enviroparks

APPENDIX 9.7

Health impact assessment

GF Environmental Limited

Enviroparks Ltd

Health Impact Assessment for the Enviroparks Facility at Hirwaun

January 2017

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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 Enviroparks facility to be developed on land at Hirwaun in South Wales. Detailed atmospheric dispersion modelling of emissions from the three chimneys associated with the Enviroparks facility was undertaken using the ADMS Version 5.2 model to predict increases in pollutant concentrations at nearby sensitive receptors such as residential properties, farms and other locations where people may congregate for significant periods of time. The assessment involved a comparison of model-predicted process contributions against health-based air quality standards and relevant environmental assessment levels.

Short term acute effects for NO_2, SO_2 and PM_{10} were assessed in line with COMEAP procedures and showed that increases in background pollutant concentrations at nearby residential properties were low and would not have a significant impact on the health of people living and working nearby. Similar conclusions were drawn for other pollutants with short term, acute effects (HCl, HF and CO). Process contributions for pollutants such as VOCs and heavy metals were also low and their potential health effects screened out as insignificant in relation to health-based air quality standards and relevant EALs recommended by Natural Resources Wales.

The US EPA Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities was used to assess the potential risk to health of people living and working in the vicinity of the Enviroparks facility due to emissions of dioxins and furans. The assessment considered the potential health risks associated with the intake of dioxins due to the consumption of potentially contaminated foodstuffs due to emissions to atmosphere from the three chimneys of the Enviroparks facility. The assumptions used within the assessment are conservative and therefore the study was undertaken on a pessimistic worst case basis.

The assessment indicates that the risk to health of the local population due to exposure to dioxins in emissions from the Enviroparks facility is likely to be low, with exposure levels well below the Tolerable Daily Intake (TDI) of 2 pg/kg, at nearby residential receptor locations.

The results from the assessment show that the predicted risks to the health of people living in the vicinity of the Enviroparks facility are well within limits for the protection of human health defined in current DEFRA, Natural Resources Wales and/or US-EPA guidance.

The conclusions from the assessment are considered reliable on the basis of the worst case approach adopted in the characterisation of dioxin emissions from the Enviroparks facility, the conservatism incorporated into the US-EPA HHRAP calculation procedures, and the series of worst case exposure scenarios considered in the assessment.

1. Introduction

1.1 Introduction

1.1.1 Enviroparks Ltd is proposing to develop an integrated waste management facility on land in Hirwaun in South Wales. The proposed development is a highly efficient integrated waste management facility that initially sorts the incoming feedstock materials to extract recyclables, before preparing the feedstock for further processing. The company plans to operate a resource recovery and energy production plant using the concept of integrated technologies to extract recyclables from the incoming waste stream, and to create a Refuse Derived Fuel (RDF) for use in an advanced thermal treatment process. The site will include three gasification lines which will each serve a single site electricity generating turbine.

1.1.2 The primary source of potential pollutant emissions from the proposed Enviroparks facility is the chimneys associated with boilers, and their pollution control systems, that recover thermal energy from the waste gasification processes. Detailed atmospheric dispersion modelling was undertaken using ADMS Version 5.2 in order to quantify the potential impact on local air quality of emissions from the combustion sources within the Enviroparks facility.

1.1.3 Air Quality Standards (AQS) have been established primarily to protect the health of the general population and detailed atmospheric dispersion modelling has shown that there are unlikely to be any exceedences of any AQS objective value or Environmental Assessment Level. Accordingly, it is expected that the operation of the proposed Enviroparks facility is unlikely to pose a significant risk to the health of the local population living in Hirwaun and the surrounding area. In order to quantify the potential impact of airborne pollutants on the health of surrounding communities, a health impact assessment (HIA) has been carried out. This report updates an earlier health risk assessment undertaken by GF Environmental Ltd to take account of process changes that have occurred in the intervening period.

1.1.4 This document presents the results from the health impact assessment studies undertaken on the basis of model predictions for increases in ambient pollutant concentrations arising from the operation of the currently proposed Enviroparks facility.

1.2 Health Issues Associated with Emissions from the Enviroparks Facility

1.2.1 The primary source of pollutant emissions from the Enviroparks facility is emissions to atmosphere from the three main chimneys. 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 in the health impact assessment (HIA) fall into the following categories:

Acute Effects

- Oxides of Nitrogen (NO_X) and their subsequent conversion to Nitrogen Dioxide (NO_2);
- Sulphur Dioxide (SO_2);
- Particulates;
- Carbon Monoxide (CO);
- Hydrogen Chloride (HCl);
- Hydrogen Fluoride (HF).

Chronic Effects

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

1.2.2 The assessment considered the direct risks associated with the inhalation and consumption of substances released from the three main chimneys of the Enviroparks facility. For most of the pollutants considered, the assessment is based upon the incremental increase in background concentration, the Process Contribution (PC), associated with emissions to atmosphere from the Enviroparks facility. Where data are available on current background concentrations, then reference is made to the Predicted Environmental Concentration (PEC), which is the sum of the PC and the current background.

1.2.3 The HIA considers the potential impact of emissions of all of the pollutants regulated by the Industrial Emissions Directive for waste incineration facilities, on the health of local residents living in the vicinity of the Enviroparks development site.

1.2.4 The assessment of the significance of these effects has been determined in relation to the following criteria:

- Comparison with the relevant Air Quality Standards or EALs;
- The ratio between the Process Contribution and the AQS or EAL; and,
- The incremental impact on health (in accordance with COMEAP procedures[1]); and,
- The US EPA Human Health Risk Assessment Protocol (HHRAP) for dioxins, dioxin-like PCBs and PAH.

1.2.5 The COMEAP procedure involves the calculation of the potential number of members of the population that might be admitted to hospital as a result of exposure to pollutants. The following formula is used in the calculation procedure:

[1] COMEAP (Committee on the Medical Effects of Air Pollutants) (1998) The quantification of the effects of air pollution on health in the United Kingdom. Department of Health, London: The Stationary Office

$$\text{Incremental Impact} = C_{avg} \times \left(\frac{D_{Pollutant}}{10} \right) \times B_{Health}$$

1.2.6 Where:

C_{avg} is the modelled concentration (annual average - µg m^{-3} derived from modelling);
$D_{Pollutant}$ is the COMEAP dose-response coefficient (% increase per 10 µg m^{-3})
B_{Health} is the baseline rate for the health effect (per annum)

1.2.7 The dose-risk coefficients specified in the COMEAP study are summarised below.

Table 1 COMEAP Dose-Risk Coefficients

Pollutant	Health Outcome	Dose-Response Coefficient
PM_{10}	Deaths brought forward (all causes) Respiratory hospital admissions	+ 0.75% per 10 µg m^{-3} (24 hour mean) + 0.80% per 10 µg m^{-3} (24 hour mean)
Sulphur dioxide	Deaths brought forward (all causes) Respiratory hospital admissions	+ 0.6% per 10 µg m^{-3} (24 hour mean) + 0.5% per 10 µg m^{-3} (24 hour mean)
NO_2	See note below	See note below
Notes: For NO_2 a dose-response coefficient of 0.5% per 10 µg m^{-3} was used to estimate the effect on respiratory hospital admissions in a sensitivity analysis.		
Source: COMEAP (1998)		

1.2.8 It should be noted that the preliminary assessment is based upon the location of the maximum Process Contribution (PC). The corresponding values at nearby residential receptors are predicted by detailed modelling to be lower, as the magnitude of the PC decreases significantly with distance from the chimneys.

1.2.9 It should also be noted that the assessment refers to potential hospital re-admissions for individuals with a pre-existing respiratory complaint, and not members of the general public who are in reasonably good health.

2. Health Impact Assessment for Pollutants with Acute Effects

2.1 Introduction

2.1.1 The following assessment relates to those pollutants identified in Section 1.2.1 that are associated with short term acute health impacts.

2.2 Nitrogen Dioxide (NO_2)

2.2.1 The potential impact on human health of NO_2, arising from emissions of NO_X from the Enviroparks facility, has been considered in relation to both the maximum hourly peak, based upon the half hourly IED emission limit value (ELV) and 50% conversion of NO_X to NO_2, and maximum annual average predictions. The values for the hourly average Process Contribution differ from those in the main dispersion modelling report which were based upon the daily average IED ELV of 200 mg Nm^{-3}.

Table 2 Relationship Between Model Predictions for NO_2 and AQS Values

Maximum PC	Existing Background Concentration	AQS	Ratio of AQS/EAL to PC (PEC)
~156 µg m^{-3}	-	200 µg m^{-3}	~1.3
~5.1 µg m^{-3}	~8.7 µg m^{-3}	40 µg m^{-3}	~8 (2.9)

2.2.2 The atmospheric chemistry module in ADMS was not used to calculate the conversion of NO_X to NO_2 in the emissions from the Enviroparks facility. Instead, the following methodology for calculating annual average and hourly average NO_2 ground-level concentration was used, which is based upon conversion of the ADMS model predictions for NO_X as shown in Equation 1 and Equation 2:

Equation 1 Calculation of Annual Average NO_2 Predicted Environmental Concentration

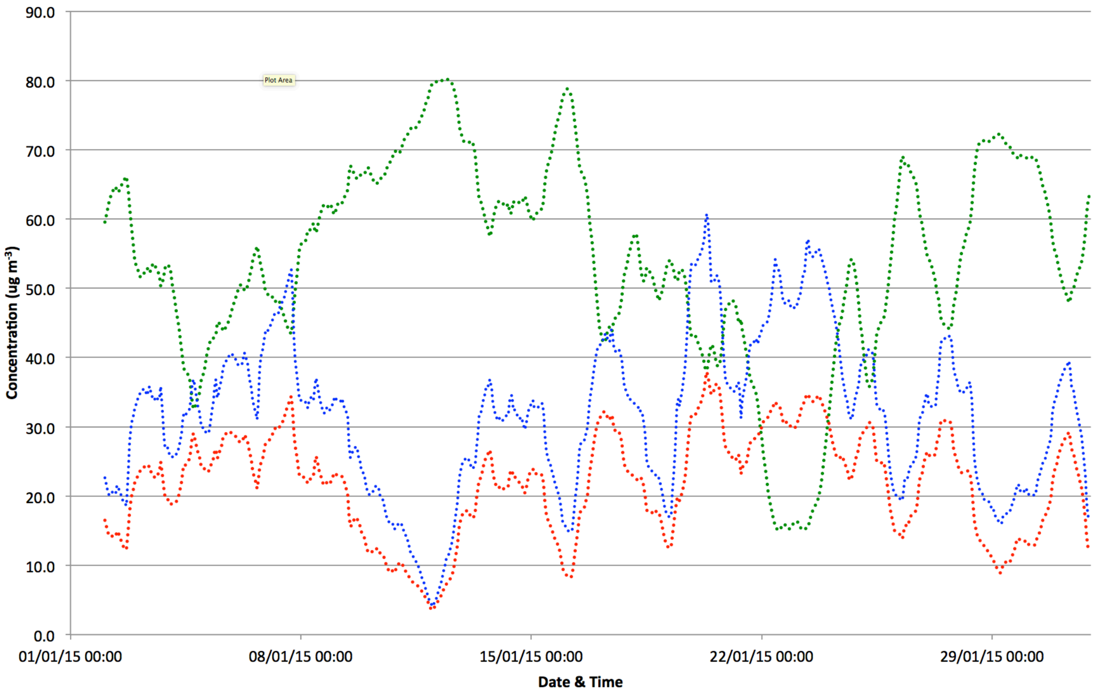
$$(\text{Annual } NO_{X\ \text{Modelled}} \times 1.0) + \text{Annual } NO_{2\ \text{Background}}$$

Equation 2 Calculation of Hourly Average NO_2 Predicted Environmental Concentration

$$(\text{Hourly } NO_{X\ \text{Modelled}} \times 0.5) + (\text{Annual } NO_{2\ \text{Background}} \times 2)$$

2.2.3 This methodology, which is approved by Natural Resources Wales, is likely to overestimate the PEC for NO_2 in close proximity to the site, as the conversion of NO_X to NO_2 is unlikely to be instantaneous as it requires mixing of the plume with the ambient air and its associated oxidant species (O_3, etc). Atmospheric chemistry in the South Wales area is complex and highly variable, as shown by data from the Port Talbot AURN site which is ~25km to the south-west of Hirwaun, and which is considered to be representative of conditions in Hirwaun. Archive data for January 2015 show the variability of hourly average NO_2, NO_X and ozone concentrations, and indicate that the availability of atmospheric oxidants such as ozone may be significantly lower at certain times, and varies significantly on a daily basis.

Figure 2-1 Variation in Hourly Average NO_X & Ozone Concentrations at the Port Talbott Urban Industrial AURN Site – January 2015



2.2.4 As can be seen, the NO_X (blue dashed line) and ozone (green dashed line) curves tend to mirror one another, with ozone concentrations higher when the NO_X concentrations are lower and vice versa. Similar patterns are exhibited for other months throughout the year. The NO_2 concentrations (red dashed line) are significantly higher when ozone concentrations are lower, with higher levels of nitric oxide (NO). Similar trends were shown for other months of the year.

2.2.5 Under these variable conditions, the atmospheric transformation of NO_X to NO_2, associated with emissions from the Enviroparks facility will be affected to a varying degree. Accordingly, there is likely to be a proportion of the year when the atmospheric chemistry in the vicinity of the development site may be restricted in its capacity to convert NO_X to NO_2 and the dispersion model predictions may overestimate the significance of annual average NO_2 predictions at receptors in the vicinity of the development site.

2.2.6 Accordingly, applying the 100% conversion of NO_X to NO_2 at locations close to the point of release may overestimate significantly the potential NO_2 process contributions at these locations. As the plume migrates away from the stack it disperses and mixes with the ambient air resulting in lower concentrations of pollutants, so the PC for NO_X and hence associated NO_2, will be lower farther afield.

2.2.7 As can be seen, there is a significant factor of ~1.3 for the ratio between the maximum (100%) hourly average PC of ~156 µg m^{-3} and the hourly average AQS objective value of 200 µg m^{-3}, assuming emissions occur throughout that hour at the half hourly average IED ELV (400 mg Nm^{-3}). The corresponding factor for the annual average is ~8, which reduces to ~3 when the

PEC value is taken into account. Nevertheless, the predicted PEC is ~35% of the annual AQS for NO_2, which indicates that there is little risk of exceeding the health-based AQS for NO_2.

2.2.8 When the COMEAP methodology is applied to the data for NO_2, the estimated increase in respiratory re-admissions to hospital per year could increase by ~0.3%, which is considered to be low. However, this is based upon the maximum Process Contribution, which occurs ~350 metres to the north-east of the chimneys associated with the Enviroparks facility, where few people are likely to be exposed to emissions for extended periods.

2.2.9 At Receptor No. 3, the location of the nearby residential property at Penderyn Reservoir, ~500 metres to the north-east of the chimneys associated with the Enviroparks facility, the annual average NO_2 Process Contribution was predicted to be ~2.6 µg m^{-3}, with an associated ~0.1% potential increase in hospital re-admissions due to respiratory complaints.

2.2.10 Maximum hourly average NO_2 PEC values, based upon the half hourly IED ELV of 400 mg Nm^{-3} are likely to be about 130 µg m^{-3}, or about 65% of the hourly average AQS. This corresponds to an air quality description in the "Low Band", with an Air Quality Index of 2, with the associated advice for health for "at-risk individuals" (Adults and children with heart or lung problems are at greater risk of symptoms.) "*Enjoy your usual outdoor activities*"[2].

2.3 Sulphur Dioxide (SO_2)

2.3.1 The potential impact on human health of SO_2, arising from emissions from the three chimneys associated with the Enviroparks facility, has been considered in relation to both the hourly peak (100% hourly average, based upon the half hourly IED ELV of 200 mg Nm^{-3}) and annual predictions.

Table 3 Relationship Between Model Predictions for SO_2 and AQS Values

Maximum PC	Existing Background Concentration	AQS	Ratio of AQS/EAL to PC
~140 µg m^{-3}	-	350 µg m^{-3}	~2.5
~1.2 µg m^{-3}	1.9	20 µg m^{-3}	~17(6.5)

2.3.2 As can be seen, there is a significant factor of ~2.5 for the ratio between the maximum (100%) hourly average PC of ~140 µg m^{-3} (based upon the maximum Process Contribution and the half hourly average IED ELV of 200 mg Nm^{-3}), and the hourly average AQS of 350 µg m^{-3}, and the corresponding factor for the annual average is ~17, which indicates that there is little risk of exceeding the health-based AQS for SO_2.

2.3.3 When the COMEAP methodology is applied to the data for SO_2, and based upon the worst case maximum Process Contribution value, the estimated increase in respiratory re-admissions to hospital per year could increase by 0.06%, and can probably be discounted as insignificant. As noted above, this relates to the location of maximum Process Contribution, which is within ~350 metres of the chimneys associated with the Enviroparks facility.

[2] http://uk-air.defra.gov.uk/air-pollution/daqi

2.3.4 At Receptor No. 3, the location of the nearby residential property at Penderyn Reservoir, ~500 metres to the north-east, the annual average SO_2 Process Contribution was predicted to be ~0.6 µg m^{-3}, with an associated 0.03% potential increase in hospital re-admissions due to respiratory complaints.

2.3.5 Maximum 15 minute average SO_2 PC values in the Hirwaun area are likely to be about 150 µg m^{-3}, or about 39% of the AQS objective value. This corresponds to an air quality description in the "Low Band", with an Air Quality Index of 2, with the associated advice for health for at-risk individuals "*Enjoy your usual outdoor activities*".

2.3.6 The magnitude of the number of predicted additional re-admissions to hospital per year due to respiratory complains associated with increased background concentrations of SO_2 due to emissions from the chimneys of the Enviroparks facility is small, and can probably be screened out as insignificant.

2.4 Particulates

2.4.1 The potential impact on human health of particulates, arising from emissions from the chimneys associated with the Enviroparks facility, has been considered in relation to both the daily peak (100% hourly average, based upon the half hourly IED ELV of 30 mg Nm^{-3}) and annual predictions.

Table 4 Relationship Between Model Predictions for PM_{10} and AQS Values

Maximum PC	Existing Background Concentration	AQS	Ratio of AQS/EAL to PC
~18 µg m^{-3} (Hourly)	-	50 µg m^{-3}	~2.8
~0.2 µg m^{-3}	13.2	40 µg m^{-3}	~200 (~3.0)

2.4.2 As can be seen, there is a significant factor for the ratio of ~2.8 between the maximum (100%) hourly average PC of ~18 µg m^{-3}, based upon the half hourly IED ELV of 30 mg Nm^{-3}, and the daily average AQS of 50 µg m^{-3}, and the corresponding factor for the annual average is ~200, which falls to about 3.0 when the existing background concentration is taken into account, indicating that there is little risk of exceeding the health-based AQS for PM_{10}. It should be noted that the AQS applies to PM_{10} whereas the emissions from the chimneys of the Enviroparks facility are based upon total particulate emission. Therefore, the assessment may overestimate the significance of particulate emissions from the Enviroparks facility.

2.4.3 When the COMEAP methodology is applied to the data for particulates as PM_{10}, and based upon the worst case maximum Process Contribution value, the estimated number of respiratory re-admissions to hospital due to respiratory complaints could increase by 0.01%.

2.4.4 At Receptor No. 3, the location of the residential property at Penderyn Reservoir, ~500 metres to the north-east of the Enviroparks facility chimney, the annual average PM_{10} Process Contribution was predicted to be ~0.09 µg m^{-3}, with an associated 0.007% increase in hospital re-admissions due to respiratory complaints.

2.4.5 The magnitude of the number of predicted additional re-admissions to hospital per year due to respiratory complains associated with increased background concentrations of PM_{10} due to emissions from the chimneys of the Enviroparks facility is very small, and can probably be screened out as insignificant.

2.5 Hydrogen Chloride (HCl)

2.5.1 The health effects associated with exposure to hydrogen chloride are primarily acute impacts on the respiratory system, accordingly, the assessment is based upon the short term modelling predictions. The maximum hourly PC for hydrogen chloride is ~41 µg m^{-3}, based upon the half hourly average IED ELV of 60 mg Nm^{-3}, which gives a factor of ~18, for the ratio of the PC to the short term EAL[3] of 750 µg m^{-3}. Consequently no significant effects on the health of the community are expected as a result of the emission of HCl from the chimneys of the Enviroparks facility.

2.6 Hydrogen Fluoride (HF)

2.6.1 The health effects associated with exposure to hydrogen fluoride are primarily acute impacts on the respiratory system, accordingly, the assessment is based upon the short term modelling predictions. The maximum hourly PC for hydrogen fluoride is ~2.9 µg m^{-3}, based upon the half hourly average IED ELV of 4 mg Nm^{-3}, which gives a factor of ~56 for the ratio of the PC to the short term EAL of 160 µg m^{-3}. Consequently no significant effects on the health of the community are expected as a result of the emission of HF from the chimneys of the Enviroparks facility.

[3] https://www.gov.uk/guidance/air-emissions-risk-assessment-for-your-environmental-permit

3. Health Impact Assessment for Pollutants with Chronic Effects

3.1 Introduction

3.1.1 The following assessment relates to those pollutants identified in Section 1.2.1 that are associated with long term chronic health impacts.

3.2 Volatile Organic Compounds (VOCs)

3.2.1 There are no environmental assessment levels for VOCs, therefore to provide a worst case assessment, the PC values for VOCs were compared against the AQS for benzene, which is 5 µg m^{-3} expressed as an annual average. The health effects associated with exposure to benzene in the ambient air are primarily chronic impacts, accordingly, the assessment is based upon the long term modelling predictions. It should also be noted that benzene is likely to comprise a small proportion (probably <5%) of the total VOC emission, and therefore this assessment represents a gross overestimation of the potential impact of VOC emissions on the health of people living nearby.

3.2.2 The maximum annual average PC for VOCs was 0.26 µg m^{-3}, which gives a factor of ~19 for the ratio of the annual PC to the annual AQS for benzene of 5 µg m^{-3}, which indicates that there are unlikely to be any significant long term effects on the health of the community as a result of exposure to emissions of VOCs from the chimneys of the Enviroparks facility.

3.3 Group 3 Metals

3.3.1 A detailed assessment for the significance of Group 3 metal emissions was undertaken in relation to the latest Environment Agency guidance[4]. The IED stipulates emission limits on Group 3 Metals including antimony (Sb), arsenic (As), lead (Pb), chromium (Cr), cobalt (Co), copper (Cu), manganese (Mn), nickel (Ni), and vanadium (V).

3.3.2 The Environment Agency recommends a stepwise approach to assessment of emissions of Group 3 Metals. The guidance is based upon the presumption that the assessment is applicable for Municipal Waste Incineration (MSW) and waste wood co-incineration facilities, which is also presumed to be relevant to the case for the Enviroparks facility.

3.3.3 The first step is based upon the assumption that each of the nine metal species is emitted at the IED emission limit value of 0.5 mg Nm^{-3} for Other Metals. The results from this initial screening assessment are presented below.

[4] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/532474/LIT_7349.pdf

Table 3-1 Maximum Annual Average Process Contribution for Group 3 Metals – Step 1 Screening

Metal	Exceedence Threshold (μg m^{-3})	Process Contribution (μg m^{-3})	PC as %AQS/EAL
Antimony	5	1.27E-02	0.3%
Arsenic	0.003	1.27E-02	423%
Chromium$^{(VI)}$	0.0002	1.27E-02	6350%
Cobalt	0.2*	1.27E-02	*6.4%*
Copper	10	1.27E-02	0.1%
Lead	0.25	1.27E-02	5%
Manganese	150	1.27E-02	8%
Nickel	0.02	1.27E-02	64%
Vanadium	5	1.27E-02	*0.06%*

3.3.4 As can be seen, emissions of Arsenic, Chromium$^{(VI)}$, Cobalt, Lead, Manganese and Nickel are identified as being potentially significant (PC is >1% of the AQS or EAL) by this initial screening assessment (values highlighted in red). It should be noted that the assessment assumes that all of the chromium present in the emissions to atmosphere is present as Chromium$^{(VI)}$, therefore representing an absolute worst case basis for assessment.

3.3.5 Environment Agency guidance recommends that a second stage screening assessment should be carried out for those metals with significant process contributions, and based on measured emissions data from currently operational MSW incineration and waste wood co-incineration plant. On the basis of measurements undertaken at facilities between 2007 and 2015, the Environment Agency published the following emissions data for use as an indicative basis for assessment of the metalloid species whose process contributions were >1% of the long term assessment level.

Table 3-2 Guidance for the Step 2 Assessment of Group 3 Metals

Measurement	Maximum (mg Nm^{-3})	Mean (mg m^{-3})	Minimum (mg m^{-3})
Antimony	0.0115	0.0014	0.0001
Arsenic	0.025	0.001	0.0002
Chromium$^{(VI)}$	1.3×10^{-4}	3.5×10^{-5}	2.3×10^{-6}
Cobalt	0.0056	0.0011	0.0002
Copper	0.029	0.0075	0.0019
Lead	0.0503	0.0109	0.0003
Manganese	0.06	0.0168	0.0015
Nickel	0.22	0.015	0.0025
Vanadium	0.006	0.0004	0.0001
Note: * Based upon concentration in the APC Residues			

3.3.6 In the first instance, the Step 2 screening assessment should be based upon the maximum values in Table 3-2. The maximum concentration values in the above table were used as the initial basis for the Step 2 assessment for those metals with significant process contributions in Step 1, and the results are presented in Table 3-3.

Table 3-3 Maximum Annual Average Process Contribution for Arsenic, Chromium^{VI}, Cobalt, Lead, Manganese and Nickel – Step 2 Screening

Metal	Exceedence Threshold (μg m^{-3})	Process Contribution (μg m^{-3})	PC as %AQS/EAL (%)
Arsenic	0.003	6.35E-04	21.2%
Chromium$^{(VI)}$	0.0002	3.30E-06	1.7%
Cobalt	0.02	1.42E-04	*0.07%*
Lead	0.25	1.27E-03	0.5%

Metal	Exceedence Threshold ($\mu g\ m^{-3}$)	Process Contribution ($\mu g\ m^{-3}$)	PC as %AQS/EAL (%)
Manganese	150	1.52E-03	1.0%
Nickel	0.02	5.59E-03	27.9%

3.3.7 On the basis of Environment Agency Guidance, the Step 2 screening assessment for "Group 3 Metals" based upon the above metalloid species, the values for the annual average Process Contribution for Arsenic, Chromium$^{(VI)}$, Manganese and Nickel are still above the 1% insignificance threshold, and are still considered to be significant by the Step 2 assessment.

3.3.8 When the process contributions for Arsenic, Chromium$^{(VI)}$, Manganese and Nickel were considered in relation to measured background concentrations[5] for Swansea Coedgwilym, ~30km to the west of the Enviroparks facility, the following results were obtained.

Table 3-4 Maximum Annual Average Predicted Environmental Concentrations for Arsenic, Chromium$^{(VI)}$, Manganese and Nickel – Step 2 Screening

Metal	Exceedence Threshold ($\mu g\ m^{-3}$)	PC ($\mu g\ m^{-3}$)	Background ($\mu g\ m^{-3}$)	PEC ($\mu g\ m^{-3}$)	PEC as %AQS (%)
Arsenic	0.003	6.35E-04	5.30E-04	5.66E-04	6%
Chromium$^{(VI)}$	0.0002	6.35E-04	6.71E-06	1.42E-03	21%
Manganese	0.15	1.52E-03	3.10E-03	3.03E-03	3%
Nickel	0.02	5.59E-03	1.26E-02	1.69E-03	91%

3.3.9 As can be seen, the PEC values for Arsenic, Chromium$^{(VI)}$, Manganese and Nickel are all less than 100% of their respective AQS values and in line with Environment Agency guidance can be screened out as **insignificant**.

3.4 Dioxins and Furans

3.4.1 The maximum annual Process Contribution for dioxins and furans associated with emissions from the chimneys of the Enviroparks facility was ~2.4 fg m^{-3}, at the point of maximum Process Contribution, which is ~350 metres to the north-east of the chimneys of the Enviroparks facility. Emissions from the Enviroparks facility are 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.

3.4.2 The maximum daily average PC for dioxins was predicted to be ~16 fg m^{-3}. It should be noted that the emissions profile was based on the long term ELV prescribed for dioxin emissions from incineration plant specified by the Industrial Emissions Directive (0.1 ng Nm^{-3} @ 11% O_2, dry and STP). The Enviroparks facility will operate in compliance with the IED, and dioxin emissions are expected to be substantially below the limit value. The emissions profile is therefore considered to be overly pessimistic, and to result in higher predicted process contributions than are considered likely.

3.4.3 A dioxin health risk assessment was undertaken using the US EPA Human Health Risk Protocol (HHRAP) calculation procedures to estimate intake of dioxins via the dietary and inhalation routes in the vicinity of the Enviroparks development site. The assessment was

[5] https://uk-air.defra.gov.uk/data/non-auto-data?uka_id=UKA00520&network=metals&s=View+Site

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 section.

4. Dioxin Health Risk Assessment

4.1 Introduction

4.1.1 The basis for the dioxin health risk assessment is predictive modelling using the ADMS 5.2 atmospheric dispersion model to estimate likely ground level concentrations and deposition rates for dioxins as a result of emissions to atmosphere from the chimneys associated with the Enviroparks facility. The assessment is based upon the incremental increase in dioxin concentrations due to emissions from the Enviroparks facility, and does not take account of any existing dioxin contamination at the location of the specific receptors. The assessment does, however, take account of ambient dioxin concentrations in the atmosphere using measured data from the TOMPS network of monitoring stations operated by DEFRA[6]. The Enviroparks development site is situated within a predominantly rural location, accordingly, the average dioxin concentration for rural locations was used in the calculations.

4.1.2 GF Environmental Ltd undertook an earlier dioxin health risk assessment for the Enviroparks facility in 2008, and the current assessment takes account of process changes that have occurred in the intervening period, including changes to stack height of the proposed sources, with emissions based upon IED ELVs for waste incineration plant.

4.1.3 The health risk assessment for the Enviroparks facility is based upon the US EPA calculation procedures outlined in the "*Human Health Risk Assessment Protocol (HHRAP) for Hazardous Waste Combustion Facilities, EPA530-R-05-006, September 2005*". There is currently no formal guidance in the UK on the assessment of health risks associated with exposure to emissions from waste management facilities, and in Wales, Natural Resources Wales' Air Quality Modelling and Risk Assessment Team (AQMRAT) approve the use of the US EPA methodology as an alternative.

4.2 Potential Pathways for Exposure

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

- Inhalation;
- Ingestion of soil;
- Consumption of fruit and vegetables;
- Consumption of milk; and,
- Consumption of poultry and eggs; and,
- Drinking water.

4.2.2 Members of the local population are only likely to be exposed to significant effects associated with emissions of dioxins from the Enviroparks facility if:

- They spend significant periods of time at locations where and when emissions from the

[6] http://uk-air.defra.gov.uk/networks/network-info?view=tomps

Enviroparks facility increase the concentration of dioxins above the existing background;
- They consume food grown at locations where emissions from the Enviroparks facility increase the concentration of dioxins above the concentration normally present in food from those locations; and,
- They undertake activities likely to lead to ingestion of soil at locations where emissions from the Enviroparks 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.

4.2.3 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 Enviroparks facility.

4.3 Pathways Relevant to the Enviroparks Facility

Inhalation

4.3.1 People living in the vicinity of the development site may be exposed to marginally higher levels of dioxins as a result of the operation of the Enviroparks facility 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. Reference was also made to the average rural background concentration for dioxins and furans of 4.6 fg/m^3 in 2010, considered to be a worst case basis for assessment, based upon measured data for Hazelrigg, High Muffles, Auchencorth and Weybourne[7].

Ingestion of Soil

4.3.2 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 Enviroparks 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

4.3.3 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 Enviroparks facility.

4.3.4 People who consume fruit and vegetables grown in the vicinity of the Enviroparks 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. The likelihood of individuals obtaining almost all of their fruit and vegetable consumption from gardens or allotments in the vicinity of the

[7] http://uk-air.defra.gov.uk/data/dioxins/Dioxins_and_Furans_2010.xlsx

development site is likely to be low. Nevertheless, dioxin intake via the consumption of fruit and vegetables is included in the assessment as the situation could change in future.

Consumption of Local Dairy Produce

4.3.5 The development site is situated within a predominantly rural area, where the grazing of animals may occur on pasture land in the vicinity of the development site that could be contaminated by deposition of dioxins from the Enviroparks facility. Accordingly, the consumption of locally produced dairy produce has been considered in this assessment.

Consumption of Poultry and Eggs

4.3.6 Free-range poultry may be exposed to dioxins through soil ingested with food picked up from the ground. It is not known if the rearing of free-range poultry occurs to a significant level in the vicinity of the development site. However, a future scenario might see a change in land use that could be used for rearing chickens. Under this scenario, the consumption of chicken meat and eggs could be a realistic exposure pathway in future, and has therefore been considered further in this assessment.

Consumption of Beef and Pork

4.3.7 Consumption of beef and pork reared on land in the vicinity of the development site could be significant potentially. However, as the assessment for the consumption of chicken meat revealed that this dietary pathway represented <1% of the total potential dioxin intake, and that beef and pork consumption was similar to that of chicken, similar conclusions were drawn for beef and pork and no further assessment was carried out.

Breast Milk

4.3.8 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, the dioxin intake via the consumption of cow's milk has been considered and dioxin levels in both milks are likely to be of a similar level. Where an infant is consuming breast milk it is unlikely that it will also be consuming cow's milk, and vice versa, therefore, the assessment for cow's milk is considered to be representative of the situation for the consumption of breast milk, and no further assessment has been carried out.

Drinking Water

4.3.9 The likelihood of contamination of groundwater aquifers occurring due to the deposition of dioxins associated with emissions from the Enviroparks facility is considered highly unlikely given the very low solubility of dioxins in water (0.1 ng $litre^{-1}$)[8]. The Penderyn Reservoir and associated infrastructure of the service reservoir were modelled as specific receptors, and showed that dioxin deposition rates were very low. Given the extremely low solubility of dioxins in water, deposition of dioxins in the area surrounding the reservoir were unlikely to give rise to

[8] US EPA HHRAP Database

significant concentrations in drinking water drawn from the reservoirs. Furthermore, the likelihood of local residents collecting rain water 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.

4.4 Exposure Scenarios

4.4.1 For all of the exposure scenarios, being at the location of exposure for less than 100% of the time, and obtaining less than 100% of the total consumption of relevant food, would reduce proportionately any exposure to potential emissions of dioxins from the Enviroparks facility. Accordingly, the estimates of exposure resulting from this assessment are likely to overestimate considerably, those likely to be experienced by local residents when the Enviroparks facility is operational.

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

General Population Exposure

4.4.3 The area in the immediate vicinity of the development site is predominantly commercial/industrial with agricultural land beyond, and with the nearest downwind residential property ~500 metres to the north-east. Twenty one specific receptors were included in the assessment representing nearby locations where members of the general public may be present for significant periods of time, and locations where food may be grown. People living and working in the vicinity of the development site may be exposed to emissions of dioxins from the Enviroparks facility via the inhalation route, although the facility will not be the only source of airborne dioxins in the wider area.

Exposure by the Consumption of Poultry

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

Exposure via the Consumption of Fruit and Vegetables

4.4.5 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 Enviroparks facility development site.

Exposure via the Consumption of Milk

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

Ingestion of Soil

4.4.7 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 the emissions from the Enviroparks facility.

4.5 Exposure Factors

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

Inhalation Rates

4.5.2 For a 70 kg adult the daily respiration volume was taken as ~20 m^3 day^{-1} which is in line with US EPA recommendations. This corresponds to an average value of ~0.012 m^3 kg^{-1} hr^{-1}. The corresponding value for an infant weighing ~14.5 kg was 5.1 m^3 day^{-1}, or ~0.015 m^3 kg^{-1} hr^{-1}.

Consumption of Eggs and Poultry Meat

4.5.3 Information on the intake of eggs and poultry meat was obtained from the Food Standards Agency website[9] and is summarised in the following table.

Table 5 UK Official Figures for the Consumption of Poultry Products (g/kg/day)

Food Category	UK Adult Mean (g/kg BW/day)	UK Infant Mean (g/kg BW/day)
Poultry Meat	0.81	1.90
Eggs	0.26	0.69

4.5.4 The above figures are based upon the average values for men and women to give an overall average for an adult member of the population. The values relate to the average daily consumption of eggs and chicken meat in terms of g/kg body weight/day, and the values are derived from the "National Diet and Nutrition Survey, Year 1 Report", published in 2010[10], and co-authored by Beverley Bates, Alison Lennox and Gillian Swan of the Food Standards Agency.

4.5.5 The values in Table 5 are the average values for consumption of eggs and chicken by males and females (Table 5.1 of the above report), normalised for daily consumption on the basis of an average adult weighing 70kg, and an average child weighing 14.5kg, in line with the US EPA HHRAP approach. The National Nutrition and Diet Survey covers adults between the ages of 19 and 64, and values for infants were based upon the data for children aged between 4 and 10 years.

4.5.6 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. Accordingly, the majority of poultry meat consumed is likely to have come from sources outside the area, and the assessment is likely to overestimate considerably the potential impact of poultry meat consumption.

[9] http://tna.europarchive.org/20110116113217/http://www.food.gov.uk/science/dietarysurveys/ndnsdocuments/ndns0809year1

[10] National Diet and Nutrition Survey. Headline results from Year 1 of the Rolling Programme (2008/2009). August 2010

Consumption of Fruit and Vegetables

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

Table 6 US EPA HHRAP Estimates for the Consumption of Fruit and Vegetables

Category	Ingestion Rate (kg/kg-day 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

4.5.8 As can be seen the values for the case of the "Farmer" 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, the consumption figures for the "Farmer" were used in the assessment.

Consumption of Milk

4.5.9 Information on the intake of milk was obtained from the Food Standards Agency website and is summarised in the following table.

Table 7 UK Official Figures for the Consumption of Milk (g/kg/day)

Food Category	UK Adult Mean	UK Infant Mean
Whole Milk	0.42	5.24

4.5.10 The above figures are based upon the average values for men and women, including non-consumers, to give an overall average for an adult member of the population. The values relate to the average daily consumption of whole milk in terms of g/kg body weight/day, and the values are derived from the "National Diet and Nutrition Survey", published in 2009. Whole milk has a higher fat content than semi-skimmed or skimmed milk, and therefore provides a worst case basis for assessment.

4.5.11 It has been assumed that all of the milk consumed has been produced on pastures in the vicinity of the Enviroparks facility development site. This will overestimate considerably the potential impact of milk consumption.

Ingestion of Soil

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

Table 8 US EPA HHRAP Estimates for Soil Ingestion

	Adult	Child
Soil Intake Rate (kg day^{-1})	0.0001	0.0002

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

4.6 Emissions Scenario

4.6.1 The Enviroparks facility will be subject to regulation by Natural Resources Wales in line with the emission limit values (ELVs) for dioxins and furans for incineration plant as defined by the EU Industrial Emissions Directive (IED). Atmospheric dispersion modelling was undertaken on the basis of Normal Operation with emissions of dioxins at the 0.1 ng Nm^{-3} ELV specified by the IED, which is the design point and performance guarantee for the proposed technology.

4.6.2 It is expected that when the Enviroparks facility becomes operational, dioxin emissions will be significantly lower than the IED limit, therefore the results from this assessment are likely to overestimate significantly the situation that might be expected when the facility becomes operational.

4.6.3 Exposure via the dietary route was assessed by modelling dioxin deposition in both the gaseous and particulate phases. 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 and poultry products to provide an estimate of dietary intake of dioxins as a result of the operation of the new Enviroparks facility. 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 guidance[11], and the modelling results were adjusted accordingly. The results were compared against the Tolerable Daily Intake (TDI) value of 2 pg kg^{-1} day^{-1} recommended by the UK Committee on Toxicity[12].

4.6.4 The values predicted by modelling represent Process Contributions, but in certain instances also take into account estimated background levels for urban 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.

4.7 Area Covered and Specific Receptors Included in the Assessment

4.7.1 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 Enviroparks facility. Hourly average meteorological data were used in the modelling. The model was also run in dry deposition mode to estimate likely dioxin deposition rates in the vicinity of the development site.

4.8 Results from Detailed Modelling - Concentration Mode

4.8.1 The results from modelling emissions of dioxins from the Enviroparks facility, based upon the IED limit of 0.1 ng Nm^{-3} gave a maximum Process Contribution of ~16 fg m^{-3} (~16 x 10^{-15} g m^{-3}) expressed as a daily average value. The corresponding annual average Process Contribution was ~2.4 fg m^{-3}.

4.9 Deposition Mode

4.9.1 Wet deposition is usually considered to be the most significant mode of deposition close to the

[11] HHRAP Companion Database
[12] Statement On The Tolerable Daily Intake For Dioxins And Dioxin-like Polychlorinated Biphenyls, COT/2001/07, October 2001

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.

4.9.2 The ADMS model was run in deposition mode and the value for total deposition, i.e., the combination of both dry and wet deposition, was obtained by multiplying the dry deposition rate by a factor of three. This is the procedure recommended in recent guidance from the Environment Agency, which is assumed to be still relevant.

> *The value of 3 is a nominal factor to convert dry deposition to total deposition.*
> *Source: Horizontal Guidance Note H1 Annex F, Environment Agency, December 2011*

4.9.3 The results from deposition modelling of emissions from the Enviroparks facility, assuming emissions at the maximum IED ELV of 0.1 ng Nm^{-3}, gave a maximum value for total dioxin deposition at Receptor 3, the nearest downwind residential receptor at Penderyn Reservoir, of ~1.1×10^{-11} μg m^{-2} s^{-1} for dioxins in the gaseous and particulate phases.

4.10 Specific Receptor Locations and Exposure Pathways

4.10.1 Exposure is potentially possible at any location to a greater or lesser degree depending upon its distance from the point of release, and the locations of twenty one specific receptors were included in the modelling study, including residential areas, farms and nearby places of employment. The locations of the specific receptors included in the dioxin deposition modelling study are detailed in Table 9.

Table 9 Specific Receptors Included in Dioxin Deposition Modelling

Receptor No.	Receptor Name	X	Y	Distance from Chimney of the Enviroparks facility (metres)
1	Penderyn Reservoir	293839	207170	351
2	Eden Trading	294020	206800	178
3	House at Penderyn Reservoir	294100	207270	519
4	Ty Newydd Hotel	294600	206940	767
5	Caer Llwyn Cottage	293253	207151	677
6	Rhombic Farm	292958	206712	891
7	Castell Farm	292871	206783	973
8	TY Newydd Cottage	294514	207025	702
9	Residence Woodland Park	294824	207560	1,229
10	Pontbren Llwyd School	295057	208264	1,887
11	Ffynnon Ddu (spring)	292273	208364	2,203
12	Ton-Y-Gilfach	289565	208712	4,678
13	Rose Cottage	291284	208150	2,884
14	The Don Bungalow	291512	207044	2,342
15	Werfa Farm	291944	206721	1,902
16	Willows Farm	294129	205879	983
17	Trebanog Uchaf Farm	294063	207416	636
18	Tai-Cwpla Farm	293519	207024	383
19	Neuadd Farm	294906	207282	1,159
20	John Street Allotments, Hirwaun	296180	205605	2,634
21	Dwr Cymru Service Reservoir	294068	206939	255

4.11 Results and Discussion

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

- Location of the receptor with regard to exposure to emissions from the Enviroparks facility;
- Proportion of time spent by the receptor at locations where dioxin concentrations may increase as a result of emissions from the Enviroparks facility;
- Proportions of the types of food consumed that are produced at locations where dioxin concentrations may increase as a result of emissions from the Enviroparks facility; and
- The emissions scenario.

4.11.2 The results from the dioxin health risk assessment reported here represent the maximum potential incremental increase as a result of emissions from the Enviroparks facility for each of the pathways included, based upon emissions of dioxins at the ELV of 0.1 ng Nm^{-3} specified by the IED, which is the design point and performance guarantee for the proposed technology. When operational, emissions of dioxins from the Enviroparks facility are expected to be significantly lower than the IED ELV, and therefore represent a worst case assessment.

4.11.3 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 Enviroparks facility.

4.12 Exposure via Inhalation

4.12.1 The following equation was used in the calculation of the Maximum Daily Intake due to inhalation of dioxins as a result of exposure to emissions from the Enviroparks facility. The equation is taken from *HMIP Report, "Risk Assessment of Dioxin Releases from Municipal Waste Incineration Processes", 1996*:

Equation 3 Maximum Daily Intake Due to Inhalation

$$\text{Maximum Daily Intake Due to Inhalation} = \frac{((C + B) \times IR)}{BW}$$

where :

$$C = \text{Maximum daily average dioxin concentration (pg/m}^3\text{)}$$
$$B = \text{Estimated background concentration (pg/m}^3\text{)}$$
$$IR = \text{Inhalation Rate (m}^3\text{/day)}$$
$$BW = \text{Body Weight (kg)}$$

4.12.2 The following input data were assumed:

- The estimated background dioxin concentration (B) was taken to be 0.0046 pg m^{-3}. This is the average of the 2010 annual average values for the rural measurement stations (Hazelrigg, High Muffles, Auchencorth and Weybourne) in the TOMPS (Toxic Organic Micropollutants) monitoring stations within the UK network[13]. It is assumed that the data are representative of the situation in the vicinity of the Enviroparks facility development site;

[13] http://uk-air.defra.gov.uk/data/dioxins/Dioxins_and_Furans_2010.xlsx

- The inhalation rate (IR) was 19.92 m^3 day^{-1} for an adult and 5.1 m^3 day^{-1} for an infant (US EPA recommended value);
- Body weight (BW) was taken as 70 kg for an adult and 14.5 kg for an infant (US EPA recommended value).

4.12.3 Using these data, the maximum daily intake of dioxins due to inhalation by adults at the nearest downwind residential receptor (Receptor No. 3), was calculated to be 0.0038 pg kg^{-1} day^{-1}. For infants the corresponding figure was 0.0047 pg kg^{-1} day^{-1}. The Tolerable Daily Intake (TDI) for dioxins is 2 pg kg^{-1} day^{-1}; accordingly the estimated exposure via inhalation for adults and infants represents ~0.2% of the TDI in both cases.

4.13 Potential Increase in Concentration of Dioxins in Soil Due To Emissions from the Enviroparks Facility

4.13.1 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 in dioxin concentration in the soil as a result of deposition due to emissions from the Enviroparks facility.

4.13.2 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 Enviroparks 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 µm represents an appropriate worst case value for assessment of dioxin deposition to soils in the vicinity of the Enviroparks facility. The following deposition rates were predicted at the twenty one specific receptor locations in the vicinity of the development site.

Table 10 Deposition Modelling of Dioxins in the Gaseous and Particulate Phases Based Upon Normal Operating Conditions at the IED ELV of 0.1 ng Nm^{-3}

Receptor Number	Distance from Source (metres)	Total Deposition Rate* (Gaseous & Particulate) (µg m^{-2} s^{-1})	Annual Deposition Rate (ng m^{-2} $annum^{-1}$)
1	351	5.33E-12	0.1680
2	178	2.71E-12	0.0855
3	519	1.14E-11	0.3583
4	767	5.18E-12	0.1632
5	677	2.11E-12	0.0666
6	891	1.63E-12	0.0514
7	973	1.33E-12	0.0421
8	702	8.01E-12	0.2527
9	1,229	5.97E-12	0.1884
10	1,887	3.10E-12	0.0978
11	2,203	4.10E-13	0.0129
12	4,678	2.18E-13	0.0069
13	2,884	4.00E-13	0.0126
14	2,342	4.16E-13	0.0131
15	1,902	5.56E-13	0.0175
16	983	1.15E-12	0.0361
17	636	6.33E-12	0.1995
18	383	2.65E-12	0.0837
19	1,159	5.05E-12	0.1592
20	2,634	7.42E-13	0.0234
21	255	1.72E-11	0.5415

Note: * Total Deposition Rate calculated according to Environment Agency guidance (3 x dry deposition rate)

4.13.3 The above values represent a worst case based upon the ELV of 0.1 ng Nm^{-3} specified by the IED, however, when operational, emissions of dioxins from the Enviroparks facility are expected to be significantly lower than the ELV.

4.13.4 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 0.19 ng $litre^{-1}$ for the solubility in water.

4.13.5 The following assessment is based upon the maximum deposition rate at the location of Receptor No.3 which is the nearest downwind residential receptor at Penderyn Reservoir, in relation to the chimneys of the Enviroparks facility.

4.13.6 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 4 The Increase in Dioxin Concentration in the Soil Due to Deposition

$$Cs = \frac{\left(\frac{Ds \cdot tD - Cs_{tD}}{ks}\right) + \left(\frac{Cs_{tD}}{ks} \cdot \left[1 - exp\left(-ks \cdot \left(T_2 - tD\right)\right)\right]\right)}{\left(T_2 - T_1\right)};$$

$$Cs_{tD} = \frac{Ds \cdot \left[1 - \exp\left(-ks \cdot tD\right)\right]}{ks}; and$$

$$Ds = \frac{100 \cdot Q}{Z_s \cdot BD} \cdot \left[F_v \cdot \left(Dydv + Dywv\right) + \left(Dydp + Dywp\right) \cdot \left(1 - F_v\right)\right]$$

Where:

- Cs = Maximum average incremental increase in soil concentration over exposure duration;
- Cs_{tD} = Soil concentration at time tD - calculated;
- Ds = Deposition Term – mg/kg soil/yr;
- tD = Time period over which deposition occurs – 30 years;
- ks = Dioxin soil loss constant due to all mechanisms – calculated;
- T_2 = Length of exposure duration – 30 years;
- T_1 = 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 m^3;
- F_v = Fraction of dioxin air concentration in the vapour phase – 0.664 (US EPA HHRAP value);
- Dydv = Unitised annual average dry deposition from vapour phase – derived from ADMS output;
- Dywv = Unitised annual average wet deposition from vapour phase – derived from ADMS output;
- Dydp = Unitised annual average dry deposition from particulate phase – derived from ADMS output; and

- Dywp = Unitised annual average dry deposition from particulate phase – derived from ADMS output.

4.13.7 Using the above equations and input parameters, gave a value for the increase in soil dioxin concentration due to deposition of ~0.0035 ng kg^{-1}. This value represents the maximum Process Contribution at Receptor No. 3 based upon Normal Operating Conditions at the IED emissions limit value, and is ~0.07% of the maximum concentration of dioxin in soils in rural locations (~4.7 ng kg^{-1}) reported by the Environment Agency[14]. As discussed earlier, the rural category of land classification is considered to be appropriate for the area surrounding the Enviroparks facility.

4.13.8 The value reported above is based upon the maximum deposition rate at Receptor No. 3 which is the nearest downwind residential receptor, approximately 500 metres to the north-east of the chimneys of the Enviroparks facility, while deposition at specific receptors farther afield is predicted to occur at significantly lower rates as indicated in Table 10. Receptor No.18, Tai Cwpla Farm (which could be residential), is nearer to the site, but is upwind so generally experiences lower Process Contributions.

4.14 Exposure from Dietary Intake of Poultry and Eggs

4.14.1 The potential link between human receptors and the consumption of locally reared poultry meat or eggs is not known, and it is unclear to what extent chickens are reared locally. Nevertheless, the consumption of chickens and eggs could be a potential exposure pathway in the future. This is a foreseeable scenario since there is no requirement for a householder or allotment holder to seek permission to keep chickens or other livestock and to notify the owners of a nearby industrial process if they did. This could be a key pathway for dioxin exposure and as such it is appropriate that it should be investigated.

4.14.2 Accordingly, an assessment for exposure to dioxins has been undertaken for the intake of dioxins via the consumption of eggs and chicken in order to represent a possible future scenario where the rearing of free-range eggs and poultry became significant.

4.14.3 The US EPA Human Health Risk Assessment Protocol (HHRAP) for Hazardous Waste Combustion Facilities methodology was used to assess the potential exposure to dioxins arsing from emissions from the proposed Enviroparks facility. The equation in Table B-3-13 in Appendix B of the HHRAP was used to determine the concentration of dioxins in eggs at locations in the in the vicinity of the Enviroparks facility development, and the equation in Table B-3-14 was used to determine the corresponding concentration of dioxins in poultry meat.

4.14.4 The results presented in the following section relate to the deposition rate at Receptor No.3, the nearest downwind residential receptor at Penderyn Reservoir, approximately 500 metres to the north-east of the chimneys of the Enviroparks facility.

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[14] UK Soil and Herbage Pollutant Survey, UKSHS Report No. 10. The Environment Agency, June 2007

Dioxin Concentration in Eggs

4.14.5 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 Foraging on Contaminated Soil

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

4.14.6 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
- Qp_i = Quantity of grain ingested by chickens – assumed to be 0.2 (US EPA HHRAP)
- 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)
- C_s = Maximum annual average incremental increase in dioxin concentration in soil – estimated by modelling to be 0.0035 ng kg^{-1};
- B_s = Soil bioavailability factor – assumed to be 1.0 (US EPA HHRAP)
- Ba_{egg} = Biotransfer factor for chicken eggs – assumed to be 1.09984 (US EPA HHRAP Database)

4.14.7 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

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

4.14.8 Where:

- P_i = Concentration of dioxin in grain;
- C_s = Annual average increase in dioxin concentration in soil – estimated by modelling to be 0.0035 ng kg^{-1};
- Br_{forage} = Plant-soil bioconcentration factor for grain – assumed to be 0.00455 (US EPA HHRAP Database);

4.14.9 Using the above equations, a value of ~8.8 x 10^{-11} mg kg^{-1} Fresh Weight (FW) basis (~0.09 pg kg^{-1}) was derived for the dioxin concentration in eggs due to the foraging of chickens on soil with an incremental annual average increase in dioxin concentration in the soil of 0.0035 ng kg^{-1}, due to the operation of the Enviroparks facility.

Dioxin Concentration in Chicken Meat

4.14.10 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

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

4.14.11 Where:

- $A_{Chicken}$ = Concentration of dioxin in chicken meat
- F_i = Fraction of grain grown on contaminated soil and ingested by chickens – assumed to be 1.0

- Qp_i = Quantity of grain ingested by chickens – assumed to be 0.2 (US EPA HHRAP)
- P_i = Concentration of dioxin in grain – derived from the equation in Section 4.14.7 above
- Q_s = Quantity of soil ingested by chickens – assumed to be 0.022 kg day^{-1} (US EPA HHRAP)
- C_s = Maximum annual average incremental increase in dioxin concentration in soil – estimated by modelling to be 0.0035 ng kg^{-1};
- B_s = Soil bioavailability factor – assumed to be 1.0 (US EPA HHRAP)
- Ba_{egg} = Biotransfer factor for chicken carcase – assumed to be 1.09984 (US EPA HHRAP Database)

4.14.12 Using the above equations, a value of ~1.5 x 10^{-10} mg kg^{-1} (~0.15 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 Enviroparks facility, of 0.0035 ng kg^{-1}.

Dietary Intake Due to the Combined Consumption of Chicken Meat and Eggs

4.14.13 Data published by the Food Standards Agency gave the following dietary intakes of eggs and chicken for adults and infants in the UK:

Table 11 UK Data on the Consumption of Eggs and Chicken

Food Category	UK Adult Mean (g/kg BW/day)	UK Infant Mean (g/kg BW/day)
Poultry Meat	0.81	1.90
Eggs	0.26	0.69

4.14.14 The above figures are based upon the average values for men and women, and boys and girls, to give an overall average for an adult or infant member of the population. The values relate to the average daily consumption of eggs and chicken meat in terms of g/kg body weight/day, and the values are derived from the “National Diet and Nutrition Survey”, published in 2010.

4.14.15 The values in Table 11 are the average values for consumption of eggs and chicken by males and females (Table 5.1 of the above report), normalised for daily consumption on the basis of an average adult weighing 70kg, and an average child weighing 14.5kg, in line with the US EPA HHRAP approach. The National Nutrition and Diet Survey covers adults between the ages of 19 and 64, and the data for infants relate to children aged between 4 years and 10 years.

4.14.16 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. Accordingly, the majority of poultry meat consumed is likely to have come from sources outside the area, and the assessment is likely to overestimate considerably the potential impact of poultry meat consumption.

4.14.17 When the dietary intake data are combined with the estimated dioxin concentration data for eggs and chicken meat calculated above, the following daily intake values were derived for adults with a body weight of 70 kg, and infants with a body weight of 14.5 kg:

Table 12 Dietary Intake of Dioxins via the Consumption of Eggs and Chicken Reared at the Location of the Maximum Process Contribution

Food Category	UK Adult Mean	UK Infant Mean
	pg day^{-1}	
Chicken	~0.009	~0.004
Eggs	~0.002	~0.001
	Percentage of Tolerable Daily Intake (2 pg kg^{-1})	
Chicken	~0.4%	~0.2%
Eggs	~0.08%	~0.04%

4.14.18 As can be seen in the above table, the estimated daily intake of dioxins due to the consumption of chicken meat, arising from the maximum incremental annual average increase in dioxin concentration in the soil of 0.0035 ng kg^{-1}, represent values that are ~0.4% or less of the Tolerable Daily Intake value of 2 pg kg^{-1} day^{-1}. The values for egg consumption are generally about three or more times lower than those for the consumption of chicken meat, due to the greater amount of chicken meat consumed.

4.14.19 As stated earlier, it is likely that the consumption of chicken meat would be significantly lower under this scenario as the chickens would be required to supply the eggs, and therefore a significant proportion of the chicken meat consumed would very likely be sourced from outside of the area. Furthermore, the assessment is based upon worst case scenario with emissions at the IED ELV of 0.1 ng Nm^{-3}. However, when operational, emissions of dioxins from the Enviroparks facility are expected to be significantly lower than the IED ELV.

4.15 Exposure from Dietary Intake of Milk

4.15.1 The potential link between human receptors 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.

4.15.2 The US EPA Human Health Risk Assessment Protocol (HHRAP) for Hazardous Waste Combustion Facilities methodology was used to assess the potential exposure to dioxins arsing from emissions from the Enviroparks 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 in the vicinity of the Enviroparks facility development.

4.15.3 The results presented in the following section relate to the maximum deposition rate at Receptor No.3, the nearest downwind residential receptor at Penderyn Reservoir, ~500 metres to the north-east of the chimneys of the Enviroparks facility.

Dioxin Concentration in Milk

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

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

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

4.15.5 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)
- P_i = Concentration of dioxin in forage – derived from separate equation below
- Q_s = Quantity of soil ingested by cows – assumed to be 0.04 kg day^{-1} (US EPA HHRAP)
- C_s = Maximum annual average incremental increase in dioxin concentration in soil – estimated by modelling to be 0.0035 ng kg^{-1};
- B_s = Soil bioavailability factor – assumed to be 1.0 (US EPA HHRAP)
- Ba_{milk} = Biotransfer factor for milk – assumed to be 5.499 (US EPA HHRAP Database)

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

Equation 9 The Intake of Dioxin in Forage Due to Increase in Soil Concentration

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

4.15.7 Where:

- P_i = Concentration of dioxin in forage;
- C_s = Annual average increase in dioxin concentration in soil – estimated by modelling to be 0.0035 ng kg^{-1};
- Br_{forage} = Plant-soil bioconcentration factor for forage – assumed to be 0.00455 (US EPA HHRAP Database);

4.15.8 Using the above equations, a value of ~8.9 x 10^{-9} mg kg^{-1} Fresh Weight (FW) basis (~9 pg kg^{-1}) was derived for the dioxin concentration in milk due to the grazing of cows on soil with an incremental annual average increase in dioxin concentration in the soil of 0.0035 ng kg^{-1}, due to the operation of the Enviroparks facility.

Dietary Intake Due to the Consumption of Milk

4.15.9 Data published by the Food Standards Agency gave the following dietary intake of whole milk for adults and infants in the UK:

Table 13 UK Data on the Consumption of Milk

Food Category	UK Adult Mean (g/kg BW/day)	UK Infant Mean (g/kg BW/day)
Whole milk	0.42	5.24

4.15.10 The above figures are based upon the average values for men and women, and boys and girls between the ages of 4 and 10, to give an overall average for an adult or infant member of the population. The values relate to the average daily consumption of whole milk in terms of g/kg body weight/day, and the values are derived from the "National Diet and Nutrition Survey", published in 2010. The value for whole milk was selected because dioxins tend to collect in fats and fatty tissue, and therefore are likely to be more concentrated in whole milk than in semi-skimmed milk, and therefore the results represent a worst case for dioxin intake via milk consumption. Furthermore, the assessment assumes that the milk is produced by cows grazing at a location ~500 metres to the north-east of the chimneys of the Enviroparks facility for the whole of the year, which is unrealistic, and highlights further the fact that the assessment represents a worst case scenario.

4.15.11 The values in Table 13 are the average values for consumption of milk by males and females, and boys and girls between the ages of 4 and 10 (Table 5.1 of the FSA report), normalised for daily consumption on the basis of an average adult weighing 70kg, and an average child weighing 14.5kg, in line with the US EPA HHRAP approach.

4.15.12 When the dietary intake data are combined with the estimated dioxin concentration data for milk calculated above, the following daily intake values were derived for adults with a body weight of 70 kg, and infants with a body weight of 14.5 kg:

Table 14 Dietary Intake of Dioxins via the Consumption of Milk Produced at the Location of Receptor No. 11

Food Category	UK Adult Mean	UK Infant Mean
	pg day^{-1}	
Whole milk	~0.26	~0.67
	Percentage of Tolerable Daily Intake (2 pg kg^{-1})	
Whole milk	~13%	~34%

4.15.13 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 0.0035 ng kg^{-1}, represent values that are ~13% of the Tolerable Daily Intake for adults and ~34% for infants. These values are considerably higher than those for eggs and chicken meat 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, with its higher fat content, and as such the results probably overestimate considerably the significance of dioxin intake via the consumption of milk.

4.15.14 It should also be noted that this assessment is based upon potential dioxin deposition at a location ~500 metres to the north-east of the chimneys of the Enviroparks facility, based upon continuous emissions at the IED ELV for dioxins (0.1 ng Nm^{-3}) for the whole of the year, and for individuals who source all of their milk from animals grazing at this location for the whole of the year. Accordingly, this represents an absolute worst case assessment for the potential impact of emissions of dioxins from the Enviroparks facility on dioxin intake via the consumption of locally produced milk. As stated earlier, when operational, emissions of dioxins from the facility are expected to be significantly lower than the IED ELV.

4.16 Exposure from Dietary Intake Due to Ingestion of Soil

4.16.1 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 Enviroparks facility:

Equation 10 The Intake of Dioxin Due to Ingestion of Soil

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

4.16.2 Where:

- I_{Soil} = Daily intake of dioxin via soil ingestion;
- Cs = Maximum incremental increase in dioxin concentration in the soil due to deposition - estimated by modelling to be 0.0035 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; and,
- BW = Body weight

4.16.3 Using the above equation, a dioxin intake as a result of soil ingestion of ~0.000005 pg kg^{-1} day^{-1} for adults and ~0.00005 pg kg^{-1} day^{-1} for infants, and represents ~0.0002% and ~0.002% respectively of the TDI of 2 pg day^{-1} and are considered to be negligible.

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

4.17.1 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 Enviroparks facility.

4.17.2 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 11 The Intake of Dioxin in Produce Due to Increase in Concentration in the Soil

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

4.17.3 Where:

- I_{ag} = Daily intake of dioxins from the consumption of fruit and vegetables;
- Pd = 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;
- Pv = Aboveground exposed fruit and vegetables concentration due to air-to-plant transfer – calculated using Equation B-2-8 in Appendix B of HHRAP methodology;
- 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;
- 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;
- 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 Pd

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

Equation 12 The Increase in Dioxin Concentration in Aboveground Produce Due to Deposition

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

4.17.5 Where:

- Pd = 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.

4.17.6 Using the above equation, a value of ~1.7 x 10^{-10} mg dioxin per kg Dry Weight was obtained for Pd.

Calculation of Pv

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

Equation 13 The Increase in Dioxin Concentration in Aboveground Produce Due to Air-Plant Transfer

$$Pv = Q \times F_v \times \frac{Cyv \times Bv_{ag} \times Vg_{ag}}{\rho_a}$$

4.17.8 Where:

- Pv = 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;
- Cyv = Unitised annual average atmospheric concentration – ADMS modelling;
- Bv_{ag} = Dioxin air-to-plant Biotransfer factor fro aboveground fruit and vegetables – US EPA HHRAP value = 6.55 x 10^{-4};
- Vg_{ag} = Empirical correction factor for aboveground fruit and vegetables – US EPA HHRAP value = 0.01;
- P_a = Density of air (1,200 g m^{-3}).

4.17.9 Using the above equation, a value of ~4.2 x 10^{-10} mg dioxin per kg Dry Weight was obtained for Pv.

Calculation of Pr_{ag}

4.17.10 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 14 The Increase in Dioxin Concentration in Aboveground Produce Due to Root Intake

$$\mathrm{Pr}_{ag} = Cs \times Br_{ag}$$

4.17.11 Where:

- Pr_{ag} = Concentration of dioxins in aboveground fruit and vegetables due to root intake;
- Cs = 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.

4.17.12 Using the above equation, a value of ~1.6 x 10^{-11} mg dioxin per kg Dry Weight was obtained for Pr_{ag}.

Calculation of Pr_{bg}

4.17.13 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 15 The Increase in Dioxin Concentration in Belowground Produce Due to Deposition

$$\mathrm{Pr}_{bg} = Cs \times Br_{rootveg} \times Vg_{rootveg}$$

4.17.14 Where:

- Pr_{bg} = Concentration of dioxins in belowground fruit and vegetables due to root intake;
- Cs = 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.

4.17.15 Using the above equation, a value of ~3.6 x 10^{-11} mg dioxin per kg Dry Weight was obtained for Pr_{bg}.

Calculation of Dioxin Intake from the Consumption of Fruit and Vegetables

4.17.16 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:

Equation 16 The Daily Intake of Dioxins Due to the Consumption of Fruit & Vegetables

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

4.17.17 Where:

- I_{ag} = Daily intake of dioxins from the consumption of fruit and vegetables;
- Pd = 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 = 1.7 x 10^{-11} mg/kg-day DW;

- Pv = Aboveground exposed fruit and vegetables concentration due to air-to-plant transfer – calculated using Equation B-2-8 in Appendix B of HHRAP methodology = 4.2 x 10^{-10} mg/kg-day 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 = 1.6 x 10^{-11} mg/kg-day 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 = 3.6 x 10^{-11} mg/kg-day DW;
- CR_{ag} = Consumption rate of aboveground fruit and vegetables (US EPA HHRAP Value) = 0.00047 kg/kg-day DW for adults and 0.00113 kg/kg-day DW for children;
- CR_{pp} = Consumption rate of protected aboveground fruit and vegetables (US EPA HHRAP Value) = 0.00064 kg/kg-day DW for adults and 0.00157 kg/kg-day DW for children;
- CR_{bg} = Consumption rate of belowground fruit and vegetables (US EPA HHRAP Value) = 0.00017 kg/kg-day DW for adults and 0.00028 kg/kg-day DW for children;
- F_{ag} = Fraction of fruit and vegetables that is contaminated – assumed to be 1.0

4.17.18 Using the above equation, a value of 0.0003 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 0.0007 pg kg^{-1} dioxin per kg Dry Weight for children.

Combined Dietary Intake via the Consumption of Chicken and Eggs, Milk, Fruit & Vegetables and the Ingestion of Soil

4.17.19 When the results from the above calculation procedures for dietary intake of dioxins are added together with the estimated intake via inhalation, the following results are obtained:

Table 15 Intake of Dioxins at the Location of Receptor No.3

Food Category	UK Adult Mean (pg kg^{-1})	UK Infant Mean (pg kg^{-1})
Chicken	~0.009	~0.004
Eggs	~0.002	~0.001
Whole Milk	~0.26	~0.67
Soil Ingestion	~0.000005	~0.00008
Fruit & Vegetables	~0.0003	~0.0007
Inhalation	~0.004	~0.005
Total	**~0.28**	**~0.68**

Table 16 Intake of Dioxins at the Location of Receptor No.3 as a Percentage of the Tolerable Daily Intake

Food Category	UK Adult Mean	UK Infant Mean
Chicken	~0.4%	~0.2%
Eggs	~0.08%	~0.04%
Whole Milk	~13%	~34%
Soil Ingestion	~0.0002%	~0.002%
Fruit & Veg.	~0.02%	~0.04%
Inhalation	~0.2%	~0.2%
Total	**~14%**	**~34%**

4.17.20 The results presented in Table 15 and Table 16 represent a worst case estimate, based upon dioxin deposition rates due to emissions at the IED ELV (0.1 ng Nm^{-3}), at the location of Receptor No.3, the nearest downwind residential receptor at Penderyn Reservoir, which is ~500 metres to the north-east of the chimneys of the Enviroparks facility. It is also assumed that total dietary intake of eggs, chicken meat, milk, and fruit and vegetables is derived from produce grown at that specific location. Emissions of dioxins when operational are expected to be significantly lower than the IED ELV.

4.17.21 Nevertheless, the results show that the potential impact of dioxin release from the Enviroparks facility on dioxin concentrations in the soil, and on the associated increase in dietary intake through the consumption of eggs, chicken meat, fruit and vegetables, as well as via the ingestion of soil through the working of the land, is likely to be well below the recommended Tolerable Daily Intake of 2 pg kg^{-1} day^{-1}.

4.17.22 When combined with the potential intake of dioxins via inhalation the value for adults represents ~14% of the TDI, with that for infants ~34% of the TDI. It should be noted that the 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.*

4.17.23 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.

4.17.24 It should also be noted that this assessment is based upon a series of pessimistic assumptions, including the fact that potential dioxin deposition is based upon a location ~550 metres from the site; that the cows graze only on grass or feed on forage grown at this location; that emissions of dioxins from the Enviroparks facility are at the IED ELV of 0.1 ng Nm^{-3} for the whole of the year; and that individuals source all of their milk from animals grazing at this location for the whole of the year.

4.17.25 The corresponding values, based upon the maximum process contributions for nearby specific receptors, varied in relation to their distance from the site.

Table 17 Exposure to Dioxins at Specific Receptors in the Vicinity of the Enviroparks Facility

Receptor Number	Receptor Name	Percentage of Tolerable Daily Intake * (Adult)	Percentage of Tolerable Daily Intake * (Infant)
1	Penderyn Reservoir	~11%	~27%
2	Eden Trading	~6%	~15%
3	House at Penderyn Reservoir	~14%	~34%

Receptor Number	Receptor Name	Percentage of Tolerable Daily Intake * (Adult)	Percentage of Tolerable Daily Intake * (Infant)
4	Ty Newydd Hotel	~7%	~17%
5	Caer Llwyn Cottage	~3%	~7%
6	Rhombic Farm	~2%	~6%
7	Castell Farm	~2%	~5%
8	TY Newydd Cottage	~10%	~26%
9	Residence Woodland Park	~7%	~18%
10	Pontbren Llwyd School	~4%	~10%
11	Ffynnon Ddu (spring)	~1%	~1%
12	Ton-Y-Gilfach	~0.4%	~1%
13	Rose Cottage	~1%	~1%
14	The Don Bungalow	~1%	~2%
15	Werfa Farm	~1%	~2%
16	Willows Farm	~2%	~4%
17	Trebanog Uchaf Farm	~8%	~20%
18	Tai-Cwpla Farm	~4%	~9%
19	Neuadd Farm	~7%	~16&
20	John Street Allotments, Hirwaun	~1%	~3%
21	Dwr Cymru Service Reservoir	~21%	~51%

Note: * Based upon Total Deposition Rate calculated according to guidance (3 x dry deposition rate)

4.17.26 The assessment indicates that the risk to the health of the local population due to exposure to dioxins in emissions from the Enviroparks facility is likely to be low in comparison to the recommended Tolerable Daily Intake of 2 pg/kg/yr.

4.17.27 It should be noted also that the above results are based upon dioxin emissions at the ELV of 0.1 ng Nm^{-3} specified by the IED, and that when operational, emissions of dioxins are likely to be significantly lower, with proportionate benefits for lower exposure levels for individuals living in the vicinity of the site.

5. Conclusions

5.1.1 A health impact assessment has been undertaken to assess the risk to the health of people living and working in the vicinity of the Enviroparks facility to be developed on land at Hirwaun in South Wales. Detailed atmospheric dispersion modelling of emissions from the three chimneys associated with the Enviroparks facility was undertaken using the ADMS Version 5.2 model to predict increases in pollutant concentrations at nearby sensitive receptors such as residential properties, farms and other locations where people may congregate for significant periods of time. The assessment involved a comparison of model-predicted process contributions against health-based air quality standards and relevant environmental assessment levels.

5.1.2 Short term acute effects were for NO_2, SO_2 and PM_{10} were assessed in line with COMEAP procedures and showed that increases in background pollutant concentrations at nearby residential properties were low and would not have a significant impact on the health of people living and working nearby. Similar conclusions were drawn for other pollutants with short term, acute effects (HCl, HF and CO). Process contributions for pollutants such as VOCs and heavy metals were also low and their potential health effects screened out as insignificant in relation to health-based air quality standards and relevant EALs recommended by Natural Resources Wales.

5.1.3 The US EPA Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities was used to assess the potential risk to health of people living and working in the vicinity of the Enviroparks facility due to emissions of dioxins and furans. The assessment considered the potential health risks associated with the intake of dioxins due to the consumption of potentially contaminated foodstuffs due to emissions to atmosphere from the three chimneys of the Enviroparks facility. The assumptions used within the assessment are conservative and therefore the study was undertaken on a pessimistic worst case basis.

5.1.4 The assessment indicates that the risk to health of the local population due to exposure to dioxins in emissions from the Enviroparks facility is likely to be low, with exposure levels well below the Tolerable Daily Intake (TDI) of 2 pg/kg, at nearby residential receptor locations.

5.1.5 The results from the assessment show that the predicted risks to the health of people living in the vicinity of the Enviroparks facility are well within limits for the protection of human health defined in current DEFRA, Natural Resources Wales and/or US-EPA guidance.

5.1.6 The conclusions from the assessment are considered reliable on the basis of the worst case approach adopted in the characterisation of dioxin emissions from the Enviroparks facility, the conservatism incorporated into the US-EPA HHRAP calculation procedures, and the series of worst case exposure scenarios considered in the assessment.