



Environmental Visage

**BIOMASS UK NO. 4 LIMITED; DARTMOOR
HEALTH IMPACT ASSESSMENT**

**BIOMASS UK NO. 4 LIMITED
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Executive Summary

A health impact assessment has been undertaken to assess the risk to the health of people living and working in the vicinity of the Dartmoor Bio Power facility, which is now proposed for conversion from wood fired energy production, to the firing of Refuse Derived Fuel (RDF).

A detailed air quality assessment has been undertaken on behalf of Biomass UK No. 4 Limited in order to consider their proposal to convert the existing wood fired Energy from Waste (EfW) plant, for the receipt and use of RDF and determines the resultant impact on air quality. Dartmoor Bio Power was built as a 4.3 MW_e waste wood incineration plant. The generation capacity of the facility will remain at 4.3 MW_e with the switch to RDF and the facility will in future be known as Biomass Number 4 (Biomass No. 4).

Discharge characteristics for the proposed facility were provided by the technology providers via Biomass UK No. 4 Limited and suggest an overall increase in the volumetric flow-rate from that measured in 2018, although a proposed increase in the diameter of the stack results in a reduction in the velocity, and an increase in the temperature of the discharge from that of the existing, albeit not operational, facility. Mass emission rates for Dioxins and Furans, and Dioxins, Furans and Poly Chlorinated Biphenyls (PCBs) were also reduced from the original scheme due to changes in the regulatory limits that will be applied to the site operations through the Environmental Permitting regime.

Detailed atmospheric dispersion modelling of emissions from the proposed 35 m high chimney was undertaken using the ADMS Version 5.2 model to predict increases in pollutant concentrations at nearby sensitive receptors such as residential properties, schools and locations where people may congregate for significant periods of time. The assessment, which was reported in the 'Biomass UK No. 4 Limited; Dartmoor Dispersion Model and Air Quality Assessment' involved a comparison of model-predicted process contributions against health-based Air Quality Standards (AQS) and Environmental Assessment Levels (EALs) recommended by the Environment Agency.

In the absence of any relevant AQS / EALs for the impacts of Dioxin and Furan releases, the US EPA Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities (HHRAP) has been applied here to assess the potential risk to the health of people living and working in the locality of the proposed EfW facility due to emissions of Dioxins and Furans, and Dioxin-like PCBs. The assessment applied the results from the original Air Quality Assessment modelling, and considered the potential human health risks associated with the intake of Dioxins from inhalation and the consumption of potentially contaminated foodstuffs due to emissions to atmosphere from the chimney of the proposed EfW plant. All assumptions used within the assessment are conservative and as such, the study was undertaken on a worst-case basis.

The assessment indicates that the risk to health of the local population due to exposure to Dioxins in emissions from the facility is likely to be low, remaining within 1 % of the Tolerable Daily Intake (TDI) of 2 pg kg⁻¹ for adults. The inclusion of Dioxin-like PCBs into the assessment resulted in a marginal increase in the resulting process contributions, which remained a very small proportion of the 2 pg kg⁻¹ TDI.

The assessment for health risks associated with exposure to emissions of PAH demonstrated that process contributions at the sensitive receptors equate to between 0.1 % and 2.4 % of the Air Quality Standard (0.25 ng m⁻³ PAH as B[a]P). However, where contributions were not immediately screened as insignificant, all were screened at the secondary assessment stage.

In conclusion, the results from the health impact assessment confirms that there is no significant health risk associated with potential exposure to emissions of Dioxins, Furans, PCBs or PAH from the converted facility, which proposes to fire RDF in the Biomass No. 4 EfW plant.

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Issue and Revision Record

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DRAFT	26/07/2021	Amanda Owen	ENVISAGE	Initial draft for Client comment
1	19/09/2023	Amanda Owen	ENVISAGE	Minor editorial changes and formal issue

1. Introduction

Environmental Visage Limited (Envisage) was commissioned by Biomass UK No. 4 Limited to undertake a human health impact assessment in support of planning and Environmental Permit application submissions. This assessment considers the release of Dioxins and Furans (Dioxins) and Dioxin-like PCBs (PCBs) from the proposed development, with other human health impacts being assessed in another report entitled 'Biomass UK No. 4 Limited; Dartmoor Dispersion Model and Air Quality Assessment' (AQA).

Biomass UK No. 4 Limited propose to convert the existing Dartmoor Bio Power facility, based off Belliver Way in Robrough, Plymouth from a wood waste incineration plant to a Refuse Derived Fuel (RDF) process. The total output capacity of the site will remain the same despite the change in fuel, at 4.3 MWe. For the purpose of this study, the plant is assumed to operate at maximum output, that is, at the maximum allowable emission limit values, continually throughout the year. It is noted that, although not currently operational, the Biomass No. 4 plant will replace the Dartmoor Bio Power facility which has operated for short periods in the past. Therefore, the assessment of the Biomass No. 4 plant as an entirely new process could result in an over-estimate of the overall predicted environmental concentration from the operation of the renewed site.

Air Quality Standards (AQS) have been established primarily to protect the health of the general population and the detailed atmospheric dispersion modelling reported in the AQA showed that there will be no off-site exceedances of any AQS objective value or Environmental Assessment Level. Accordingly, it is expected that the operation of the proposed facility is unlikely to pose a significant risk to the health of the local population living in the surrounding area. However, no such standards exist for the consideration of the impact of Dioxins and Furans and, in order to quantify the potential impact of these airborne pollutants on the health of surrounding communities, a Health Impact Assessment (HIA) has been carried out.

This document presents the results from the HIA studies undertaken on the basis of model predictions for increases in ambient pollutant concentrations arising from the operation of the proposed EfW, and should be read in conjunction with the associated air quality assessment report.

1.1 Health Issues Associated with Emissions from the Proposed ERF

The primary source of Dioxin and Furan and Dioxin-like PCB emissions from the proposed development will be emissions from the EfW. Exhaust gases from the process will be routed to discharge through a 35-m high chimney stack which protrudes from the main process building. Health effects associated with exposure to pollutants are generally associated with either acute effects (noticeable effects soon after exposure), or chronic effects (noticeable effects after prolonged exposure).

The pollutants considered within the detailed AQA fall into the following categories:

Acute Effects

- Oxides of Nitrogen (NO_x) including Nitrogen Dioxide (NO₂);
- Sulphur Dioxide (SO₂);
- Particulates;
- Carbon Monoxide (CO);
- Hydrogen Chloride (HCl);
- Hydrogen Fluoride (HF).

Each of the pollutants above has associated Air Quality Standards (AQS) or Environmental Assessment Levels (EALs) and was compared to their respective assessment level within the AQA report.

Chronic Effects

- Volatile Organic Compounds (VOCs);
- Heavy Metals;
- Dioxins and Furans;
- Polynuclear Aromatic Hydrocarbons (PAH); and,
- Polychlorinated Biphenyls (PCBs).

The process contributions of VOCs, heavy metals, PCBs and PAH (as Benzo[a]Pyrene – B[a]P) were also compared against their respective assessment levels within the detailed AQA. However, there are no similar assessment levels for emissions of Dioxins and Furans and hence, further assessment and consideration must be provided.

This HIA considers the direct health risks associated with the inhalation and consumption of Dioxin and Dioxin-like substances released from the chimney of the proposed Biomass No. 4 plant. The HIA quantifies the potential impact of emissions of pollutants on the health of local residents living in the vicinity of the proposed plant through the application of the US EPA Human Health Risk Assessment Protocol (HHRAP) for Dioxins and Dioxin-like PCBs. The impact of emissions of PAH, and the in-combination effects of Dioxins and Dioxin-like PCBs are considered in Section 4.

It should be noted that the preliminary assessment is based upon the maximum value for the annual average process contribution (PC) experienced across the entire modelled 4 km x 4 km grid. The maximum PC for each pollutant is predicted to occur a relatively short distance from the chimney of the proposed plant and does not necessarily impact on a sensitive human or ecological receptor. The corresponding values at nearby residential receptors are predicted to be significantly lower, as the magnitude of the PC decreases markedly with distance from the source.

2. Process Contribution of Dioxins and Furans

The detailed dispersion modelling assessment predicted that the maximum annual average PC for Dioxins associated with emissions from the proposed EfW facility was approximately 0.415 fg m^{-3} , at the point of maximum process contribution, which occurs about 240 metres to the north-east of the 35 m high chimney. The maximum daily average PC for Dioxins was predicted to be about 4 fg m^{-3} , occurring approximately 207 m to the west of the EfW facility chimney, within the boundary of the industrial estate. Emissions from the facility are therefore not expected to significantly increase the airborne concentrations or deposition rate of Dioxins and Furans over what may be currently experienced in the vicinity of the development site.

In the absence of any appropriate AQS or EALs for the assessment of Dioxins and Furans, Section 3 of this report presents a full health risk assessment of emissions of Dioxins from the EfW facility.

3. Dioxin Health Risk Assessment

3.1 Introduction

A Dioxin health risk assessment has been undertaken using the US EPA Human Health Risk Assessment Protocol (HHRAP) calculation procedures to estimate the intake of Dioxins via the dietary and inhalation routes in the vicinity of the proposed EfW plant. The assessment was based upon the US EPA methodology outlined in the “*Human Health Risk Assessment Protocol (HHRAP) for Hazardous Waste Combustion Facilities, EPA530-R-05-006, September 2005*”. The results are discussed in the following sections.

The basis for the Dioxin health risk assessment is predictive modelling using the ADMS atmospheric dispersion model to estimate likely ground level concentrations and deposition rates for Dioxins as a result of emissions to atmosphere from the EfW plant now proposed at the Biomass No. 4 site, Belliver Way in Robrough, Plymouth. The total output capacity of the site will remain the same despite the change in fuel, at 4.3 MWe. The assessment is based upon the incremental increase in Dioxin concentrations due to emissions from the chimney of the facility and does not take account of any existing Dioxin sources, such as the historically operational Dartmoor Bio Power facility. The assessment does, however, consider ambient Dioxin levels in the atmosphere using measured data from the TOMPS network of monitoring stations operated by DEFRA¹.

The EfW plant is located on the outskirts of Plymouth, approximately 8.9 km to the north of Plymouth Sound. Although Plymouth itself is a city, the Biomass No. 4 plant is located at the most northerly extent of the urban area and with largely open fields and rural land-uses to the north of the site the average Dioxin concentration for rural locations was applied where necessary in the calculations.

3.2 Potential Pathways for Exposure

The following pathways were considered as part of the health risk assessment:

- Inhalation;
- Ingestion of soil;
- Consumption of fruit and vegetables;
- Consumption of milk by the general population and breast milk consumption by infants;
- Consumption of meat (beef, pork and poultry) and eggs; and
- Drinking water.

Members of the local population are only likely to be exposed to significant effects associated with emissions of Dioxins from the proposed process if:

- They spend significant periods of time at locations where and when emissions from the facility increase the concentration of Dioxins above the existing background;
- They consume food grown at locations where emissions from the facility increase the concentration of Dioxins above the concentration normally present in food from those locations;
- They undertake activities likely to lead to the ingestion of soil at locations where emissions from the facility have increased the concentration of Dioxins in the soil above those normally present; and
- They drink water from sources exposed to increased concentrations of Dioxins above the levels normally present.

The extent of exposure that any person may experience will depend directly on the degree to which they engage in any or all of the above activities, and by how much existing background concentrations of Dioxins increase as a result of the operation of the facility. The drinking water exposure route is considered to be highly unlikely as very few people are likely to collect and drink rainwater in the vicinity of the development site. As such, this exposure pathway is discussed but is readily discounted.

3.3 Pathways Relevant to the Proposed EfW facility

Inhalation

People living in the vicinity of the Biomass No. 4 site may be exposed to marginally higher levels of Dioxins as a result of the operation of the proposed EfW plant for the proportion of the time that they spend there. Accordingly, this pathway is considered relevant to the current assessment, and the default values recommended by the US EPA were used as the basis for assessment.

Ingestion of Soil

People working on the land in close proximity to the development site may be exposed to marginally higher levels of Dioxins as a result of the operation of the proposed EfW facility for the proportion of the time that they work there. The potential for exposure by soil ingestion is likely to affect only a few local residents who may tend allotments or plots in their home gardens, and then for only limited periods of the year. Dioxin intake via the ingestion of soil is included in the assessment.

Consumption of Fruit and Vegetables

The majority of the general population purchase their fruit and vegetables from commercial outlets that are likely to source their produce from outside the locality. Unless a substantial proportion of fruit and vegetables sold are produced locally, the overwhelming majority of the local population's exposure to Dioxins due to consumption of fruit and vegetables will not be affected significantly by the operation of the proposed EfW facility.

People who consume fruit and vegetables grown within the vicinity of the facility may be exposed to marginally higher levels of Dioxins as a result of the operation of the process, although any increase is likely to be small. Whilst recognising the agricultural nature of much of the area to the north of the site, the likelihood of individuals obtaining almost all of their fruit and vegetable consumption from gardens or allotments in the vicinity of the development site is likely to be low. Nevertheless, Dioxin intake via the consumption of fruit and vegetables is included in the assessment.

Consumption of Local Dairy Produce

The development site is located in a largely rural area and there is therefore, the potential for grazing animals to forage on pasture land in the vicinity of the development site that could be contaminated by Dioxins deposited from the proposed Biomass No. 4 plant. Therefore, in order to provide a worst-case basis for assessment the consumption of locally sourced dairy produce has been considered in this assessment.

A separate assessment is made of the potential for infants up to 1-year old to be exposed to Dioxins through the consumption of breast milk. The consumption of breast milk by infants may be a potentially significant pathway for the dietary intake of Dioxins due to absorption from contaminated foodstuffs by the mother's lactate system. However, where an infant is consuming breast milk it is unlikely that it will also be consuming cow's milk or other significant food stuffs. As such, the assessment for potential exposure to Dioxins via breast milk is reported as a sub-section of Section 3.12.

Consumption of Meat and Eggs

Free-range animals and poultry may be exposed to Dioxins through consuming forage or grain, or soil ingested with food picked up from the ground. Dioxin exposure of poultry could also impact the level of Dioxins in eggs. It is not known if the rearing of meat or poultry occurs to a significant level in the vicinity of the development site. However, this assessment assumes that the consumption of locally sourced meat and eggs does occur. Although calculations consider the rearing of beef, pork and poultry, it is assumed that only one of the three meat types will be consumed each day, and the most significant contributor to Dioxin intake is therefore subsequently included in the total exposure calculation.

Drinking Water

The likelihood of contamination of groundwater aquifers occurring due to the deposition of Dioxins associated with emissions from the facility is considered highly unlikely given the very low solubility of Dioxins in water. Furthermore, the likelihood of local residents collecting rainwater for drinking purposes is also thought to be low and has been discounted. Accordingly, no further consideration has been given to drinking water as a potential pathway.

3.4 Exposure Scenarios

For all of the exposure scenarios, being at the location of exposure for less than 100 % of the time or obtaining less than 100 % of the total consumption of relevant food, would reduce proportionately any exposure to potential emissions of Dioxins from the proposed Biomass No. 4 plant. Accordingly, the potential exposure results calculated by this assessment are likely to over-estimate considerably, that likely to be experienced by local residents when the proposed EfW facility is operational.

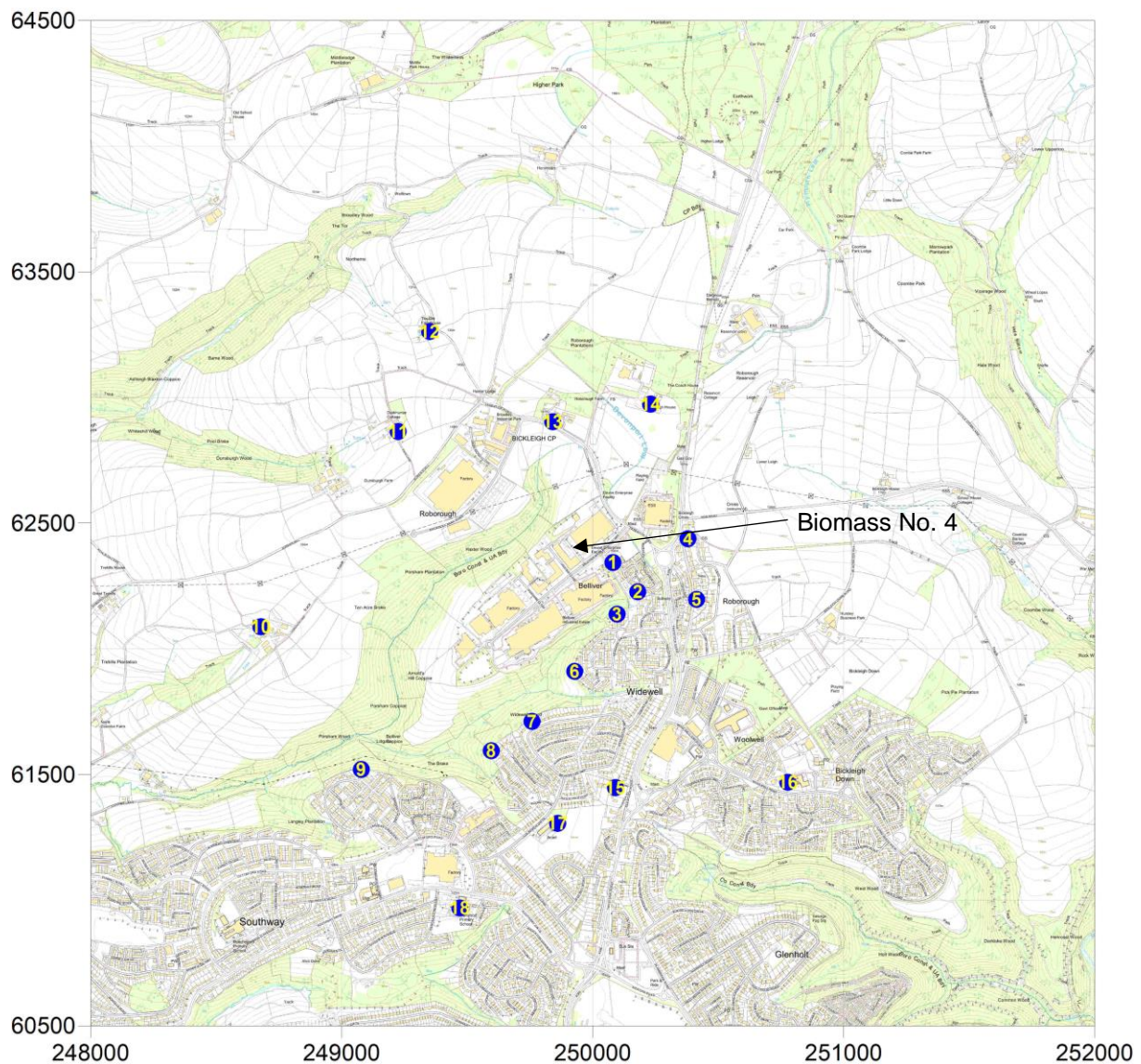
The following exposure scenarios have been considered as relevant to the exposure sites selected:

General Population Exposure

Land use in the immediate vicinity of the development site is rural to the north, but with industrial and residential areas to the south.

Nineteen specific receptors were included in the Dioxin health risk assessment representing nearby locations, all within 2.5 km of the site, where members of the general public may be present for significant periods of time. People living and working in the vicinity of the development site may be exposed to emissions of Dioxins from the facility via the inhalation route, although the proposed EfW facility will not be the only source of airborne Dioxins in the wider area.

The area covered by the modelling assessment is shown in Figure 1 over page, although receptor number 19 is not identified on the plot due to its distance from the site.

Figure 1 Location of Specific Receptors in Relation to the Site

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Ingestion of Soil

This scenario could apply to workers on nearby agricultural land and local residents working in their gardens or allotments, who may be exposed to soil that could be contaminated by Dioxins deposited from emissions, from the Biomass No. 4 facility.

Exposure via the Consumption of Fruit and Vegetables

This scenario is only likely to apply to a small proportion of the local population who grow fruit and vegetables for their own consumption either in their gardens or on allotments in the vicinity of the development site, or to those who purchase other fruit and vegetables which have been grown in the vicinity of the development site.

Exposure via the Consumption of Milk

This scenario is likely to apply to those people whose milk supply is produced by dairy herds grazing on pasture that could potentially become contaminated in the vicinity of the development site.

Exposure by the Consumption of Meat and Eggs

This scenario could apply to those individuals who derive their total consumption of meat and eggs from sources produced within the potential zone of exposure of the emissions from the proposed EfW facility.

3.5 Exposure Factors

Exposure factors were obtained from literature sources for rates of breathing and ingestion of soil and foodstuffs.

Inhalation Rates

For a 70 kg adult the daily respiration volume was taken as 20 m³ day⁻¹ which is in line with US EPA recommendations. This corresponds to an average value of about 0.012 m³ kg⁻¹ hr⁻¹. The corresponding value for a child weighing about 20 kg was 7.2 m³ day⁻¹, or about 0.015 m³ kg⁻¹ hr⁻¹.

Consumption of Meat and Eggs

Information on the intake of meat and eggs was obtained from the National Diet and Nutrition Survey (NDNS) on the gov.uk website² and is summarised in the following table.

Table 1 UK Official Figures for the Consumption of Meat and Eggs (grams day⁻¹)

Food Category	UK Adult Mean (g day ⁻¹)	UK Child Mean (g day ⁻¹)
Beef	43.7	21.1
Pork	12.2	4.5
Poultry Meat	73	40
Eggs	24.5	10.8

The above figures are based upon the average consumption values for men and women aged 19 – 64, and girls and boys between 4 and 10 years' old, including non-consumers, to give an overall average for an adult or child member of the population. The values relate to the average daily consumption of meat and eggs.

For home-reared or allotment-reared eggs and poultry meat, it is unlikely that meat consumption rates would be as high as those for eggs, as the birds are the source of the eggs in preference to a meat source. Accordingly, the assumption that poultry meat consumed in the vicinity all comes from sources produced within the potential zone of exposure of the emissions from the proposed EfW facility will likely over-estimate considerably the potential impact of poultry meat consumption.

Consumption of Fruit and Vegetables

Values for the consumption of fruit and vegetables are provided in the US EPA HHRAP methodology as follows:

Table 2 US EPA HHRAP Estimates for the Consumption of Fruit and Vegetables

Food Category	Ingestion Rate (kg kg-day ⁻¹ DW)			
	Farmer	Farmer Child	Resident	Resident Child
Exposed Aboveground fruit and vegetables	0.00047	0.00113	0.00032	0.00077
Protected Aboveground fruit and vegetables	0.00064	0.00157	0.00061	0.00150
Belowground Produce	0.00017	0.00028	0.00014	0.00023

As can be seen the values for the case of the “Farmer” and “Farmer Child” indicate a higher level of consumption due to the increased likelihood of consuming home-produced fruit and vegetables. To provide a worst-case assessment for potential dietary intake of Dioxins from the consumption of fruit and vegetables, the consumption figures for the “Farmer” and “Farmer Child” were used in the assessment.

Consumption of Milk

Information on the intake of milk was obtained from the NDNS on the gov.uk website and is summarised in the following table.

Table 3 UK Official Figures for the Consumption of Milk (grams day⁻¹)

Milk Category	UK Adult Mean (g day ⁻¹)	UK Child Mean (g day ⁻¹)
Whole Milk	24	73.7

The above figures are based upon the average consumption values for men and women aged 19 – 64, and girls and boys between 4 and 10 years’ old, including non-consumers, to give an overall average for an adult or child member of the population. The values relate to the average daily consumption of whole milk.

Whole milk has a higher fat content than semi-skimmed or skimmed milk, and therefore provides a worst-case basis for assessment. It has been assumed that all of the milk consumed has been produced on pastures in the vicinity of the development site, and this is likely to considerably overestimate the potential impact of milk consumption. The consumption of breast milk by infants to the age of 1-year applies the US EPA HHRAP ingestion rate of 0.688 kg day⁻¹.

Ingestion of Soil

Values for the ingestion of soil are provided in the US EPA HHRAP methodology as follows:

Table 4 US EPA HHRAP Estimates for Soil Ingestion (kg day⁻¹)

Soil Intake	Adult (kg day ⁻¹)	Child (kg day ⁻¹)
Soil Intake Rate	0.0001	0.0002

The higher value for a child reflects the greater likelihood of soil ingestion by children playing outdoors.

3.6 Emissions Scenario

The proposed EfW facility will be subject to regulation by the Environment Agency in line with the emission limit values (ELVs) for Dioxins and Furans for incineration plant as defined by the EU Industrial Emissions Directive (IED) and the associated BAT-Conclusions document. Accordingly, atmospheric dispersion modelling was undertaken on the basis of normal operation with emissions of Dioxins at the 0.04 ng Nm⁻³ ELV specified in the BAT-Conclusions, which is the design point and performance guarantee for the Biomass No. 4 plant.

Exposure via the dietary route was assessed by modelling Dioxin deposition in both the gaseous and particulate phases. Partitioning of Dioxins between the vapour phase and the particulate phase was assumed to be in the proportions 66.4:33.6 as provided by HHRAP guidance³, and the modelling results were adjusted accordingly. The results from deposition modelling were then taken in conjunction with the US EPA Human Health Risk Assessment Protocol for Hazardous Waste Combustion for calculating the intake of Dioxins into the soil, fruit and vegetables, dairy products, meat and eggs to provide an estimate of dietary intake of Dioxins as a result of the operation of the new facility. The potential intake of breast milk by infants aged 0 – 1 years has also been calculated using the US EPA HHRAP, although this assessment is reported in isolation from the dietary uptake by adults and older children. The results were compared against the Tolerable Daily Intake (TDI) value of 2 pg kg⁻¹ day⁻¹ recommended by the UK Committee on Toxicity⁴.

The values predicted by modelling represent process contributions, but in certain instances also take into account estimated background levels for rural areas in the UK. Where necessary, estimated background values for atmospheric Dioxin concentrations have been used as input values for some of the equations in the HHRAP methodology.

Area Covered and Specific Receptors Included in the Assessment

Atmospheric dispersion modelling using ADMS Version 5.2 was undertaken to estimate likely ground level concentrations of Dioxins at nearby sensitive receptors arising from emissions from the proposed EfW facility. Meteorological data for the Plymouth Mount Batten meteorological measurement station for 2016 to 2020 were used in the modelling and the results reported are based upon the maximum process contributions over the five-year period. The model was run separately in dispersion and in dry deposition mode to provide the maximum Dioxin vapour concentration and likely Dioxin deposition rates in the vicinity of the development site.

3.7 Results from Detailed Modelling - Concentration Mode

The results from modelling emissions of Dioxins from the facility, based upon the anticipated ELV of 0.04 ng Nm^{-3} gave a maximum process contribution of about 4 fg m^{-3} ($4.05 \times 10^{-15} \text{ g m}^{-3}$) expressed as a daily average value, and located approximately 207 metres to the west of the Biomass No. 4 discharge point. The corresponding annual average process contribution was about 0.415 fg m^{-3} .

3.8 Deposition Mode

Wet deposition is usually considered to be the most significant mode of deposition close to the point of release of buoyant plumes from waste incineration processes, as a result of “wash out” by rain droplets falling through the plume. At greater distances, plume expansion and the associated pollutant dilution, brings particulates and vapours in the plume into contact with the surface vegetation, and the “dry deposition” mechanism assumes greater importance. It is important therefore that both aspects of pollutant deposition from the plume are considered within the assessment.

The ADMS model was run in dry deposition mode only. In the absence of any additional data, it is generally considered acceptable that total deposition (wet and dry) comprises 3 x dry deposition, where it is required to be included, as is the case for the HIA.

The results from deposition modelling of emissions from the proposed EfW facility, assuming continuous emissions at the maximum ELV of 0.04 ng Nm^{-3} , gave a maximum value for total (dry and wet) Dioxin deposition of $4.37 \times 10^{-12} \text{ } \mu\text{g m}^{-2} \text{ s}^{-1}$ for Dioxins in the gaseous and particulate phases, which equates to approximately $0.138 \text{ ng m}^{-2} \text{ annum}$. The results showed deposition rates for Dioxins decreasing markedly with distance from the point of release.

Specific Receptor Locations and Exposure Pathways

Exposure is possible at any location to a greater or lesser degree, and the nearby locations shown in Figure 1, were included in the assessment as specific receptors, including residential areas and nearby places of employment. Results for nineteen specific receptors, associated with Dioxin emissions from the chimney of the proposed EfW facility, have been included in this report.

The locations of the specific receptors included in the Dioxin deposition modelling study are detailed in Table 5.

Table 5 Specific Receptors Included in Dioxin Deposition Modelling

Receptor Number	Receptor Location	OS Coordinates		Distance from Source (metres)
		X	Y	
1	Lady Fern Road, Belliver	250080	062343	185
2	Claytonia Close, Belliver	250180	062227	310
3	Hessary Drive, Belliver	250097	062138	293
4	45, Leat Walk, Woolwell	250380	062438	493
5	3, Tavistock Road, Woolwell	250414	062197	541
6	Legis Walk, Belliver	249928	061910	441
7	Beverston Way, Belliver	249758	061711	654
8	Highclere Gardens, Belliver	249596	061594	813
9	Langley Crescent, Southway	249078	061520	1,165
10	Soper's Hill, Bickleigh - North north-west	248678	062088	1,245
11	Soper's Hill, Bickleigh – North-west	249225	062865	845
12	Soper's Hill, Bickleigh - West	249350	063262	1,062
13	Tamerton Road, Woolwell	249841	062904	557
14	Roborough House, Woolwell	250231	062973	708
15	White Oaks, Widewell Lane, Belliver	250090	061447	924
16	Bickleigh Down CofE Primary School	250777	061469	1,247
17	Widewell Primary Academy, Belliver	249860	061305	1,046
18	Oakwood Primary Academy, Derriford,	249470	060969	1,445
19	Notre Dame RC School, Southway	249052	060181	2,327

3.9 Results and Discussion

Health risk estimates are directly affected by several factors, and include:

- The location of the receptor with regard to exposure to emissions from the chimney of the plant;
- The proportion of time spent by the receptor at locations where Dioxin concentrations may increase as a result of emissions from the chimney of the plant;
- The proportions of the types of food consumed that are produced at locations where Dioxin concentrations may increase as a result of emissions from the chimney of the plant; and
- The emissions scenario.

The results from the Dioxin health risk assessment reported here represent the maximum potential incremental increase as a result of emissions from the proposed EfW facility for each of the pathways included, based upon continuous emissions of Dioxins at the anticipated ELV of 0.04 ng Nm⁻³, which is the design point and performance guarantee for the proposed EfW technology.

Intake of Dioxins was estimated on the basis of the maximum daily intake due to inhalation as well as dietary consumption. The combined results were then compared against the 2 pg kg⁻¹ Tolerable Daily Intake (TDI) reference value to determine whether there is likely to be a significant risk to health as a result of potential exposure to Dioxins released from the facility.

3.10 Exposure via Inhalation

The following equation is taken from the US EPA HHRAP and was used in the calculation of the maximum daily intake due to inhalation of Dioxins as a result of exposure to emissions from the proposed EfW plant:

Equation 1 Maximum Daily Intake Due to Inhalation

$$ADI = \frac{C_a \cdot IR \cdot ET \cdot EF \cdot ED \cdot 0.001 \text{ mg}/\mu\text{g}}{BW \cdot AT \cdot 365 \text{ day/yr}}$$

Where:

- ADI = Average daily intake via inhalation ($\text{mg kg}^{-1} \text{ day}^{-1}$);
- C_a = Total air concentration (Daily Average) – derived from ADMS output;
- IR (Adult) = 0.833; Inhalation Rate ($\text{m}^3 \text{ hr}^{-1}$) - (US EPA HHRAP value);
- IR (Child) = 0.300; Inhalation Rate ($\text{m}^3 \text{ hr}^{-1}$) - (US EPA HHRAP value);
- ET = 24; Exposure time (hrs day^{-1}) - (US EPA HHRAP value);
- EF = 350; Exposure frequency (days year^{-1}) - (US EPA HHRAP value);
- ED = 30; Exposure duration (years) - (US EPA HHRAP value);
- BW (Adult) = 70; Body Weight (kg) - (US EPA HHRAP value);
- BW (Child) = 20; Body Weight (kg) - UK Toxicological assessment report
- AT = 70; Averaging time - (US EPA HHRAP value);
- 0.001 = Units conversion – $\text{mg } \mu\text{g}^{-1}$
- 365 = Units conversion – days year^{-1}

The following input data were assumed:

- The inhalation rate (IR) was assumed to be $20 \text{ m}^3 \text{ day}^{-1}$ for an adult and $7.2 \text{ m}^3 \text{ day}^{-1}$ for a child (US EPA recommended values);
- Body weight (BW) was taken as 70 kg for an adult (US EPA HHRAP and UK Human Health Toxicological Report⁵ recommended value) and 20 kg for a child (UK Human Health Toxicological Report).

The maximum daily adult intake of Dioxins due to inhalation was calculated to be $0.0005 \text{ pg kg}^{-1} \text{ day}^{-1}$. For children the corresponding figure was $0.0006 \text{ pg kg}^{-1} \text{ day}^{-1}$. The Tolerable Daily Intake (TDI) for Dioxins is $2 \text{ pg kg}^{-1} \text{ day}^{-1}$; accordingly the estimated exposure via inhalation for adults represents approximately 0.02 % of the TDI, while the estimated value for children is about 0.03 % of the TDI.

The calculated daily inhalation rates above do not include any existing background figure. Monitoring of Dioxins is undertaken at a small number of sites around the country representing rural and urban background locations. For the purpose of this study, reference was made to the latest available average rural background concentration for Dioxins and Furans of $0.005945 \text{ pg m}^{-3}$ in 2016, as measured by the Toxic Organic Micro Pollutants (TOMPs) monitoring network⁶ at sites in Auchencorth Moss, Hazelrigg, High Muffles, and Weybourne. This figure was therefore applied as the background and adds an additional $0.0017 \text{ pg kg}^{-1} \text{ day}^{-1}$ to adult inhalation and $0.0021 \text{ pg kg}^{-1} \text{ day}^{-1}$ to child inhalation. The overall inhalation rates therefore equate to 0.11 % of the TDI for adults and 0.14 % of the TDI for children, with the existing background accounting for the most significant contribution.

3.11 Potential Increase in Concentration of Dioxins in Soil Due to Emissions from the Proposed Biomass No. 4 Plant

Any increase in Dioxin concentration in the soil has the potential to transfer into the food chain and to add to the daily intake via the dietary pathway. An assessment was made of the potential increase of Dioxin concentrations in the soil as a result of deposition due to emissions from the proposed EfW plant.

Deposition modelling of Dioxins, in the particulate and gaseous phases, was carried out using ADMS Version 5.2. The likelihood is that the majority of Dioxins released from the facility would be associated with the particulates in the emission to atmosphere. Accordingly, the model predictions for Dioxin deposition associated with the particulates with a diameter of $1 \mu\text{m}$ represents an appropriate worst-case value for assessment of Dioxin deposition to soils in the vicinity of the Biomass No. 4 plant. The following deposition rates were predicted at the nineteen specific receptor locations in the vicinity of the development site.

Table 6 Deposition Modelling of Dioxins in the Gaseous and Particulate Phases Based Upon Normal Operating Conditions at the ELV of 0.04 ng Nm⁻³

Receptor Number	Distance from Source (metres)	Total Deposition Rate - Gaseous and Particulate ($\mu\text{g m}^{-2} \text{s}^{-1}$)	Annual Deposition Rate ($\text{ng m}^{-2} \text{annum}^{-1}$)
Maximum	239	4.37×10^{-12}	0.1378
1	185	1.36×10^{-12}	0.0430
2	310	1.01×10^{-12}	0.0320
3	293	9.24×10^{-13}	0.0291
4	493	2×10^{-12}	0.0631
5	541	1.02×10^{-12}	0.0322
6	441	4.14×10^{-13}	0.0131
7	654	2.34×10^{-13}	0.0074
8	813	1.66×10^{-13}	0.0052
9	1,165	1.79×10^{-13}	0.0057
10	1,245	4.24×10^{-13}	0.0134
11	845	2.64×10^{-13}	0.0083
12	1,062	2.39×10^{-13}	0.0075
13	557	1.12×10^{-12}	0.0354
14	708	1.42×10^{-12}	0.0447
15	924	2.5×10^{-13}	0.0079
16	1,247	2.63×10^{-13}	0.0083
17	1,046	1.61×10^{-13}	0.0051
18	1,445	7.91×10^{-14}	0.0025
19	2,327	4.95×10^{-14}	0.0016

Little of the deposited Dioxins are likely to penetrate far into the ground due to the low solubility of Dioxins in water. Absorption of Dioxins by the soil is also likely to decrease mobility. The US EPA HHRAP database quotes a value of approximately 19 ng litre⁻¹ for the solubility of Dioxins in water.

The following assessment is based upon the maximum deposition rate at the location of the maximum process contribution, approximately 240 metres to the north-east of the 35 metre high Biomass No. 4 chimney.

Increase in Soil Concentration

The increase in Dioxin loading of soils as a result of deposition was estimated using the equations in Table B-3-1 in Appendix B of the US EPA Human Health Risk Assessment Protocol (HHRAP) for Hazardous Waste Combustion Facilities.

Equation 2 The Increase in Dioxin Concentration in the Soil Due to Deposition

$$C_s = \frac{\left(\frac{D_s \cdot tD - C_{s_{tD}}}{k_s} \right) + \left(\frac{C_{s_{tD}}}{k_s} \cdot [1 - \exp(-k_s \cdot (T_2 - tD))] \right)}{(T_2 - T_1)};$$

$$C_{s_{tD}} = \frac{D_s \cdot [1 - \exp(-k_s \cdot tD)]}{k_s}, \text{ and}$$

$$D_s = \frac{100 \cdot Q}{Z_s \cdot BD} \cdot [F_v \cdot (D_{ydv} + D_{ydv}) + (D_{ydp} + D_{ywp}) \cdot (1 - F_v)]$$

Where:

- Cs = Maximum average incremental increase in soil concentration over exposure duration;
- Cs_{ID} = Soil concentration at time tD - calculated;
- Ds = Deposition Term – mg kg soil⁻¹ yr⁻¹;
- tD = Time period over which deposition occurs – 30 years;
- ks = Dioxin soil loss constant due to all mechanisms – calculated;
- T₂ = Length of exposure duration – 30 years;
- T₁ = Time period at the beginning of combustion – 0;
- 100 = Conversion Factor;
- Q = Dioxin emission rate (g s⁻¹);
- Z_s = Soil Mixing Zone depth – 2 cm;
- BD = Soil Bulk Density – 1.5 kg m³;
- F_v = Fraction of Dioxin air concentration in the vapour phase – 0.664 (US EPA HHRAP value);
- Dy_{dv} = Unitised annual average dry deposition from vapour phase – derived from ADMS output;
- Dy_{wv} = Unitised annual average wet deposition from vapour phase – derived from ADMS output;
- Dy_{dp} = Unitised annual average dry deposition from particulate phase – derived from ADMS output;
- Dy_{wp} = Unitised annual average dry deposition from particulate phase – derived from ADMS output.

Using the above equations and input parameters, gave a value for the increase in soil Dioxin concentration due to deposition of approximately 0.00139 ng kg⁻¹. This value represents the case at the location of the maximum process contribution based upon the emission limit value for normal operating conditions of 0.04 ng Nm⁻³, and is about 0.03 % of the maximum concentration of Dioxin in soils in rural locations (about 4.7 ng kg⁻¹) reported by the Environment Agency⁷. As discussed earlier, the rural land classification is considered to be appropriate for the area surrounding the Biomass No. 4 site.

The value reported above is based upon the maximum deposition rate at the location of the maximum annual average process contribution which occurs approximately 240 metres to the north-east of the release point, and is located within the industrial estate. Deposition at specific receptors further afield is predicted to occur at lower rates as indicated by the deposition results reported in Table 6.

Exposure from Dietary Intake of Meat and Eggs

The potential link between human receptors and the consumption of locally reared meat or eggs is not known. However, as the consumption of locally sourced meat and eggs could be a potential exposure pathway such sources could provide a key pathway for Dioxin exposure and as such it is appropriate that they should be investigated.

Accordingly, an assessment for exposure to Dioxins has been undertaken for the intake of Dioxins via the consumption of beef, pork, chicken and eggs, although it is noted that only the consumption of beef is included into the total daily dietary intake calculation. It is unlikely that local residents would consume full portions of all three meats each day and hence the application of a single meat is deemed appropriate. As the results in the following sections demonstrate, the contribution of Dioxins to the total daily intake are significantly higher from beef consumption than from either pork or chicken, either in isolation or combined, and hence the inclusion of the Dioxin intake from beef consumption as a worst-case total daily intake from meats, is considered to represent an appropriate worst-case.

The US EPA Human Health Risk Assessment Protocol (HHRAP) for Hazardous Waste Combustion Facilities methodology was used to assess the potential exposure to Dioxins arising from emissions from the proposed EfW facility. The equations in Table B-3-10 and Table B-3-12 in Appendix B of the HHRAP were used to determine the concentration of Dioxins in beef and pork respectively at locations in the vicinity of the development site. The equation in Table B-3-13 in Appendix B of the HHRAP was used to determine the concentration of Dioxins in eggs and the equation in Table B-3-14 was used to determine the corresponding concentration of Dioxins in poultry meat.

The results presented in the following section relate to the deposition rate at the location of the maximum annual average process contribution, approximately 240 metres to the north-east of the Biomass No. 4 release point.

Dioxin Concentration in Beef

The following formula was used to estimate the potential Dioxin concentration consumed by cattle through the ingestion of contaminated plant-based feed items and soil:

Equation 3 The Intake of Dioxin by Cattle Foraging on Contaminated Feed and Soil

$$A_{beef} = (\sum(F_i \cdot Qp_i \cdot P_i) + Qs \cdot Cs \cdot Bs) \cdot Ba_{beef} \cdot MF$$

Where:

- A_{beef} = Concentration of Dioxin in beef (mg kg⁻¹ FW tissue);
- F_i = Fraction of plant type i grown on contaminated soil and ingested by the cattle (unitless);
- Qp_i = Quantity of plant type i eaten by the cattle per day (kg DW plant day⁻¹);
- P_i = Concentration of Dioxin in each plant type i eaten by the cattle (mg kg⁻¹ DW);
- Qs = Quantity of soil eaten by the cattle each day (kg day⁻¹);
- Cs = Average soil concentration over exposure duration (mg kg⁻¹ soil);
- Bs = Soil bio-availability factor (unitless);
- Ba_{beef} = Dioxin bio-transfer factor for beef (day kg⁻¹ FW tissue);
- MF = Metabolism factor (unitless).

Using the above equation, a value of approximately 6.8 x 10⁻⁰⁹ mg kg⁻¹ (about 7 pg kg⁻¹) of fresh meat was derived for the Dioxin concentration in beef due to the ingestion of contaminated feed and soil with an incremental annual average increase in Dioxin concentration, due to the operation of the proposed EfW plant, of 0.00139 ng kg⁻¹.

Dioxin Concentration in Pork

The following formula was used to estimate the potential Dioxin concentration consumed by pigs through the ingestion of contaminated plant-based feed items and soil:

Equation 4 The Intake of Dioxin by Pigs Foraging on Contaminated Feed and Soil

$$A_{pork} = (\sum(F_i \cdot Qp_i \cdot P_i) + Qs \cdot Cs \cdot Bs) \cdot Ba_{pork} \cdot MF$$

Where:

- A_{pork} = Concentration of Dioxin in pork (mg kg⁻¹ FW tissue);
- F_i = Fraction of plant type i grown on contaminated soil and ingested by the pig (unitless);
- Qp_i = Quantity of plant type i eaten by the pig each day (kg DW plant day⁻¹);
- P_i = Concentration of Dioxin in plant type i eaten by the pig (mg kg⁻¹ DW);
- Qs = Quantity of soil eaten by the pig (kg day⁻¹);
- Cs = Average soil concentration over exposure duration (mg kg⁻¹ soil);
- Bs = Soil bio-availability factor (unitless);
- Ba_{pork} = COPC bio-transfer factor for pork (day kg⁻¹ FW tissue);
- MF = Metabolism factor (unitless).

Using the above equation, a value of approximately 2.57 x 10⁻¹¹ mg kg⁻¹ (about 0.026 pg kg⁻¹) of fresh meat was derived for the Dioxin concentration in pork due to the ingestion of contaminated feed and soil with an incremental annual average increase in Dioxin concentration, due to the operation of the proposed EfW plant, of 0.00139 ng kg⁻¹.

Dioxin Concentration in Eggs

The following formula was used to estimate the potential Dioxin concentration in eggs due to ingestion of soil and grain by free-range chickens reared in the locality:

Equation 5 The Intake of Dioxin in Eggs Due to Chickens Foraging on Contaminated Soil

$$A_{\text{egg}} = \left(\sum (F_i \cdot Q_{p_i} \cdot P_i) + Q_s \cdot C_s \cdot B_s \right) Ba_{\text{egg}}$$

Where:

- A_{egg} = Concentration of Dioxin in egg;
- F_i = Fraction of grain grown on contaminated soil and ingested by chickens – assumed to be 1.0;
- Q_{p_i} = Quantity of grain ingested by chickens – assumed to be 0.2 (US EPA HHRAP value);
- P_i = Concentration of Dioxin in grain – derived from separate equation below;
- Q_s = Quantity of soil ingested by chicken – assumed to be 0.022 kg day⁻¹ (US EPA HHRAP value);
- C_s = Maximum annual average incremental increase in Dioxin concentration in soil – estimated by modelling to be 0.00139 ng kg⁻¹;
- B_s = Soil bio-availability factor – assumed to be 1.0 (US EPA HHRAP value);
- Ba_{egg} = Bio-transfer factor for chicken eggs – assumed to be 1.09984 (US EPA HHRAP Database).

The value of P_i was derived using the equation in Table B-3-9 of Appendix B of the HHRAP:

Equation 6 The Intake of Dioxin in Grain Due to Increase in Soil Concentration

$$P_i = C_s \cdot Br_{\text{forage}}$$

Where:

- P_i = Concentration of Dioxin in forage as grain;
- C_s = Annual average increase in Dioxin concentration in soil – estimated by modelling to be 0.00139 ng kg⁻¹;
- Br_{forage} = Plant-soil bio-concentration factor for grain – assumed to be 0.00455 (US EPA HHRAP Database).

Using the above equations, a value of 3.49 x 10⁻¹¹ mg kg⁻¹ Fresh Weight (FW) basis (approximately 0.035 pg kg⁻¹) was derived for the Dioxin concentration in eggs due to the consumption of grain and foraging of chickens on soil with an incremental annual average increase in Dioxin concentration in the soil of 0.00139 ng kg⁻¹, due to the operation of the proposed EfW facility.

Dioxin Concentration in Chicken Meat

The following formula was used to estimate the potential Dioxin concentration in chicken meat due to ingestion of soil and grain by free-range chickens reared in the locality:

Equation 7 The Intake of Dioxin in Chicken Meat Due to Foraging on Contaminated Soil

$$A_{\text{Chicken}} = \left(\sum (F_i \cdot Q_{p_i} \cdot P_i) + Q_s \cdot C_s \cdot B_s \right) Ba_{\text{Chicken}}$$

Where:

- A_{Chicken} = Concentration of Dioxin in chicken meat;
- F_i = Fraction of grain grown on contaminated soil and ingested by chickens – assumed as 1.0;
- Q_{p_i} = Quantity of grain ingested by chickens – assumed to be 0.2 (US EPA HHRAP value);
- P_i = Concentration of Dioxin in grain – derived from the equation above;

- Q_s = Quantity of soil ingested by chickens – assumed to be $0.022 \text{ kg day}^{-1}$ (US EPA HHRAP value);
- C_s = Maximum annual average incremental increase in Dioxin concentration in soil – estimated by modelling to be $0.00139 \text{ ng kg}^{-1}$;
- B_s = Soil bio-availability factor – assumed to be 1.0 (US EPA HHRAP value);
- B_{chicken} = Bio-transfer factor for chicken carcass – assumed to be 1.924722 (US EPA HHRAP Database).

Using the above equations, a value of approximately $6.11 \times 10^{-11} \text{ mg kg}^{-1}$ (about 0.06 pg kg^{-1}) of fresh meat was derived for the Dioxin concentration in chicken meat due to the foraging for food on soil with an incremental annual average increase in Dioxin concentration, due to the operation of the proposed EfW plant, of $0.00139 \text{ ng kg}^{-1}$.

Dietary Intake Due to the Combined Consumption of Meat and Eggs

Data published by Public Health England (PHE) and the UK Food Standards Agency (FSA) on the gov.uk website was presented in Table 1 and provides the dietary intakes of meat and eggs for adults and children in the UK. The data are based upon the average values for men and women, and boys and girls, to give an overall average for an adult or child member of the population. The values relate to the average daily consumption of meat and eggs normalised to include non-consumers, to give an overall average for an adult or child member of the population.

When the dietary intake data presented in Table 1 are combined with the estimated Dioxin concentration data for meat and eggs calculated above, the following daily intake values were derived for adults with a body weight of 70 kg, and children with a body weight of 20 kg:

Table 7 Dietary Intake of Dioxins via the Consumption of Meat and Eggs Reared at the Location of the Maximum Process Contribution

Food Category	UK Adult Mean	UK Child Mean
	pg kg ⁻¹ day ⁻¹	
Beef	0.00422	0.00713
Pork	0.000004	0.000006
Chicken	0.000064	0.000122
Eggs	0.000012	0.000019
	Percentage of Tolerable Daily Intake (2 pg kg ⁻¹)	
Beef	0.21%	0.36%
Pork	0.0002%	0.0003%
Chicken	0.0032%	0.0061%
Eggs	0.0006%	0.0009%

As can be seen in the above table, the estimated daily intake of Dioxins due to the consumption of beef is substantially higher than that from pork or chicken. As only a single full portion of meat is likely to be consumed by each individual on any day, the intake rate from the consumption of beef is carried forward in the assessment of the total, in addition to the contribution from the consumption of eggs. The intake values for beef represent approximately 0.21 % of the Tolerable Daily Intake value of $2 \text{ pg kg}^{-1} \text{ day}^{-1}$ for adults, and 0.36 % of the TDI for children. The values for egg consumption are much lower, equating to approximately 0.0006 % and 0.0009 % of the TDI for adults and children respectively.

It is noted that the process contributions above actually occur within the industrial estate, which is not an area that will be used for the production of meat or eggs, and hence consideration of the results above represent a significantly conservative approach.

3.12 Exposure from Dietary Intake of Milk

The potential link between human receptors in the vicinity of the Biomass No. 4 site and the consumption of locally produced milk is not known. Nevertheless, to provide a worst-case basis for assessment, exposure to Dioxins via the consumption of milk has been undertaken.

The US EPA Human Health Risk Assessment Protocol (HHRAP) for Hazardous Waste Combustion Facilities methodology was used to assess the potential exposure to Dioxins arising from emissions from the facility. The equation in Table B-3-11 in Appendix B of the HHRAP was used to determine the concentration of Dioxins in milk at locations in the vicinity of the Biomass No. 4 site.

The results presented in the following section relate to the deposition rate at the point of maximum annual average process contribution which occurs within the industrial estate, approximately 240 metres to the north-east of the chimney of the proposed EfW plant.

Dioxin Concentration in Milk

The following formula was used to estimate the potential Dioxin concentration in milk due to ingestion of soil and grass by cows reared in the locality:

Equation 8 The Intake of Dioxin in Milk Due to Grazing on Contaminated Soil

$$A_{milk} = \left(\sum (F_i \cdot Qp_i \cdot P_i) + Q_s \cdot C_s \cdot B_s \right) \cdot Ba_{milk} \cdot MF$$

Where:

- A_{milk} = Concentration of Dioxin in milk;
- F_i = Fraction of forage grown on contaminated soil and ingested by cows – assumed to be 1.0;
- Qp_i = Quantity of forage ingested by cows – assumed to be 13.2 (US EPA HHRAP value);
- P_i = Concentration of Dioxin in plant type i eaten by the dairy cows (mg kg^{-1} DW);
- Q_s = Quantity of soil ingested by cows – assumed to be 0.04 kg day^{-1} (US EPA HHRAP value);
- C_s = Maximum annual average incremental increase in Dioxin concentration in soil – estimated by modelling to be $0.00139 \text{ ng kg}^{-1}$;
- B_s = Soil bioavailability factor – assumed to be 1.0 (US EPA HHRAP value);
- Ba_{milk} = Biotransfer factor for milk – assumed to be 5.499 (US EPA HHRAP Database).

The value of P_i was derived from the sum of the equations in Tables B-3-7, B-3-8 and B-3-9 of Appendix B of the HHRAP which take account of the overall concentration in forage which may contain fresh matter and silage which will have been exposed to pollutants through direct deposition, air to plant transfer and root uptake; and grain which absorbs pollution through root uptake.

Using the above equation, a value of $1.87 \times 10^{-8} \text{ mg kg}^{-1}$ Fresh Weight (FW) basis (approximately 19 pg kg^{-1}) was derived for the Dioxin concentration in milk due to the grazing of cows on grass and soil with an incremental annual average increase in Dioxin concentration in the soil of $0.00139 \text{ ng kg}^{-1}$, due to the operation of the EfW facility.

Dietary Intake Due to the Consumption of Milk

Data published by Public Health England (PHE) and the UK Food Standards Agency (FSA) on the gov.uk website was presented in Table 1 and provides the dietary intakes of milk for adults and children in the UK. The data are based upon the average values for men and women, and boys and girls, to give an overall average for an adult or child member of the population. The values relate to the average daily consumption of milk normalised to include non-consumers, to give an overall average for an adult or child member of the population.

When the dietary intake data presented in Table 1 are combined with the estimated Dioxin concentration data for whole milk calculated above, the following daily intake values were derived for adults with a body weight of 70 kg, and children with a body weight of 20 kg:

Table 8 Dietary Intake of Dioxins via the Consumption of Milk Produced at the Location of the Maximum Process Contribution

Food Category	UK Adult Mean	UK Child Mean
Whole Milk	pg kg⁻¹ day⁻¹	
	0.00641	0.06885
	Percentage of Tolerable Daily Intake (2 pg kg⁻¹)	
	0.32 %	3.44 %

As can be seen in the above table, the estimated daily intake of Dioxins due to the consumption of potentially contaminated milk, arising from the maximum incremental annual average increase in Dioxin concentration in the soil of 0.00139 ng kg⁻¹, represents values that are about 0.3 % of the Tolerable Daily Intake for adults and about 3.5 % for children. These values are significantly higher than those for meat and eggs and reflect the fact that Dioxins tend to concentrate in fats and fatty tissues, which includes an animal's lactate system. The above assessment is based upon the consumption of whole milk, and as such the results probably overestimate considerably the significance of Dioxin intake via the consumption of milk for many people.

Dietary Intake of Infants Due to the Consumption of Breast Milk

An assessment was made of the potential for infants up to 1-year old to be exposed to Dioxins through the consumption of breast milk, as this would represent a potentially significant pathway for the dietary intake of Dioxins for very young children. However, where an infant is consuming breast milk it is unlikely that it will also be consuming cow's milk or other significant food stuffs and as such, this assessment is reported as a simple, worst-case assessment and is not subsequently included in the total which otherwise represents the potential impact on older children and adults.

The following formulae were used to estimate the potential Dioxin concentration in breast milk due to ingestion by the mother (Equation 9 below taken from Table C-3-1 of Appendix C of the HHRAP), and then the uptake of Dioxin by the feeding infant (Equation 10, taken from Table C-3-2 of Appendix C of the HHRAP):

Equation 9 The Concentration of Dioxin in Breast Milk Due to Maternal Ingestion

$$C_{milkfat} = \frac{m \cdot 1 \times 10^9 \cdot h \cdot f_1}{0.693 \cdot f_2}$$

Where:

- C milk/fat = Concentration of Dioxins in breast milk (pg kg⁻¹ of milk fat);
- m = 1.28 x 10⁻¹¹ - the calculated average maternal Dioxin intake via the dietary route (mg kg⁻¹ BW day⁻¹);
- 1 x 10⁹ = Conversion factor (pg mg⁻¹);
- h = 2,555 - the half-life of dioxins in adults (days) – (US EPA HHRAP value);
- f₁ = 0.9 - Fraction of ingested dioxins stored in fat – (US EPA HHRAP value);
- f₂ = 0.3 - Fraction of mother's weight that is fat – (US EPA HHRAP value).

Equation 10 The Uptake of Dioxin by the Feeding Child

$$ADD_{infant} = \frac{C_{milkfat} \cdot f_3 \cdot f_4 \cdot IR_{milk} \cdot ED}{BW_{infant} \cdot AT}$$

Where:

- ADD infant = Average daily dose for infant exposed to contaminated breast milk;
- C milk/fat = Concentration of dioxins in breast milk as calculated (pg kg⁻¹ of milk fat);
- f₃ = 0.04 - Fraction of mother's milk that is fat – (US EPA HHRAP value);
- f₄ = 0.9 - Fraction of dioxin that is absorbed – (US EPA HHRAP value);
- IR milk = 0.688 - Ingestion rate of breast milk by infant (kg day⁻¹) – (US EPA HHRAP value);
- ED = 1 - Exposure duration (years) – (US EPA HHRAP value);
- BW infant = 9.4 - Body weight of infant (kg) – (US EPA HHRAP value);
- AT= 1 - Averaging time (years) – (US EPA HHRAP value).

Using the above equations, a maximum value of 141.76 pg kg⁻¹ milk fat was derived for the Dioxin concentration in breast milk, with an incremental increase in daily Dioxin uptake by the infant of 0.374 pg kg⁻¹, due to the operation of the proposed EfW plant. This equates to a daily dietary intake by infants from the consumption of breast milk, of approximately 18.7 % of the Tolerable Daily Intake.

3.13 Exposure from Dietary Intake Due to Ingestion of Soil

The formula in Table C-1-1 in Appendix C of the US EPA HHRAP was used to estimate the potential intake of Dioxins due to ingestion of soil in the locality of the Biomass No. 4 plant:

Equation 11 The Intake of Dioxin Due to Ingestion of Soil

$$I_{Soil} = \frac{C_s \times CR_{Soil} \times F_{Soil}}{BW}$$

Where:

- I_{Soil} = Daily intake of Dioxin via soil ingestion;
- C_s = Maximum incremental increase in Dioxin concentration in the soil due to deposition - estimated by modelling to be 0.00139 ng kg⁻¹;
- CR_{Soil} = Consumption rate of soil (US EPA HHRAP Values);
- F_{Soil} = Fraction of soil contaminated by Dioxins – US EPA HHRAP recommends the use of 1.0;
- BW = Body weight.

Using the above equation, a Dioxin intake as a result of soil ingestion of 0.00000198 pg kg⁻¹ day⁻¹ for adults and 0.0000139 pg kg⁻¹ day⁻¹ for children was predicted, due to the operation of the proposed EfW facility. These values represent approximately 0.0001 % and 0.00069 % respectively of the TDI of 2 pg day⁻¹ and are considered to be negligible.

3.14 Exposure from Dioxin Intake Due to the Consumption of Fruit and Vegetables

An assessment for exposure to Dioxins has been undertaken for the consumption of fruit and vegetables in order to represent a scenario where local residents are obtaining their dietary intake of fruit and vegetables from plants grown in soil that could potentially be contaminated by Dioxins in the emissions from the Biomass No. 4 plant.

The equation in Table C-1-2 in Appendix C of the HHRAP methodology was used to estimate the daily intake of Dioxins via the consumption of fruit and vegetables:

Equation 12 The Intake of Dioxin in Produce Due to Increase in Concentration in the Soil

$$I_{aeg} = \left[\left((Pd \times Pv \times Pr_{aeg}) \times CR_{aeg} \right) + \left(Pr \times CR_{pp} \right) + \left(Pr_{bg} \times CR_{bg} \right) \right] \times F_{aeg}$$

Where:

- I_{ag} = Daily intake of Dioxins from the consumption of fruit and vegetables;
- P_d = Aboveground exposed fruit and vegetables concentration due to direct deposition onto plant surfaces – calculated using Equation B-2-7 in Appendix B of HHRAP methodology;
- P_v = Aboveground exposed fruit and vegetables concentration due to air-to-plant transfer – calculated using Equation B-2-8 in Appendix B of HHRAP methodology;
- P_{rag} = Aboveground exposed and protected fruit and vegetables concentration due to root intake – calculated using Equation B-2-9 in Appendix B of HHRAP methodology;
- P_{rbg} = Belowground exposed and protected fruit and vegetables concentration due to root intake – calculated using Equation B-2-10 in Appendix B of HHRAP methodology;
- CR_{ag} = Consumption rate of aboveground fruit and vegetables (US EPA HHRAP Value);
- CR_{pp} = Consumption rate of protected aboveground fruit and vegetables (US EPA HHRAP Value);
- CR_{bg} = Consumption rate of belowground fruit and vegetables (US EPA HHRAP Value);
- F_{ag} = Fraction of fruit and vegetables that is contaminated – assumed to be 1.0.

Calculation of P_d

Equation B-2-7 in Appendix B of the US EPA HHRAP methodology was used for the calculation of P_d and is as follows:

Equation 13 The Increase in Dioxin Concentration in Aboveground Produce Due to Deposition

$$P_d = \frac{1000 \times Q \times (1 - F_v) \times [Dydp + (Fw \times Dywp)] \times Rp \times [1.0 - e^{-(kp \times Tp)}]}{Yp \times kp}$$

Where:

- P_d = Concentration of Dioxins in aboveground fruit and vegetables due to direct deposition;
- Q = Dioxin emission rate;
- F_v = Fraction of Dioxin in the vapour phase – US EPA HHRAP value for Dioxins = 0.664;
- $Dydp$ = Unitised yearly average dry deposition from particulate phase – ADMS modelling;
- Fw = Fraction of Dioxin that adheres to plant surfaces – US EPA HHRAP value = 0.6 for organics;
- $Dywp$ = Unitised yearly average wet deposition from particulate phase – ADMS modelling;
- Rp = Interception fraction of the edible portion of the plant – US EPA HHRAP value = 0.39;
- Kp = Plant surface loss coefficient – US EPA HHRAP value = 18;
- To = Length of plant exposure to deposition per harvest of edible portion of plant – US EPA HHRAP value = 0.16;
- Yield of standing crop biomass of the edible portion of the plant (productivity) – US EPA HHRAP value = 2.24.

Using the above equation, a value of 6.97×10^{-11} mg Dioxin per kg Dry Weight was obtained for P_d .

Calculation of P_v

Equation B-2-8 in Appendix B of the US EPA HHRAP methodology was used for the calculation of P_v and is as follows:

Equation 14 The Increase in Dioxin Concentration in Aboveground Produce Due to Air-Plant Transfer

$$P_v = Q \times F_v \times \frac{C_{yv} \times B_{v_{ag}} \times V_{g_{ag}}}{\rho_a}$$

Where:

- P_v = Concentration of Dioxins in aboveground fruit and vegetables due to air-to-plant transfer;
- Q = Dioxin emission rate;
- F_v = Fraction of Dioxin in the vapour phase – US EPA HHRAP value for Dioxins = 0.664;
- C_{yv} = Unitised annual average atmospheric concentration – ADMS modelling;
- B_{vag} = Dioxin air-to-plant Biotransfer factor for aboveground fruit and vegetables – US EPA HHRAP value = 6.55×10^{-4} ;
- V_{gag} = Empirical correction factor for aboveground fruit and vegetables – US EPA HHRAP value = 0.01;
- P_a = Density of air ($1,200 \text{ g m}^{-3}$).

Using the above equation, a value of 1.39×10^{-10} mg Dioxin per kg Dry Weight was obtained for P_v .

Calculation of Pr_{ag}

Equation B-2-9 in Appendix B of the US EPA HHRAP methodology was used for the calculation of Pr_{ag} and is as follows:

Equation 15 The Increase in Dioxin Concentration in Aboveground Produce Due to Root Intake

$$Pr_{ag} = Cs \times Br_{ag}$$

Where:

- Pr_{ag} = Concentration of Dioxins in aboveground fruit and vegetables due to root intake;
- C_s = Incremental increase in Dioxin concentration in the soil over exposure period;
- Br_{ag} = Plant-soil bioconcentration factor for aboveground fruit and vegetables – US EPA HHRAP value for Dioxins = 0.00455.

Using the above equation, a value of 6.3×10^{-12} mg Dioxin per kg Dry Weight was obtained for Pr_{ag} .

Calculation of Pr_{bg}

Equation B-2-10 in Appendix B of the US EPA HHRAP methodology was used for the calculation of Pr_{bg} and is as follows:

Equation 16 The Increase in Dioxin Concentration in Belowground Produce Due to Deposition

$$Pr_{bg} = Cs \times Br_{rootveg} \times Vg_{rootveg}$$

Where:

- Pr_{bg} = Concentration of Dioxins in belowground fruit and vegetables due to root intake;
- C_s = Incremental increase in Dioxin concentration in the soil over exposure period;
- $Br_{rootveg}$ = Plant-soil bioconcentration factor for belowground fruit and vegetables – US EPA HHRAP value for Dioxins = 1.03;
- $Vg_{rootveg}$ = Empirical correction factor for belowground fruit and vegetables – US EPA HHRAP value = 0.01.

Using the above equation, a value of 1.43×10^{-11} mg Dioxin per kg Dry Weight was obtained for Pr_{bg} .

Calculation of Dioxin Intake from the Consumption of Fruit and Vegetables

Equation C-1-2 in Appendix C of the US EPA HHRAP methodology was used to calculate the overall intake of Dioxins due to the consumption of fruit and vegetables, as specified in Equation 12 above, and specifically where:

- I_{ag} = Daily intake of Dioxins from the consumption of fruit and vegetables;
- P_d = Aboveground exposed fruit and vegetables concentration due to direct deposition onto plant surfaces – calculated using Equation B-2-7 in Appendix B of HHRAP methodology = 6.97×10^{-11} mg kg^{-1} day $^{-1}$ DW;
- P_v = Aboveground exposed fruit and vegetables concentration due to air-to-plant transfer – calculated using Equation B-2-8 in Appendix B of HHRAP methodology = 1.39×10^{-10} mg kg^{-1} day $^{-1}$ DW;
- Pr_{ag} = Aboveground exposed and protected fruit and vegetables concentration due to root intake – calculated using Equation B-2-9 in Appendix B of HHRAP methodology = 6.3×10^{-12} mg kg^{-1} day $^{-1}$ DW;
- Pr_{bg} = Belowground exposed and protected fruit and vegetables concentration due to root intake – calculated using Equation B-2-10 in Appendix B of HHRAP methodology = 1.43×10^{-11} mg kg^{-1} day $^{-1}$ DW;
- CR_{ag} = Consumption rate of aboveground fruit and vegetables (US EPA HHRAP Value) = 0.00047 $kg\ kg^{-1}$ day $^{-1}$ DW for adults and 0.00113 $kg\ kg^{-1}$ day $^{-1}$ DW for children;
- CR_{pp} = Consumption rate of protected aboveground fruit and vegetables (US EPA HHRAP Value) = 0.00064 $kg\ kg^{-1}$ day $^{-1}$ DW for adults and 0.00157 $kg\ kg^{-1}$ day $^{-1}$ DW for children;
- CR_{bg} = Consumption rate of belowground fruit and vegetables (US EPA HHRAP Value) = 0.00017 $kg\ kg^{-1}$ day $^{-1}$ DW for adults and 0.00028 $kg\ kg^{-1}$ day $^{-1}$ DW for children;
- F_{ag} = Fraction of fruit and vegetables that is contaminated – assumed to be 1.0

Using the above equation, a value of 0.00011 $pg\ kg^{-1}$ Dioxin per kg Dry Weight for adults was obtained for I_{ag} , the dietary intake via the consumption of fruit and vegetables, and a value of 0.00026 $pg\ kg^{-1}$ Dioxin per kg Dry Weight for children.

3.15 Combined Dietary Intake via the Consumption of Meat, Eggs, Milk, Fruit and Vegetables and the Ingestion of Soil

When the results from the above calculation procedures are converted to dietary intake ($pg\ kg^{-1}$ BW day $^{-1}$) of Dioxins and are added together with the estimated intake via inhalation, the following results are obtained:

Table 9 Intake of Dioxins at the Location of Maximum Process Contribution

Food Category	pg kg^{-1} BW day $^{-1}$	
	UK Adult Mean	UK Child Mean
Beef (for all meat)	0.0042	0.0071
Eggs	0.00001	0.00002
Whole Milk	0.0064	0.0689
Soil Ingestion	0.0000020	0.0000139
Fruit and Vegetables	0.0000015	0.0000129
Inhalation (PC plus background)	0.0022	0.0027
Total	0.0128	0.0788

Table 10 Intake of Dioxins at the Location of Maximum Process Contribution as a Percentage of the Tolerable Daily Intake

Food Category	UK Adult Mean	UK Child Mean
Beef (for all meat)	0.21%	0.36%
Eggs	0.0006%	0.0009%
Whole Milk	0.32%	3.44%
Soil Ingestion	0.00010%	0.00069%
Fruit and Vegetables	0.00008%	0.00064%
Inhalation (PC plus background)	0.11%	0.14%
Total	0.64%	3.94%

The results presented in Tables 9 and 10 represent a worst-case estimate, based upon Dioxin deposition rates due to continuous emissions at the ELV of 0.04 ng Nm⁻³, at the location of the maximum annual average process contribution which is about 240 metres to the north of the Biomass No. 4 chimney, and occurs within the boundary of the industrial estate. It also assumes that total dietary intake of meat, eggs, milk, and fruit and vegetables is derived from produce grown at that specific location, which is clearly a significantly conservative assessment.

Nevertheless, the results show that the potential impact of Dioxin release from the proposed EfW facility on Dioxin concentrations in the soil, and on the associated increase in dietary intake through the consumption of meat, eggs, fruit and vegetables, as well as via the ingestion of soil through the working of the land, and through inhalation, is likely to be considerably below the recommended Tolerable Daily Intake of 2 pg kg⁻¹ day⁻¹.

The overall potential intake of Dioxins for adults represents about 0.64 % of the TDI, with that for children equating to less than 4 % of the TDI. It should be noted that in defining a TDI of 2 pg kg⁻¹ for Dioxins, the Committee on Toxicity acknowledged the uncertainties associated with the approach:

We concluded that the available human data did not provide a sufficiently rigorous basis for establishment of a tolerable intake. This was because:

- *the epidemiological studies do not reflect the most sensitive population identified by animal studies;*
- *there are considerable uncertainties in the exposure assessments and inadequate allowance for confounding factors;*
- *the patterns of exposure did not reflect exposures experienced in the general UK population, which are mainly from diet.*

We therefore found it necessary to base our evaluation on the data from studies conducted in experimental animals.

Accordingly, the results from this assessment, which are based upon a series of overly pessimistic assumptions relating to emissions of Dioxins and the associated deposition, should be viewed within the context that they are low relative to an inexact assessment level. This is particularly the case with regard to the predictions for the consumption of milk. These values reflect the fact that Dioxins tend to concentrate in fats and fatty tissues, and pass through into an animal's lactate system.

The corresponding values for the nineteen nearby specific receptors were lower in relation to their distance from the site, as shown in Table 11, over page.

Table 11 Exposure to Dioxins at Specific Receptors in the Vicinity of the Biomass No. 4 Plant

Receptor Number	Distance from the Facility (metres)	Percentage of Tolerable Daily Intake (Adult)	Percentage of Tolerable Daily Intake (Child)
1	185	0.28%	1.41%
2	310	0.24%	1.16%
3	293	0.23%	1.09%
4	493	0.37%	2.07%
5	541	0.24%	1.18%
6	441	0.16%	0.59%
7	654	0.13%	0.38%
8	813	0.12%	0.30%
9	1,165	0.11%	0.30%
10	1,245	0.15%	0.57%
11	845	0.13%	0.38%
12	1,062	0.12%	0.35%
13	557	0.23%	1.10%
14	708	0.28%	1.44%
15	924	0.13%	0.40%
16	1,247	0.13%	0.41%
17	1,046	0.11%	0.30%
18	1,445	0.10%	0.20%
19	2,327	0.09%	0.17%

The assessment indicates that the risk to the health of the local population due to exposure to Dioxins in emissions from the proposed EfW plant is likely to be very low in comparison to the recommended Tolerable Daily Intake of 2 pg kg⁻¹ yr⁻¹.

When the above exposure data are translated into associated Cancer Risk data, the following values were obtained.

Table 12 Cancer Risk Due to Exposure to Dioxins at Residential Receptors in the Vicinity of the Biomass No. 4 Plant

Receptor	Distance from the Facility (m)	Cancer Risk (Adult)		Cancer Risk (Child)	
		Risk Level	1 Adult in	Risk Level	1 Child in
Maximum	239	8.24 x 10 ⁻⁰⁷	1,213,723	5.06 x 10 ⁻⁰⁶	197,484
1	185	3.56 x 10 ⁻⁰⁷	2,812,836	1.81 x 10 ⁻⁰⁶	551,402
2	310	3.08 x 10 ⁻⁰⁷	3,250,705	1.49 x 10 ⁻⁰⁶	670,794
3	293	2.97 x 10 ⁻⁰⁷	3,365,245	1.40 x 10 ⁻⁰⁶	715,137
4	493	4.73 x 10 ⁻⁰⁷	2,114,580	2.67 x 10 ⁻⁰⁶	374,961
5	541	3.11 x 10 ⁻⁰⁷	3,220,535	1.52 x 10 ⁻⁰⁶	656,992
6	441	2.04 x 10 ⁻⁰⁷	4,895,465	7.52 x 10 ⁻⁰⁷	1,328,934
7	654	1.63 x 10 ⁻⁰⁷	6,153,094	4.85 x 10 ⁻⁰⁷	2,061,812
8	813	1.48 x 10 ⁻⁰⁷	6,761,927	3.83 x 10 ⁻⁰⁷	2,612,980
9	1,165	1.46 x 10 ⁻⁰⁷	6,856,158	3.82 x 10 ⁻⁰⁷	2,620,058
10	1,245	1.96 x 10 ⁻⁰⁷	5,108,357	7.29 x 10 ⁻⁰⁷	1,371,557
11	845	1.63 x 10 ⁻⁰⁷	6,131,713	4.93 x 10 ⁻⁰⁷	2,029,527
12	1,062	1.56 x 10 ⁻⁰⁷	6,403,864	4.50 x 10 ⁻⁰⁷	2,221,250
13	557	2.96 x 10 ⁻⁰⁷	3,379,842	1.42 x 10 ⁻⁰⁶	706,378
14	708	3.57 x 10 ⁻⁰⁷	2,802,865	1.85 x 10 ⁻⁰⁶	539,437
15	924	1.67 x 10 ⁻⁰⁷	5,975,627	5.19 x 10 ⁻⁰⁷	1,926,180
16	1,247	1.67 x 10 ⁻⁰⁷	5,993,105	5.23 x 10 ⁻⁰⁷	1,913,097
17	1,046	1.47 x 10 ⁻⁰⁷	6,813,936	3.83 x 10 ⁻⁰⁷	2,613,284
18	1,445	1.28 x 10 ⁻⁰⁷	7,836,956	2.57 x 10 ⁻⁰⁷	3,887,936
19	2,327	1.22 x 10 ⁻⁰⁷	8,224,850	2.18 x 10 ⁻⁰⁷	4,579,896

The above Cancer Risk estimates represent the incremental probability that an individual, living continuously at a particular receptor location, will develop cancer over that person's lifetime as a result of a specific exposure to Dioxins emitted from the chimney of the proposed EfW facility. The position in the UK at present is that a risk level of 1×10^{-05} is considered to be appropriate for use as the basis for assessment for carcinogenic contaminants such as Dioxins^{8,9}. Accordingly, the above results can be screened out as insignificant.

It should be noted that the above results are based upon a series of worst case, conservative assumptions:

1. Emissions of Dioxins are continuously discharged at the ELV of 0.04 ng Nm⁻³ for waste incineration plants.
2. It is assumed that all of the food consumed by individuals is grown at that location, which is highly unlikely given the likelihood that for the majority of the population food is purchased from supermarkets, or other outlets, and is grown outside of the area; and,
3. All of the milk consumed is produced by cows grazing at the specific receptor location for the entire year, which is highly unlikely. Furthermore, the consumption of milk accounts for between approximately 50 % and 87 % of the estimated dietary intake due to the propensity for Dioxins to accumulate in fatty body tissue and pass through into the cows' lactate system

Accordingly, the above results are considered to provide a worst-case and an overly conservative assessment of the potential exposure to Dioxins in the vicinity of the proposed Biomass No. 4 site.

To put the Cancer Risk data into perspective, information is presented below relating to risk of death from a range of causes¹⁰.

Table 13 Risk of an Individual Dying in Any One Year

Activity	Risk
Smoking 10 cigarettes a day	1 in 200
All natural causes, age 40	1 in 850
All violence and poisoning	1 in 3,300
Influenza	1 in 5,000
Accident on the road	1 in 8,000
Leukaemia	1 in 12,000
Accident at home	1 in 26,000
Accident at work	1 in 43,000
Murder	1 in 100,000
Accident on railway	1 in 500,000
Hit by lightning	1 in 10,000,000
Radiation from nuclear reactor	1 in 10,000,000

These values are not absolute, but indicative, and enable the Cancer Risk estimates to be viewed in perspective with other activities that individuals may be associated with. As can be seen, when compared to the Cancer Risk scores for receptor number 4, representing one of the nearest downwind residential properties to the site, being located within 500m to the east of the site and with the highest Dioxin deposition rate of each of the receptors, the risk of dying in a road traffic accident (1 in 8,000) is about two hundred and sixty four times higher than the risk of developing cancer (approximately 1 in 2,114,580 adults), due to exposure to Dioxins released from the proposed EfW facility.

4. The Impact of Emissions of PAH and Dioxin-like PCBs

PAH (Polynuclear Aromatic Hydrocarbons) is a term that describes a group of organic compounds, made up of Carbon and Hydrogen, comprised of fused multiple aromatic rings, and include substances such as Naphthalene, Chrysene and Benzo[a]pyrene (B[a]P), the latter being one of the more toxic of the group of compounds. PAH can be formed by the inefficient combustion of Carbon-containing fuels such as coal, diesel and biomass.

Although no limit is specified within the IED or the BREF Note or BAT-Conclusions documents which support it, the BREF does suggest an achievable range of PAH emission from incineration plant of 0.00000001 - 0.05 mg m⁻³ as total PAH or 0.000000004 - 0.001 mg m⁻³ as B[a]P. The upper end of this latter range was applied in the modelling, and results are compared with the air quality objective value of 0.25 ng m⁻³ B[a]P.

PCBs (Polychlorinated Biphenyls) are synthetic organic compounds made up of Carbon, Hydrogen and Chlorine. There are 209 different PCB compounds with up to 10 chlorine atoms attached to a two ring, Biphenyl group. They are sometimes referred to as Aroclor compounds with different numbering configurations, for example, Aroclor 1254 refers to a 12-carbon atom compound containing 54 % Chlorine by mass.

The Waste Incineration BREF¹¹ does not specify an individual achievable emission level for PCBs, instead specifying that the combined emissions of Dioxins, Furans and PCBs from waste incineration plant should remain within 0.06 ng Nm⁻³, or 1.5 times the Dioxin and Furan ELV.

4.1 Results and Discussion

Detailed atmospheric dispersion modelling of emissions of PAH and PCBs from the proposed Biomass No. 4 plant was undertaken, and the reported maximum annual average process contribution for the years 2016 to 2020, are presented in the following table for the nineteen local human health receptor locations considered in this report.

Table 14 Maximum Exposure to PAH and PCBs at Specific Receptors in the Vicinity of the Biomass No. 4 Plant

Receptor Number	Annual Average Dioxin and PCB Concentration (µg m ⁻³)	% EAL	Annual Average B[a]P Concentration (ng m ⁻³)	% AQS
1	2.33 x 10 ⁻¹⁰	0.00000012%	0.00388	1.6%
2	2.04 x 10 ⁻¹⁰	0.00000010%	0.00340	1.4%
3	1.93 x 10 ⁻¹⁰	0.00000010%	0.00321	1.3%
4	3.65 x 10 ⁻¹⁰	0.00000018%	0.00608	2.4%
5	2.12 x 10 ⁻¹⁰	0.00000011%	0.00354	1.4%
6	9.89 x 10 ⁻¹¹	0.00000005%	0.00165	0.7%
7	5.60 x 10 ⁻¹¹	0.00000003%	0.00093	0.4%
8	3.89 x 10 ⁻¹¹	0.00000002%	0.00065	0.3%
9	3.70 x 10 ⁻¹¹	0.00000002%	0.00062	0.2%
10	9.22 x 10 ⁻¹¹	0.00000005%	0.00154	0.6%
11	5.30 x 10 ⁻¹¹	0.00000003%	0.00088	0.4%
12	4.57 x 10 ⁻¹¹	0.00000002%	0.00076	0.3%
13	1.63 x 10 ⁻¹⁰	0.00000008%	0.00271	1.1%
14	2.36 x 10 ⁻¹⁰	0.00000012%	0.00394	1.6%
15	6.27 x 10 ⁻¹¹	0.00000003%	0.00105	0.4%
16	6.16 x 10 ⁻¹¹	0.00000003%	0.00103	0.4%
17	4.03 x 10 ⁻¹¹	0.00000002%	0.00067	0.3%
18	1.95 x 10 ⁻¹¹	0.00000001%	0.00032	0.1%
19	1.38 x 10 ⁻¹¹	0.00000001%	0.00023	0.1%

As can be seen, the maximum annual average process contribution of Dioxins and PCBs are all considerably below 1 % the Environmental Assessment Level for PCB (0.2 µg m⁻³) and can therefore be screened as insignificant at all of the specific receptor locations.

Contributions of PAH at the sensitive receptors equate to between approximately 0.1 and 2.4 % of the Air Quality Standard (0.25 ng m⁻³ PAH as B[a]P). However, applying the 2020 measured background figure from the Chilbolton Observatory monitoring station¹² (0.062 ng m⁻³) results in a maximum predicted environmental concentration at the receptor sites of approximately 0.068 ng m⁻³, which is approximately 27 % of the AQS, and can be screened as insignificant at the second assessment stage.

Applying the combined Dioxin, Furan and PCB Emissions Limit Value now specified for waste incineration plants, which is equivalent to 1.5 times the Dioxin and Furan emission alone, the results from the Dioxin Health Risk Assessment can be increased by a factor of 50 % in order that the potential impact of the combined emissions of Dioxins and Dioxin-like PCBs can be considered.

The Dioxin Tolerable Daily Intake value of 2 pg kg⁻¹ body weight used as the basis for assessment for Dioxins, was also applied to the process contribution of the PCBs.

Table 15 Maximum Exposure to Dioxins and PCBs at Specific Receptors in the Vicinity of the Facility

Receptor Number	Distance from Source (metres)	Dioxins Alone		Dioxins and PCBs	
		Percentage of Tolerable Daily Intake (Adult)	Percentage of Tolerable Daily Intake (Child)	Percentage of Tolerable Daily Intake (Adult)	Percentage of Tolerable Daily Intake (Child)
Maximum	239	0.64%	3.94%	0.96%	5.91%
1	185	0.28%	1.41%	0.41%	2.12%
2	310	0.24%	1.16%	0.36%	1.74%
3	293	0.23%	1.09%	0.35%	1.63%
4	493	0.37%	2.07%	0.55%	3.11%
5	541	0.24%	1.18%	0.36%	1.78%
6	441	0.16%	0.59%	0.24%	0.88%
7	654	0.13%	0.38%	0.19%	0.57%
8	813	0.12%	0.30%	0.17%	0.45%
9	1,165	0.11%	0.30%	0.17%	0.45%
10	1,245	0.15%	0.57%	0.23%	0.85%
11	845	0.13%	0.38%	0.19%	0.57%
12	1,062	0.12%	0.35%	0.18%	0.53%
13	557	0.23%	1.10%	0.35%	1.65%
14	708	0.28%	1.44%	0.42%	2.16%
15	924	0.13%	0.40%	0.20%	0.61%
16	1,247	0.13%	0.41%	0.19%	0.61%
17	1,046	0.11%	0.30%	0.17%	0.45%
18	1,445	0.10%	0.20%	0.15%	0.30%
19	2,327	0.09%	0.17%	0.14%	0.25%

As can be seen, the combined intake of Dioxins and Furans and Dioxin-like PCBs, due to emissions from the proposed EfW facility, continue to represent a very small percentage of the Tolerable Daily Intake of 2 pg kg⁻¹ body weight at all nearby specific receptor locations, with values that are less than 1 % of the adult TDI assessment level. Accordingly, inclusion of PCBs into the Dioxin HRA results in a small increase in the predicted impact, which can still be screened out as insignificant.

5. Conclusions

A health impact assessment has been undertaken to assess the risk to the health of people living and working in the vicinity of the Biomass UK No. 4 Limited site off Belliver Way in Roborough, Plymouth. Biomass UK No. 4 Limited proposes to convert the existing Dartmoor Bio Power wood fired EfW plant, for the receipt and use of RDF, and the facility will in future be known as Biomass No. 4.

Detailed atmospheric dispersion modelling of emissions from the 35 metre high chimney that will be associated with the converted process was undertaken using the ADMS Version 5.2 model to predict increases in pollutant concentrations at nearby sensitive receptors such as residential properties, schools and locations where people may congregate for significant periods of time. The Air Quality Assessment (AQA) produced to report the dispersion modelling work included detailed consideration of model-predicted process contributions against health-based Air Quality Standards and relevant Environmental Assessment Levels recommended by the Environment Agency.

In addition to the AQA, this report has applied the US EPA Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities to assess the potential risk to health of people living and working in the locality of the proposed plant due to emissions of Dioxins and Furans, and Dioxin-like PCBs. The assessment considered the potential health risks associated with the intake of Dioxins from the consumption of potentially contaminated foodstuffs due to emissions to atmosphere from the chimney of the proposed EfW facility. The assumptions used within the assessment are conservative and therefore the study is considered to represent a worst-case.

The assessment indicates that the risk to health of the local population due to exposure to Dioxins in emissions from the facility is likely to be low, remaining within 1 % of the Tolerable Daily Intake (TDI) of 2 pg kg⁻¹ for adults. The inclusion of Dioxin-like PCBs into the assessment resulted in a marginal increase in the resulting process contributions, but remained a very small proportion of the 2 pg kg⁻¹ TDI.

The assessment for health risks associated with exposure to emissions of PAH demonstrated that process contributions at the sensitive receptors equate to between 0.1 % and 2.4 % of the Air Quality Standard (0.25 ng m⁻³ PAH as B[a]P). However, where contributions were not immediately screened as insignificant, all were screened at the secondary assessment stage.

In conclusion, the results from the health impact assessment confirms that there is no significant health risk associated with potential exposure to emissions of Dioxins, Furans, PCBs or PAH from the converted facility, which proposes to fire RDF in the Biomass No. 4 EfW plant.

6. References

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