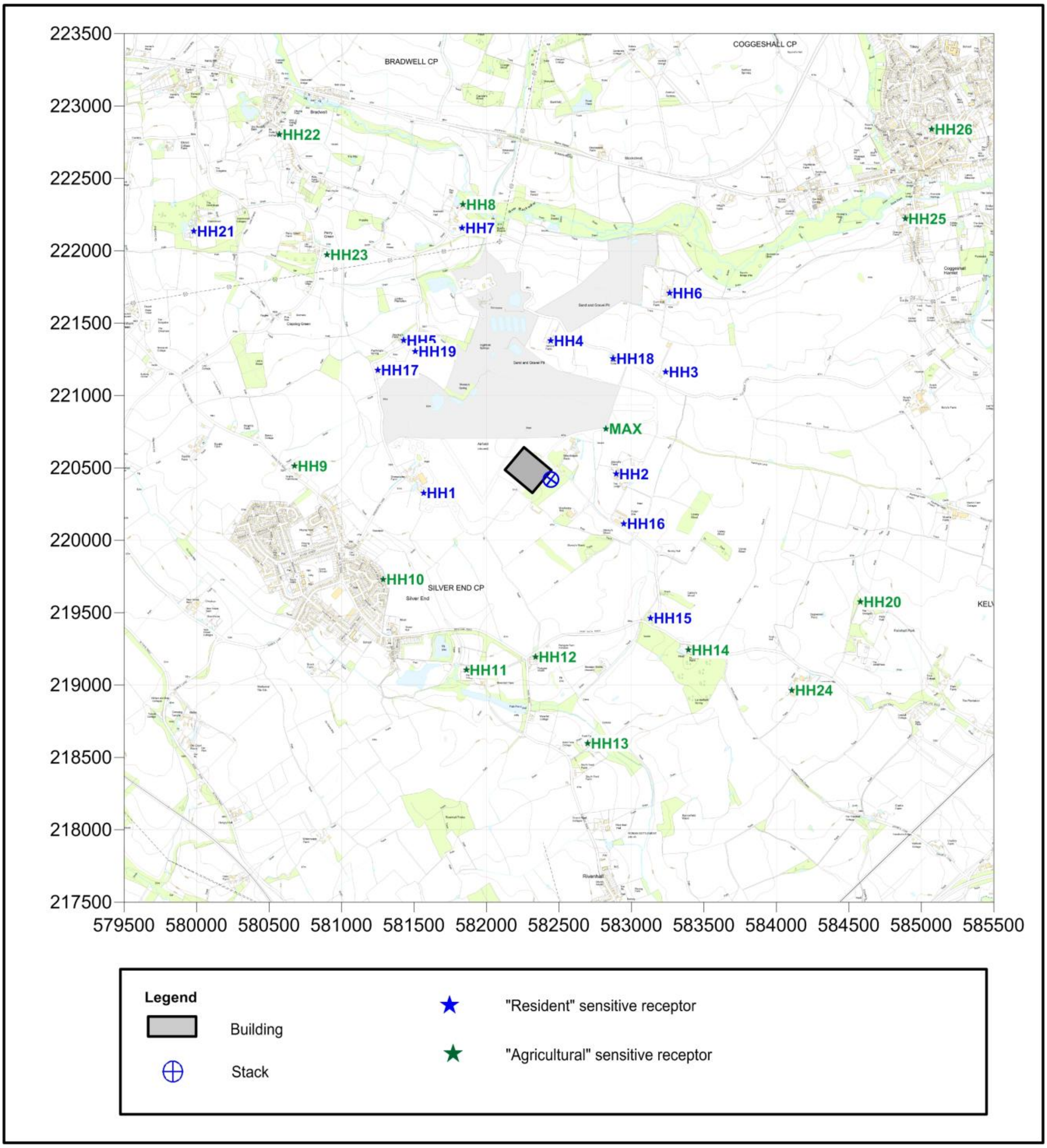

Figure 2: Sensitive Receptors

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 Concentration 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 Facility is taken as 30 years.
- The soil mixing depth is taken as 2 cm in general and 15 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 Concentration 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 Concentration in animals

The concentrations in animals, based on consumption of plants, 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 materials 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 Concentration 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 - 20 m^3/day; and
- Children – 7.2 m^3/day.

These are as specified within the Environment Agency series of reports: “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 mothers 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 — 0.688 kg/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 2009-2013 from the Stansted weather station, as used within the air quality dispersion modelling. This provides the annual average precipitation which can be used to calculate the general IRAP-h input parameters. Unfortunately the dataset does not include data on precipitation rates. Therefore the annual average precipitation from Andrewsfield climatic monitoring station between the years 1981-2010 has been used. Andrewsfield monitoring station is located in Stebbing approximately 13km to the west of the Facility:

Table 6.1: Ground Type Dependent Properties		
Input Variable	**Assumption**	**Value (cm/year)**
Annual average evapo-transpiration	70% of annual average precipitation	42.91
Annual average irrigation	0% of annual average precipitation	0.00
Annual average precipitation	100% of annual average precipitation	61.30
Annual average runoff	10% of annual average precipitation	6.13

- The average wind speed was taken as 4.23 m/s, calculated from the average of the 5 years of weather data for the period 2009-2013 from the Stansted Airport weather station.

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

Table 6.2: 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
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 Dispersion Modelling Assessment, to generate the inputs needed for the IRAP modelling. For details of the dispersion modelling methodology please refer to the Dispersion Modelling Assessment.

6.6 Modelled emissions

For the purpose of this assessment it is assumed that the Facility operates at the IED Emission Limit Values for its entire operational life. In actual fact the facility will be shut down for periods of maintenance and monitoring of similar facilities in the UK shows they do not operate at the Emission Limit Values.

The following tables gives the emissions rates of each COPC modelled and the associated Emission Limit Values which have been used to derive the emission rate.

Table 6.3: COPC Emissions Modelled		
COPC	**Emission Limit Value (mg/Nm^3)**	**Emission rate (µg/s)**
Hydrogen chloride	10	1027.2
Benzene	10	1027.2
PAHs (Benzo(a)pyrene)	0.0002	0.021
Elemental mercury	0.0001	0.010
Mercuric chloride	0.024	2.465
Cadmium	0.025	2.568
Thallium (I)	0.025	2.568
Antimony	0.055	5.650
Arsenic	0.055	5.650
Chromium	0.055	5.650
Chromium, hexavalent	0.00013	0.013
Lead	0.055	5.650
Nickel	0.055	5.650

Table 6.4: COPC Emissions Modelled		
COPC	**Emission Limit Value (ng I-TEQ/Nm^3)**	**Emission rate (pg/s)**
TetraCDD,2,3,7,8	0.1	0.318
HexaCDD,1,2,3,7,8,9		0.211
OctaCDD,1,2,3,4,6,7,8,9		0.042
HeptaCDD,1,2,3,4,6,7,8		0.175
OctaCDF,1,2,3,4,6,7,8,9		0.037
HexaCDD,1,2,3,4,7,8		0.295
PentaCDD,1,2,3,7,8		1.258
TetraCDF,2,3,7,8		0.285
HeptaCDF,1,2,3,4,7,8,9		0.044
PentaCDF,2,3,4,7,8		2.748
PentaCDF,1,2,3,7,8		0.142
HexaCDF,1,2,3,6,7,8		0.829
HexaCDD,1,2,3,6,7,8		0.265
HexaCDF,2,3,4,6,7,8		0.895
HeptaCDF,1,2,3,4,6,7,8		0.451
HexaCDF,1,2,3,4,7,8		2.238
HexaCDF,1,2,3,7,8,9		0.043
Dioxin like PCBs	0.0092	0.945

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

(1) Hydrogen chloride (Table 6.3).

a) It has been assumed that HCl is emitted at the daily ELV.

(2) Benzene (Table 6.3).

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.

(3) PAHs (Table 6.3).

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 0.105 ug/m³, or 0.000105 mg/m³ (dry, 11% oxygen, 273K). As this is not a regulated pollutant and only monitored periodically we have applied a safety factor of 2.

(4) Group 1 metals - mercury and compounds (Table 6.3).

a) It has been assumed that the ELV of total mercury is 0.05mg/Nm^3

b) The concentration of elemental mercury has been taken as 0.2% of the total mercury and compounds ELV

c) The concentration of mercury chloride has been taken as 48% of the total mercury and compounds ELV.

d) The losses to the global cycle have been taken as 51.8% of the total mercury and compounds ELV.

(5) Group 2 metals - cadmium, thallium and compounds (Table 6.3).

a) The assessment is based on the IED ELV of 0.05 mg/Nm³ for cadmium, thallium and compounds.

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

(6) Group 3 metals – antimony, arsenic, chromium, lead and nickel (Table 6.3).

a) The assessment is based on the IED ELV of 0.5 mg/Nm³ for "other metals".

b) The emissions of each of the nine "other metals" in the third group have been taken as one-ninth of the combined limit. The Environment Agency "Guidance to Applicants on Impact Assessment for Group 3 Metals Stack Releases – V.3 September 2012" considers this to be a "worst case" scenario.

c) The emission rate of Chromium (VI) has been taken as equal to 0.026% (0.00013/0.5 mg/Nm^3) of the total chromium emission from the facility. This value is from the Environment Agency "Guidance to Applicants on Impact Assessment for Group 3 Metals Stack Releases – V.3 September 2011" which is based on the speciation of chromium emissions at ten municipal waste incinerators operating under IED in the UK.

(7) Dioxins and furans (Table 6.4).

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 Appendix A. 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 0.1 ng I-TEQ/Nm³ as presented in Table A.7.

To determine the Emission Rate, the split of the different dioxins for a 0.1 ng I-TEQ/Nm^3 has been multiplied by the TEF value for the specific compound and then multiplied by the normalised flow rate as shown in Table 6.6.

(8) Dioxin like PCBs (Table 6.4).

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

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 Arocolor is based on a fixed composition of PCBs. Since we are not aware of any data on the specification 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.

As noted it is assumed that the metals are emitted as 11% of the total emission limit for group 3 metals. An analysis of monitoring of metal emissions from 10 Municipal Waste Incinerators in England and Wales is presented in Appendix B of “Guidance to Applicants on Impact Assessment for Group 3 Metals Stack Releases – V.3 September 2012”. This is reproduced in the following table.

Table 6.5: Monitoring Data from Municipal Waste Incinerators			
Pollutant	**Measured Concentration as % of IED Group 3 Limit**		
	Mean	**Max**	**Min**
Antimony	0.66%	2.30%	0.02%
Arsenic	0.14%	0.60%	0.06%
Chromium	2.18%	10.42%	0.08%
Cobalt	0.08%	0.78%	0.04%
Copper	1.54%	3.26%	0.50%
Lead	3.16%	7.36%	0.06%
Manganese	3.44%	7.30%	0.30%
Nickel	4.40%	27.24%	0.00%
Tin	0.48%	0.48%	0.48%
Vanadium	0.06%	0.20%	0.04%
Total (calculated)	**16.14%**	**59.94%**	**1.58%**

NOTES:

Nickel concentration is greater than 11% is due to one single measurement outlier. The average is around 4% of the Group ELV.

As shown, the total chromium emissions are a maximum of 10.42%, or on average 2.18% of the limit; this includes some contribution from chromium (VI). Therefore assuming that any of the metals are emitted at 11% of the total group 3 limit is conservative.

Table 6.6: Basis for the Emission Rate of Dioxins and Furans				
Dioxin / furan	**Split of Congeners for a release of 0.1 ng I-TEQ/Nm³**	**I-TEFs for the congeners[6]**	**Total (I-TEQ) ng/Nm³**	**Emission rate (pg/s)**
2,3,7,8-TCDD	0.0031	1	0.0031	0.318
1,2,3,7,8-PeCDD	0.0245	0.5	0.0123	1.258
1,2,3,4,7,8-HxCDD	0.0287	0.1	0.0029	0.295
1,2,3,6,7,8-HxCDD	0.0258	0.1	0.0026	0.265
1,2,3,7,8,9-HxCDD	0.0205	0.1	0.0021	0.211
1,2,3,4,6,7,8-HpCDD	0.1704	0.01	0.0017	0.175
1,2,3,4,6,7,8,9-OctaCDD	0.4042	0.001	0.0004	0.042
2,3,7,8-TCDF	0.0277	0.1	0.0028	0.285
1,2,3,7,8-PCDF	0.0277	0.05	0.0014	0.142
2,3,4,7,8-PCDF	0.0535	0.5	0.0268	2.748
1,2,3,4,7,8-HxCDD	0.2179	0.1	0.0218	2.238
1,2,3,6,7,8-HxCDF	0.0807	0.1	0.0081	0.829
1,2,3,7,8,9-HxCDF	0.0042	0.1	0.0004	0.043
2,3,4,6,7,8-HxCDF	0.0871	0.1	0.0087	0.895
1,2,3,4,6,7,8-HpCDF	0.4395	0.01	0.0044	0.451
1,2,3,4,7,8,9-HpCDF	0.0429	0.01	0.0004	0.044
1,2,3,4,6,7,8,9-OctaCDF	0.3566	0.001	0.0004	0.037
Total (I-TEQ)	2.0150	-	0.1000	-

[6] Kutz et al.(1990) The International Toxicity Equivalency Factor (I-TEF) method for estimating risks associated with exposures to complex mixtures of dioxins and related compounds.

7 Results

7.1 At point of maximum impact

The following tables outline the impact of emissions from the Facility at the Point of maximum impact for an 'Agricultural' receptor located on an open field (within the adjacent quarry) to the north of the Facility. As explained in section 4, 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. Reference should be made to Figure 2 for the location of the point in relation to the Facility. As shown this point is uninhabited. Where appropriate a comparison has been made to the TDI or ID.

Table 7.1: Impact Analysis – TDI – Point of Maximum Impact – "Agricultural" Receptor Located on an Open Field (within the adjacent quarry)

Substance	MDI (% of TDI)		Process Contribution (% of TDI)		Overall (% of TDI)	
	Inhalation	Ingestion	Inhalation	Ingestion	Inhalation	Ingestion
Adult						
Cadmium	21.43%	52.78%	9.70%	0.27%	31.13%	53.04%
Chromium	-	60.33%	-	0.68%	-	61.01%
Methyl mercury	-	3.04%	-	0.10%	-	3.14%
Mercuric chloride	-	0.70%	-	0.25%	-	0.95%
Nickel	15.00%	15.83%	4.98%	0.12%	19.98%	15.95%
Dioxins and dioxin like PCBs	35.00%		2.35%		37.35%	
Child						
Cadmium	50.00%	138.89%	12.22%	0.62%	62.22%	139.51%
Chromium	-	131.33%	-	1.10%	-	132.44%
Methyl mercury	-	8.26%	-	0.20%	-	8.46%
Mercuric chloride	-	1.85%	-	0.41%	-	2.26%
Nickel	33.33%	40.00%	6.27%	0.18%	39.61%	40.18%
Dioxins and dioxin like PCBs	90.00%		3.27%		93.27%	

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 for this worst-case receptor the overall impact (including the contribution from existing dietary intakes) is less than the TDI for methyl mercury, mercuric chloride, nickel and dioxins. Therefore there would not be an appreciable health risk based on the emission of these pollutants.

For a child receptor the cadmium and chromium 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 Facility would increase the health risks from cadmium or chromium for children significantly.

As noted in Section 3, 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 either 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. If we assess the lifetime exposure (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.

As shown in Table 6.5 the concentrations of total chromium in emissions from municipal waste incineration processes are typically 2.18% of the emission limit, this consists of some in the hexavalent form. Even using the worst case assumption that emissions of chromium are 11% of the group 3 IED limit the process contribution is only 1.1% of the TDI for a child at the point of maximum impact. As explained in Section 3, 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".

As explained in Section 3, although the TDI is predicted to be exceeded, this is due to existing dietary intake. The WHO have reviewed the daily intake of chromium from foods and found that existing levels do not represent a toxicity problem, and state that "in the form of trivalent compounds, chromium is an essential nutrient and is relatively non-toxic for man and other mammalian species". The TDI is based on the USEPA's Reference Dose for chromium IV. 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 emission of cadmium over a lifetime of an individual.

The total accumulation of dioxins in an infant, considering the breast milk pathway and based on the adult receptor at the point of maximum impact feeding an infant, is 0.624 pg WHO-TEQ / kg-bw / day which is 31.21% of the TDI.

Table 7.2: Impact Analysis – ID – Point of Maximum Impact – "Agricultural" Receptor Located on an Open Field (within the adjacent quarry)

Substance	Inhalation (% of ID)	Ingestion (% of ID)
Adult		
Arsenic	14.94%	1.21%
Benzene	3.88%	0.45%
Benzo[a]pyrene	1.55%	3.26%
Chromium (VI)	29.87%	-
Child		
Arsenic	18.82%	2.11%
Benzene	4.89%	1.06%
Benzo[a]pyrene	1.96%	4.71%
Chromium (VI)	37.64%	-

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 Facility are considered to have a negligible impact on human health.

7.2 Maximum impact at a receptor

The following tables outline the impact of emissions from the Facility at the most affected receptor (i.e the receptor with the greatest impact from ingestion and inhalation of emissions) (HH25 – Grange Farm). Where appropriate a comparison has been made to the TDI or ID.

Table 7.3: 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	21.43%	52.78%	6.30%	0.11%	27.73%	52.95%
Chromium	-	60.33%	-	0.14%	-	60.47%
Methyl mercury	-	3.04%	-	0.02%	-	3.07%
Mercuric chloride	-	0.70%	-	0.049%	-	0.75%
Nickel	15.00%	15.83%	3.23%	0.024%	18.23%	15.86%
Dioxins and dioxin like PCBs	35.00%		0.47%		35.47%	
Child						
Cadmium	50.00%	138.89%	7.94%	0.27%	57.94%	139.16%
Chromium	-	131.33%	-	0.22%	-	131.56%
Methyl mercury	-	8.26%	-	0.06%	-	8.32%
Mercuric chloride	-	1.85%	-	0.08%	-	1.93%
Nickel	33.33%	40.00%	4.07%	0.037%	37.41%	40.04%
Dioxins and dioxin like PCBs	90.00%		0.66%		90.66%	

As shown for the most impacted receptor the overall impact (including the contribution from existing dietary intakes) is less than the TDI for methyl mercury, mercuric chloride, nickel and dioxins. Therefore there would not be an appreciable health risk based on the emission of these pollutants.

For a child receptor the cadmium and chromium 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 Facility would increase the health risks from cadmium or chromium for children significantly.

The total accumulation of dioxins in an infant, considering the breast milk pathway and based on the adult Agricultural receptor at HH25 –feeding an infant, is 0.126 pg WHO-TEQ / kg bw / day which is 6.28% of the TDI.

The total accumulation of dioxins in an infant, considering the breast milk pathway and based on the most impacted residential receptor HH4 –feeding an infant, is 0.008 pg WHO-TEQ / kg bw / day which is 0.38% of the TDI.

Table 7.4: Impact Analysis – ID – Maximum Impacted Receptor		
Substance	**Inhalation (% of ID)**	**Ingestion (% of ID)**
Adult		
Arsenic	9.70%	0.29%
Benzene	2.52%	0.31%
Benzo[a]pyrene	1.01%	0.66%
Chromium (VI)	19.40%	-
Child		
Arsenic	12.22%	0.70%
Benzene	3.18%	0.55%
Benzo[a]pyrene	1.27%	0.95%
Chromium (VI)	24.45%	-

As shown for this worst-case receptor the process contribution is well below the ID. Therefore, emissions from the Facility are considered to have a negligible impact on human health.

7.3 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 Facility.

7.4 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/Nm^3 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 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 850ºC 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 850ºC 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 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 waste 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 facility.

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

8 Conclusions

Of all the pollutants considered with a Tolerable Daily Intake (TDI), cadmium is the pollutant that results in the highest level of existing exposure (MDI). The combined impact of cadmium from existing background sources and contributions from the proposed Facility at the point of maximum impact is 139.51% of the ingestion TDI for children. However, the process contribution from the Facility for cadmium is exceptionally small, being only 0.62% of the TDI at the point of maximum impact, and 0.27% or less at receptors. Similarly, the ingestion of chromium from existing background sources and contributions from the proposed Facility also exceeds the ingestion TDI for children. However, the process contribution from the proposed Facility for chromium is again exceptionally small, being only 1.10% of the TDI at the point of maximum impact, and 0.22% or less at receptors

The TDI is set at a level "that can be ingested daily over a lifetime without appreciable health risk". The ingestion of cadmium and chromium by children as a result of background sources is already above the TDI. On the basis that the process contribution of these substances is exceptionally small it is not considered that the Facility would increase the health risks from this pollutant significantly. For all other pollutants, the combined impact from the Facility plus the existing MDI is below the TDI, so there would not be an appreciable health risk based on the emission of these pollutants.

Although the MDI exceeds the cadmium TDI for children, the Environment Agency explains that chronic exposure to levels in excess of either 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 over the lifetime (i.e. a period as a child and adult) the overall impact is well below the TDI, so there would not be an appreciable health risk based on the emission of cadmium.

Again the TDI for chromium for children is predicted to be exceeded due to existing dietary intake. Toxicological opinion is that chromium III is of low oral toxicity and is needed as part of a health diet. The UK Committee on Medial Aspects of Food Policy recommend a minimum safe and adequate intake, but do not restrict an upper limit. The WHO have analysed human intake for chromium through food and conclude that existing levels do not represent a toxicity problem. The TDI is based on the USEPA's Reference Dose for chromium IV. Assessing the total dietary intake of chromium against this TDI is highly conservative. Therefore it is concluded that as the process contribution is so small and the TDI is set at a highly conservative level there would not be an appreciable health risk based on the emission of chromium.

For pollutants which do not have a TDI, a comparison has been made against an Index Dose (ID). The ID is a threshold below which there are considered to be negligible risks to human health. The greatest contribution from the Facility is from chromium (VI), which is only 37.64% of the Index Dose for children at the point of maximum impact. Therefore, emissions from the Facility of chromium (VI) and all other pollutants are considered to have a negligible impact on human health.

In conclusion, the Facility will not result in appreciable health risks resulting from its operation. This is the same conclusion reached in the original human health risk assessment(s) completed by Golder Associates (UK) Ltd. This confirms that the design modifications that have been made to the Facility have not changed the overall health risks resulting from its operation.

Appendix A - Detailed Results Tables

Table A.1: 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	1.206%	0.45209%	3.257%	14.937%	3.880%	1.552%	29.874%
MAX	0.069%	0.07447%	0.005%	2.320%	0.602%	0.241%	4.639%
HH1	0.186%	0.19967%	0.013%	6.218%	1.615%	0.646%	12.436%
HH2	0.290%	0.31162%	0.021%	9.702%	2.520%	1.008%	19.404%
HH3	0.115%	0.12312%	0.008%	3.834%	0.996%	0.398%	7.667%
HH4	0.115%	0.12312%	0.008%	3.834%	0.996%	0.398%	7.667%
HH5	0.130%	0.13989%	0.009%	4.357%	1.132%	0.453%	8.715%
HH6	0.044%	0.04701%	0.003%	1.462%	0.380%	0.152%	2.925%
HH7	0.110%	0.04126%	0.297%	1.363%	0.354%	0.142%	2.726%
HH8	0.086%	0.03217%	0.232%	1.062%	0.276%	0.110%	2.124%
HH9	0.198%	0.07415%	0.534%	2.450%	0.636%	0.255%	4.901%
HH10	0.176%	0.06599%	0.475%	2.180%	0.566%	0.226%	4.360%
HH11	0.204%	0.07647%	0.551%	2.527%	0.656%	0.263%	5.054%
HH12	0.133%	0.04988%	0.359%	1.648%	0.428%	0.171%	3.296%
HH13	0.178%	0.06677%	0.481%	2.206%	0.573%	0.229%	4.411%
HH14	0.087%	0.09288%	0.006%	2.893%	0.751%	0.301%	5.785%
HH15	0.121%	0.12981%	0.009%	4.042%	1.050%	0.420%	8.084%
HH16	0.061%	0.06504%	0.004%	2.026%	0.526%	0.210%	4.051%
HH17	0.194%	0.20860%	0.014%	6.495%	1.687%	0.675%	12.991%
HH18	0.062%	0.06668%	0.004%	2.077%	0.539%	0.216%	4.153%
HH19	0.110%	0.04120%	0.297%	1.362%	0.354%	0.141%	2.723%
HH20	0.034%	0.03622%	0.002%	1.128%	0.293%	0.117%	2.257%

Table A.1: Comparison with ID Limits for Adult Receptors

HH21	0.075%	0.02825%	0.204%	0.933%	0.242%	0.097%	1.866%
HH22	0.099%	0.03723%	0.268%	1.231%	0.320%	0.128%	2.462%
HH23	0.115%	0.04312%	0.311%	1.425%	0.370%	0.148%	2.851%
HH24	0.243%	0.09093%	0.655%	3.006%	0.781%	0.312%	6.011%
HH25	0.211%	0.07906%	0.570%	2.612%	0.678%	0.271%	5.223%
HH26	1.206%	0.45209%	3.257%	14.937%	3.880%	1.552%	29.874%

Table A.2: 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	2.109%	1.061804%	4.709%	18.821%	4.889%	1.955%	37.642%
HH1	0.167%	0.132110%	0.014%	2.923%	0.759%	0.304%	5.845%
HH2	0.448%	0.354233%	0.036%	7.835%	2.035%	0.814%	15.669%
HH3	0.698%	0.552835%	0.057%	12.225%	3.175%	1.270%	24.449%
HH4	0.276%	0.218430%	0.022%	4.830%	1.255%	0.502%	9.661%
HH5	0.276%	0.218430%	0.022%	4.830%	1.255%	0.502%	9.661%
HH6	0.314%	0.248177%	0.025%	5.490%	1.426%	0.570%	10.981%
HH7	0.105%	0.083406%	0.009%	1.843%	0.479%	0.191%	3.685%
HH8	0.193%	0.096901%	0.430%	1.718%	0.446%	0.178%	3.435%
HH9	0.150%	0.075558%	0.335%	1.338%	0.348%	0.139%	2.677%
HH10	0.346%	0.174157%	0.772%	3.087%	0.802%	0.321%	6.175%
HH11	0.308%	0.154995%	0.687%	2.747%	0.713%	0.285%	5.494%
HH12	0.357%	0.179614%	0.797%	3.184%	0.827%	0.331%	6.368%
HH13	0.233%	0.117158%	0.520%	2.076%	0.539%	0.216%	4.153%
HH14	0.311%	0.156814%	0.695%	2.779%	0.722%	0.289%	5.558%
HH15	0.208%	0.164771%	0.017%	3.645%	0.947%	0.379%	7.289%
HH16	0.291%	0.230293%	0.024%	5.093%	1.323%	0.529%	10.185%
HH17	0.146%	0.115388%	0.012%	2.552%	0.663%	0.265%	5.105%
HH18	0.468%	0.370097%	0.038%	8.184%	2.126%	0.850%	16.368%
HH19	0.149%	0.118305%	0.012%	2.616%	0.680%	0.272%	5.233%
HH20	0.192%	0.096781%	0.429%	1.716%	0.446%	0.178%	3.431%
HH21	0.081%	0.064257%	0.007%	1.422%	0.369%	0.148%	2.843%

Table A.2: Comparison with ID Limits for Child Receptors

HH22	0.132%	0.066339%	0.294%	1.176%	0.305%	0.122%	2.351%
HH23	0.174%	0.087441%	0.388%	1.551%	0.403%	0.161%	3.102%
HH24	0.201%	0.101267%	0.449%	1.796%	0.466%	0.187%	3.592%
HH25	0.424%	0.213572%	0.947%	3.787%	0.984%	0.393%	7.574%
HH26	0.369%	0.185678%	0.823%	3.291%	0.855%	0.342%	6.582%

Table A.3: Comparison with TDI Limits for Adult Receptors							
Receptor	**Ingestion (% of ID)**					**Inhalation (% of ID)**	
	Cadmium	**Chromium**	**Methyl Mercury**	**Mercuric Chloride**	**Nickel**	**Cadmium**	**Nickel**
MDI of TDI (%)	**52.78%**	**60.33%**	**3.04%**	**0.70%**	**15.83%**	**21.43%**	**15.00%**
Point of maximum impact	53.04%	61.01%	3.14%	0.95%	15.95%	31.13%	19.98%
HH1	52.80%	60.34%	3.05%	0.70%	15.84%	22.93%	15.77%
HH2	52.85%	60.36%	3.06%	0.71%	15.84%	25.47%	17.07%
HH3	52.89%	60.37%	3.07%	0.72%	15.84%	27.73%	18.23%
HH4	52.82%	60.35%	3.05%	0.71%	15.84%	23.92%	16.28%
HH5	52.82%	60.35%	3.05%	0.71%	15.84%	23.92%	16.28%
HH6	52.83%	60.35%	3.05%	0.71%	15.84%	24.26%	16.45%
HH7	52.79%	60.34%	3.05%	0.70%	15.83%	22.38%	15.49%
HH8	52.80%	60.39%	3.05%	0.72%	15.84%	22.31%	15.45%
HH9	52.80%	60.38%	3.05%	0.72%	15.84%	22.12%	15.35%
HH10	52.82%	60.44%	3.06%	0.74%	15.85%	23.02%	15.82%
HH11	52.82%	60.43%	3.06%	0.74%	15.85%	22.84%	15.73%
HH12	52.82%	60.45%	3.06%	0.74%	15.85%	23.07%	15.84%
HH13	52.81%	60.41%	3.05%	0.73%	15.85%	22.50%	15.55%
HH14	52.82%	60.43%	3.06%	0.74%	15.85%	22.86%	15.74%
HH15	52.81%	60.34%	3.05%	0.71%	15.84%	23.31%	15.96%
HH16	52.82%	60.35%	3.05%	0.71%	15.84%	24.05%	16.35%
HH17	52.80%	60.34%	3.05%	0.70%	15.83%	22.74%	15.68%
HH18	52.85%	60.36%	3.06%	0.71%	15.84%	25.65%	17.17%
HH19	52.80%	60.34%	3.05%	0.70%	15.83%	22.78%	15.69%

Table A.3: Comparison with TDI Limits for Adult Receptors

HH20	52.80%	60.39%	3.05%	0.72%	15.84%	22.31%	15.45%
HH21	52.79%	60.34%	3.05%	0.70%	15.83%	22.16%	15.38%
HH22	52.79%	60.38%	3.05%	0.72%	15.84%	22.03%	15.31%
HH23	52.80%	60.39%	3.05%	0.72%	15.84%	22.23%	15.41%
HH24	52.80%	60.40%	3.05%	0.72%	15.84%	22.35%	15.48%
HH25	52.83%	60.47%	3.06%	0.75%	15.86%	23.38%	16.00%
HH26	52.82%	60.45%	3.06%	0.74%	15.85%	23.12%	15.87%

Table A.4: Comparison with TDI Limits for Child Receptors							
Receptor	Ingestion (% of ID)					Inhalation (% of ID)	
	Cadmium	Chromium	Methyl Mercury	Mercuric Chloride	Nickel	Cadmium	Nickel
MDI of TDI (%)	**138.89%**	**131.33%**	**8.26%**	**1.85%**	**40.00%**	**50.00%**	**33.33%**
Point of maximum impact	139.51%	132.44%	8.46%	2.26%	40.18%	62.22%	39.61%
HH1	138.95%	131.36%	8.28%	1.87%	40.00%	51.90%	34.31%
HH2	139.06%	131.40%	8.30%	1.90%	40.01%	55.09%	35.94%
HH3	139.16%	131.44%	8.32%	1.93%	40.02%	57.94%	37.41%
HH4	138.99%	131.38%	8.29%	1.88%	40.01%	53.14%	34.94%
HH5	138.99%	131.38%	8.29%	1.88%	40.01%	53.14%	34.94%
HH6	139.01%	131.38%	8.29%	1.88%	40.01%	53.57%	35.16%
HH7	138.93%	131.35%	8.27%	1.86%	40.00%	51.20%	33.95%
HH8	138.95%	131.43%	8.28%	1.89%	40.02%	51.12%	33.91%
HH9	138.93%	131.41%	8.27%	1.88%	40.01%	50.87%	33.78%
HH10	138.99%	131.51%	8.29%	1.92%	40.03%	52.00%	34.36%
HH11	138.98%	131.49%	8.29%	1.91%	40.03%	51.78%	34.25%
HH12	138.99%	131.52%	8.29%	1.92%	40.03%	52.07%	34.39%
HH13	138.96%	131.45%	8.28%	1.90%	40.02%	51.35%	34.03%
HH14	138.98%	131.50%	8.29%	1.91%	40.03%	51.80%	34.26%
HH15	138.97%	131.37%	8.28%	1.87%	40.01%	52.37%	34.55%
HH16	139.00%	131.38%	8.29%	1.88%	40.01%	53.31%	35.03%
HH17	138.94%	131.36%	8.27%	1.87%	40.00%	51.66%	34.18%
HH18	139.07%	131.41%	8.30%	1.90%	40.01%	55.31%	36.06%
HH19	138.95%	131.36%	8.27%	1.87%	40.00%	51.70%	34.21%

Table A.4: Comparison with TDI Limits for Child Receptors							
HH20	138.95%	131.43%	8.28%	1.89%	40.02%	51.11%	33.91%
HH21	138.92%	131.35%	8.27%	1.86%	40.00%	50.92%	33.81%
HH22	138.93%	131.40%	8.27%	1.88%	40.01%	50.76%	33.73%
HH23	138.94%	131.42%	8.28%	1.88%	40.02%	51.01%	33.85%
HH24	138.95%	131.44%	8.28%	1.89%	40.02%	51.17%	33.93%
HH25	139.01%	131.56%	8.30%	1.93%	40.04%	52.46%	34.60%
HH26	139.00%	131.53%	8.30%	1.92%	40.03%	52.14%	34.43%

Table A.5: 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	1.47E-04	4.68E-02	4.69E-02	37.35%
HH1	2.28E-05	1.39E-04	1.62E-04	35.01%
HH2	6.12E-05	3.74E-04	4.35E-04	35.02%
HH3	9.55E-05	5.83E-04	6.78E-04	35.03%
HH4	3.77E-05	2.30E-04	2.68E-04	35.01%
HH5	3.77E-05	2.30E-04	2.68E-04	35.01%
HH6	4.29E-05	2.62E-04	3.05E-04	35.02%
HH7	1.44E-05	8.79E-05	1.02E-04	35.01%
HH8	1.34E-05	4.27E-03	4.28E-03	35.21%
HH9	1.05E-05	3.33E-03	3.34E-03	35.17%
HH10	2.41E-05	7.67E-03	7.70E-03	35.38%
HH11	2.15E-05	6.83E-03	6.85E-03	35.34%
HH12	2.49E-05	7.91E-03	7.94E-03	35.40%
HH13	1.62E-05	5.16E-03	5.18E-03	35.26%
HH14	2.17E-05	6.91E-03	6.93E-03	35.35%
HH15	2.85E-05	1.74E-04	2.02E-04	35.01%
HH16	3.98E-05	2.43E-04	2.83E-04	35.01%
HH17	1.99E-05	1.22E-04	1.42E-04	35.01%
HH18	6.39E-05	3.90E-04	4.54E-04	35.02%
HH19	2.04E-05	1.25E-04	1.45E-04	35.01%
HH20	1.34E-05	4.26E-03	4.28E-03	35.21%

Table A.5: 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)**
HH21	1.11E-05	6.78E-05	7.89E-05	35.00%
HH22	9.18E-06	2.92E-03	2.93E-03	35.15%
HH23	1.21E-05	3.85E-03	3.87E-03	35.19%
HH24	1.40E-05	4.46E-03	4.48E-03	35.22%
HH25	2.96E-05	9.41E-03	9.44E-03	35.47%
HH26	2.57E-05	8.18E-03	8.21E-03	35.41%

Table A.6: 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)				**90.00%**
Point of maximum impact	1.85E-04	6.51E-02	6.53E-02	93.27%
HH1	2.88E-05	4.66E-04	4.95E-04	90.02%
HH2	7.71E-05	1.25E-03	1.33E-03	90.07%
HH3	1.20E-04	1.95E-03	2.07E-03	90.10%
HH4	4.75E-05	7.70E-04	8.18E-04	90.04%
HH5	4.75E-05	7.70E-04	8.18E-04	90.04%
HH6	5.40E-05	8.75E-04	9.29E-04	90.05%
HH7	1.81E-05	2.94E-04	3.12E-04	90.02%
HH8	1.69E-05	5.95E-03	5.96E-03	90.30%
HH9	1.32E-05	4.63E-03	4.65E-03	90.23%
HH10	3.04E-05	1.07E-02	1.07E-02	90.54%
HH11	2.70E-05	9.51E-03	9.54E-03	90.48%
HH12	3.13E-05	1.10E-02	1.11E-02	90.55%
HH13	2.04E-05	7.19E-03	7.21E-03	90.36%
HH14	2.74E-05	9.62E-03	9.65E-03	90.48%
HH15	3.59E-05	5.81E-04	6.17E-04	90.03%
HH16	5.01E-05	8.12E-04	8.62E-04	90.04%
HH17	2.51E-05	4.07E-04	4.32E-04	90.02%
HH18	8.05E-05	1.31E-03	1.39E-03	90.07%
HH19	2.58E-05	4.17E-04	4.43E-04	90.02%
HH20	1.69E-05	5.94E-03	5.95E-03	90.30%

Table A.6: 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)**
HH21	1.40E-05	2.27E-04	2.41E-04	90.01%
HH22	1.16E-05	4.07E-03	4.08E-03	90.20%
HH23	1.53E-05	5.37E-03	5.38E-03	90.27%
HH24	1.77E-05	6.22E-03	6.23E-03	90.31%
HH25	3.73E-05	1.31E-02	1.31E-02	90.66%
HH26	3.24E-05	1.14E-02	1.14E-02	90.57%

Table A.7: Basis for the Emission Rate of Dioxins and Furans	
Compound	**WHO-TEF Multiplier[8]**
HeptaCDD, 1,2,3,4,6,7,8-	0.0031
HeptaCDF, 1,2,3,4,6,7,8-	0.0245
HeptaCDF, 1,2,3,4,7,8,9-	0.0287
HexaCDD, 1,2,3,4,7,8-	0.0258
HexaCDD, 1,2,3,6,7,8-	0.0205
HexaCDD, 1,2,3,7,8,9-	0.1704
HexaCDF, 1,2,3,4,7,8-	0.4042
HexaCDF, 1,2,3,6,7,8-	0.0277
HexaCDF, 1,2,3,7,8,9-	0.0277
HexaCDF, 2,3,4,6,7,8-	0.0535
OctaCDD, 1,2,3,4,6,7,8,9-	0.2179
PentaCDD, 1,2,3,7,8-	0.0807
PentaCDF, 1,2,3,7,8-	0.0042
PentaCDF, 2,3,4,7,8-	0.0871
TetraCDD, 2,3,7,8-	0.4395
TetraCDF, 2,3,7,8-	0.0429

[8] Van den Berg et al, 2006

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