GF Environmental Limited

Enviroparks Ltd

Dioxin Health Risk Assessment for the Enviroparks Facility at Hirwaun

November 2008

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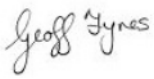
Signature: 

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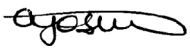
Signature: 

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Executive Summary

The US EPA Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities has been used to assess the potential risk to health of residents living in the locality of the proposed Enviroparks facility near Hirwaun. The assessment considered the potential risk associated with the uptake of dioxins due to emissions from reciprocating engines associated with the proposed development.

The assessment considered the potential risk to health due to inhalation of dioxins. The basis for assessment was Normal Operating Conditions based upon emissions of dioxins at the WID limit of 0.1 ng m^{-3}. The maximum daily dioxin inhalation rate for a 70 kg adult was estimated to be 0.008 pg kg^{-1} day^{-1}, and the corresponding figure for a 14.5 kg infant was estimated to be 0.0109 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 represents ~0.4% of the TDI, while the estimated value for infants is ~0.6% of the TDI. Corresponding values for people living and working in the vicinity of the site were considerably lower in relation to their distance from the chimneys of the Enviroparks facility.

Deposition modelling of emissions of dioxins from the proposed Enviroparks facility showed that the maximum rate of deposition for dioxins when considered in the gaseous phase was ~6.78 x 10^{-12} µg m^{-2} s^{-1}, which corresponds to an annual deposition rate of ~0.21 ng m^{-2} $annum^{-1}$. The corresponding deposition rates for dioxin release in the particulate phase were ~9.90 x 10^{-12} µg m^{-2} s^{-1}, ~2.27 x 10^{-11} µg m^{-2} s^{-1} and ~5.49 x 10^{-10} µg m^{-2} s^{-1} for particles sizes of 0.1 µm, 1 µm and 10 µm. The corresponding annual deposition rates were ~0.31 ng m^{-2} $annum^{-1}$, ~0.72 ng m^{-2} $annum^{-1}$ and ~17.3 ng m^{-2} $annum^{-1}$.

There is a clear indication that if particulate sizes were >10 µm then the associated dioxin deposition rates would increase dramatically. There is little information available on the particle size distribution of emissions from reciprocating engines, however, a reference in the US EPA Emissions Inventory to particulate emissions from natural gas combustion indicates that the majority of particles are likely to be less than 1 um in diameter. The likelihood is that the majority of any dioxins released from the proposed 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 proposed Enviroparks facility.

Using equations from the US EPA HHRAP (Human Health Risk Assessment Protocol), a value was calculated for the incremental annual average increase in dioxin concentrations in soils within the vicinity of the proposed Enviroparks facility. Based upon the dioxin emissions limit in the EC Waste incineration Directive, a value of 0.006 ng kg^{-1} for the increase in concentration due to deposition in the vicinity of the site. The corresponding value at the nearest downwind residential receptors was about one third of the maximum value.

The uptake of dioxins by free-range chickens foraging at the location of maximum deposition predicted by modelling was estimated using the US EPA HHRAP methodology. Estimates of the intake of dioxins by members of the local population deriving all of their dietary requirements for eggs and chicken meat from this location indicate that daily values for adults and children would be well within the Tolerable Daily Intake of 2 pg kg^{-1}.

The estimated daily intake of dioxins arising from the consumption of eggs and chicken meat, based upon the maximum incremental annual average increase in dioxin concentration in the soil due to the operation of the proposed Enviroparks facility, represent values that are between ~0.9% and ~0.6% of the Tolerable Daily Intake for adults and infants respectively.

The estimated daily intake of dioxins arising from the ingestion of soil, based upon the maximum incremental annual average increase in dioxin concentration in the soil due to the operation of the proposed Enviroparks facility, represent values that are <0.001% of the Tolerable Daily Intake.

The estimated daily intake of dioxins arising from the consumption of fruit and vegetables, based upon the maximum incremental annual average increase in dioxin concentration in the soil due to

the operation of the proposed Enviroparks facility, represent values that are between ~0.3 and ~0.7% of the Tolerable Daily Intake for adults and infants respectively.

The results from the assessment indicate that the operation of the proposed Enviroparks facility is likely to have a low impact on the exposure of the surrounding population to dioxins via inhalation and dietary consumption. The worst case intake from this combination of pathways would represent ~1.4% of the TDI of 2 pg kg^{-1} day^{-1} for adults and ~1.2% of the TDI for infants. This value corresponds to the location of maximum Process Contribution which is located ~330 metres to the north-east of the site. Corresponding values predicted for residential receptors and allotment areas in the vicinity of the site were three to four times lower than the maximum value, and decreased rapidly with distance from the site.

The assessment indicates that the risk to health of the local population due to exposure to dioxins in emissions from the reciprocating engines associated with the proposed Enviroparks facility is likely to be low.

1. Introduction

1.1 Introduction

1.1.1 A dioxin health risk assessment has been undertaken to provide information to support the Environmental Impact Assessment that was carried out as part of the planning application for a new integrated waste management facility, to be built by Enviroparks Hirwaun Ltd (Enviroparks). The new facility incorporates a range of waste recovery and recycling operations, with integrated, reciprocating engine-driven, power generation systems that will export electricity to the grid.

1.1.2 This document provides information on potential dioxin exposure as a result of emissions from engine exhausts associated with the Enviroparks facility, in line with the US EPA methodology outlined in the "*Human Health Risk Assessment Protocol (HHRAP) for Hazardous Waste Combustion Facilities, EPA530-R-05-006, September 2005*".

2. Methodology for the Dioxin Health Risk Assessment

2.1 Introduction

2.1.1 The basis for the health risk assessment is predictive modelling using the ADMS Version 4.1 atmospheric dispersion model to estimate likely ground level concentrations and deposition rates for dioxins as a result of emissions from the proposed Enviroparks facility.

2.1.2 The health risk assessment is 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*". 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 England and Wales the Environment Agency's Air Quality Management and Assessment Unit (AQMAU) advise the use of the US EPA methodology as an alternative.

2.2 Potential Pathways for Exposure

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

- Inhalation;
- Ingestion of soil;
- Consumption of fruit and vegetables;
- Consumption of dairy produce;
- Consumption of poultry and eggs; and
- Drinking water.

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

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

2.2.3 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 new Enviroparks facility. The drinking water route is considered to be highly unlikely as very few people are likely to collect and drink rainwater in the Hirwaun area.

2.3 Pathways Relevant to the Enviroparks Facility

Inhalation

2.3.1 People living in close proximity to the Hirwaun 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.

Ingestion of Soil

2.3.2 People working on the land within close proximity to the Hirwaun 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. Dioxin intake via the ingestion of soil is included in the assessment.

Consumption of Fruit and Vegetables

2.3.3 The majority of people purchase their fruit and vegetables from commercial outlets that are likely to resource 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 will not be affected significantly by the operation of the new Enviroparks facility.

2.3.4 People who consume fruit and vegetables grown within the vicinity of the proposed Enviroparks facility may be exposed to marginally higher levels of dioxins as a result of the operation of the process. The likelihood of individuals obtaining almost all of their fruit and vegetable consumption from gardens or allotments 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

2.3.5 There are several farms in the vicinity from the proposed development site, although it is not clear from available satellite imagery whether the land is used predominantly for arable crops or for the grazing of animals. Nevertheless, the likelihood is that the local population obtain the majority of their dairy produce from supermarkets who tend to source their produce from outside of the locality. Accordingly, this aspect of dietary uptake has not been considered in this assessment.

Consumption of Poultry and Eggs

2.3.6 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 proposed 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 chickens and eggs could be a realistic exposure pathway in future, and has therefore been considered further in this assessment.

Drinking Water

2.3.7 Dwr Cymru is the water supplier for the area. 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 their very low solubility. Furthermore, the likelihood of residents collecting rain water for drinking purposes is thought to be low. Accordingly, no further consideration has been given in this report to drinking water as a potential pathway for dioxin intake by people living and working in the vicinity of the Enviroparks facility.

2.3.8 Nevertheless, the accompanying Health Impact report considers the potential increase in the dioxin concentration in the waters of the Penderyn reservoir as a result of deposition from emissions from the Enviroparks facility. The assessment concludes that any potential increase in Dixon concentration is likely to represent a small proportion of the drinking water standard for this group of substances, and therefore unlikely to pose a significant risk to the health of people living taking their water from this source.

2.4 Exposure Scenarios

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

General Population Exposure

2.4.2 The area in the immediate vicinity of the development site is predominantly rural, with the nearest centres of population located ~2km to the north-east and south-east of the site in

Penderyn and Hirwaun. There are also isolated hamlets and farms at various locations within an approximately 5km radius of the site, and several of these were considered as specific receptors in this assessment.

2.4.3 The area covered by the modelling assessment is shown in Figure 1, which also indicates the location of specific receptors included in the assessment. It should be noted that not all of the specific receptors are shown as some are located beyond the range of the available mapping, but were included in the model input paramaters.

Exposure by the Consumption of Poultry

2.4.4 This scenario could apply in the future to those individuals who derive their total consumption of eggs and poultry meat produced within the zone of exposure of the plume from the proposed Enviroparks facility.

Exposure via the Consumption of Fruit and Vegetables

2.4.5 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 development site.

Ingestion of Soil

2.4.6 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 plume of the proposed Enviroparks facility.

2.4.7 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 proposed Enviroparks facility. Accordingly, the estimates of exposure resulting from this assessment are likely to overestimate considerably, those likely to be experienced in reality.

2.5 Exposure Factors

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

Inhalation Rates

2.5.2 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

2.5.3 Information on the intake of eggs and poultry meat was obtained from the Food Standards Agency website[1] and is summarised in the following table.

Table 1 UK Official Figures for the Consumption of Poultry Products (g/kg/day)

Food Category	UK Adult Mean	UK Infant Mean
Poultry Meat	0.84	2.64
Eggs	0.35	1.09

2.5.4 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 National Nutrition and Diet Survey covers adults between the ages of 19 and 64, and it has been assumed that infants may consume about 65% of the amount of food consumed by adults. This may be an overestimation, but provides a basis for a worst case assessment.

[1] http://www.food.gov.uk/science/dietarysurveys/ndnsdocuments/

2.5.5 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.

Consumption of Fruit and Vegetables

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

Table 2 UK Official Figures for the Consumption of Fruit and Vegetables

Food 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

2.5.7 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.

Ingestion of Soil

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

Table 3 US EPA HHRAP Estimates for Soil Ingestion

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

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

2.6 Emissions Scenario

2.6.1 Some of the processes within the proposed Enviroparks facility will be subject to regulation by the Environment Agency under the conditions of the EC Waste Incineration Directive (WID). Therefore, to provide a worst case assessment for the potential impact of emissions from all processes within the facility, atmospheric dispersion modelling was undertaken on the basis of Normal Operation with emissions of dioxins at the 0.1 ng m^{-3} WID limit. It is expected that when the Enviroparks facility becomes operational dioxin emissions will be considerably lower than the WID limit, therefore the results from this assessment probably overestimate significantly the situation that might be expected when the facility becomes operational.

2.6.2 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 uptake of dioxins into the soil, milk, fruit and vegetables and poultry products to provide an estimate of dietary intake of dioxins as a result of the operation of the proposed Enviroparks facility. 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[2].

2.6.3 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

[2] Statement On The Tolerable Daily Intake For Dioxins And Dioxin-like Polychlorinated Biphenyls, COT/2001/07, October 2001

necessary, estimated background values for atmospheric dioxin concentrations have been used as input values for some of the equations in the HHRAP methodology.

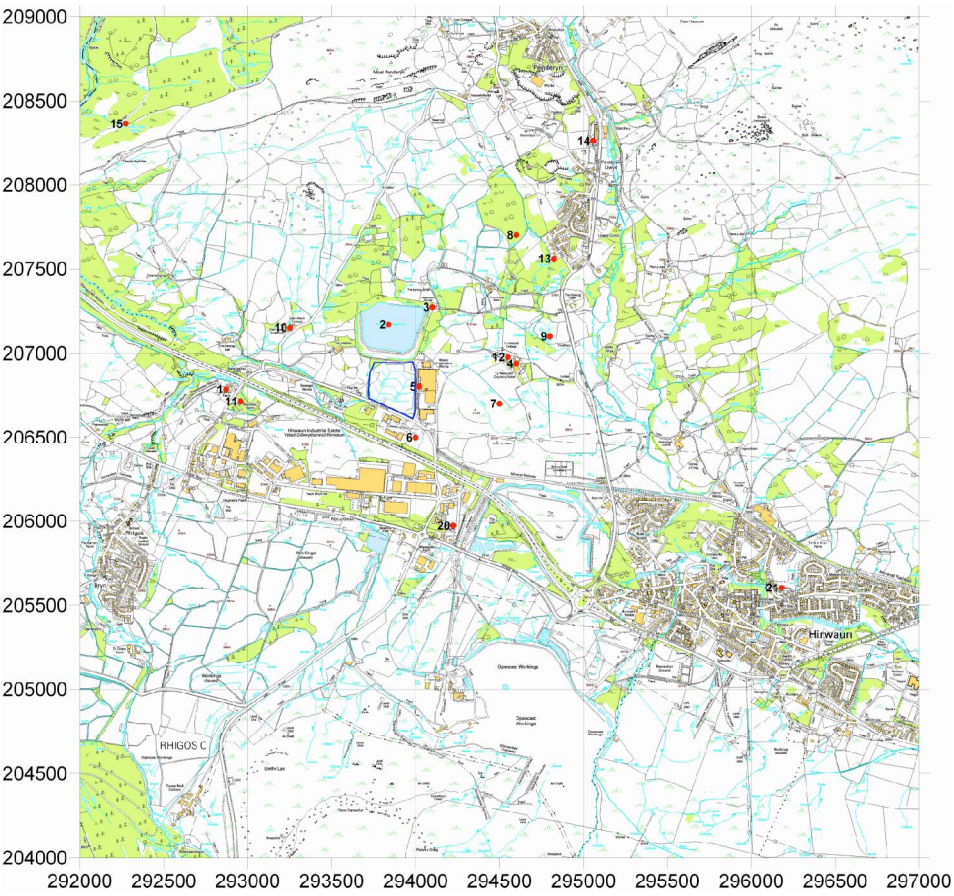
3. Area Covered and Specific Receptors Included in the Assessment

3.1 Introduction

3.1.1 Atmospheric dispersion modelling using ADMS Version 4.1 was undertaken to estimate likely ground level concentrations of dioxins at sensitive receptors arising from emissions from the proposed Enviroparks facility to be built on a site near to Hirwaun. The model was also run in deposition mode to estimate likely dioxin deposition rates in the vicinity of the site.

3.1.2 The location of the proposed Enviroparks facility site within the local area around Hirwaun is shown in Figure 1, and the extent of the development site is indicated by the blue line.

Figure 1 Location of the Proposed Enviroparks Facility at Hirwaun



3.2 Concentration Mode

3.2.1 The results from modelling emissions of dioxins from the proposed Enviroparks facility, based upon the WID limit of 0.1 ng m^{-3}, gave a maximum Process Contribution of ~17 fg m^{-3} (~17 x 10^{-15} g m^{-3}) expressed as a daily average value, and located close to the boundary of the Site. The corresponding annual average Process Contribution was ~2.3 fg m^{-3}.

3.2.2 The nearest downwind sensitive receptor to the development site is the house at Penderyn Reservoir (~500 metres to the north-east), where the maximum Process Contribution was predicted to be ~4 fg m^{-3} expressed as a daily average value, and ~0.3 fg m^{-3} for the annual average Process Contribution. For receptor locations at greater distances from the proposed Enviroparks facility, the associated process contributions were correspondingly lower.

3.3 Deposition Mode

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

3.3.2 The ADMS model was run in deposition mode to derive values for dry deposition across the receptor grid and at the locations of the specific receptors. IPPC Horizontal Guidance Note for Environmental Assessment and Appraisal of BAT (IPPC H1) recommends multiplying the dry deposition value by a factor of 3 to provide an estimate of total deposition, i.e., the combination of both dry and wet deposition.

> *The value of 3 is a nominal factor to convert dry deposition to total deposition.*
> *Source: IPPC Horizontal Guidance Note for Environmental Assessment and Appraisal of BAT*

3.3.3 The results from deposition modelling of emissions from the proposed Enviroparks facility gave a maximum value for dioxin deposition of ~2.3×10^{-12} µg m^{-2} s^{-1} for dioxins in the gaseous phase, with values approximately four times higher for dioxins in the particulate phase. The results showed deposition rates for dioxins decreasing rapidly with distance from the point of release. The corresponding dioxin deposition rate at the house at Pender Reservoir, the nearest sensitive receptor in a downwind direction, was about an order of magnitude lower at ~3.1×10^{-13} µg m^{2} s^{-1} for dioxin deposition in the gaseous phase.

3.4 Specific Receptor Locations and Exposure Pathways

3.4.1 Exposure is potentially possible at all locations to a greater or lesser degree, and the locations shown in Figure 1 were included in the modelling study as specific receptor locations, including residential receptors to the north-east and south-east of the development site as well as schools and farms at various locations in the vicinity of the site.

3.4.2 Twenty specific receptors were modelled associated with potentially sensitive locations where school children may be present for significant periods of the day, as well as residential properties and agricultural premises. The locations of the specific receptors included in the modelling are detailed in Table 3-1.

Table 3-1 Specific Receptors

Name	Receptor Number	X	Y	Distance from Site (m)
Castell Farm	1	292871	206783	970 (SW)
Penderyn Reservoir	2	293839	207170	360 (N)
House at Penderyn Reservoir	3	294100	207270	530 (NE)
Ty Newydd Hotel	4	294600	206940	770 (E)
Cors Bryn y Gaei	7	294500	206700	670 (E)
Caer Llwyn Cottage	10	293253	207151	680 (W)
Rhombic Farm	11	292958	206712	890 W)
Ty Newydd Cottage	12	294549	206979	730 (E)
Residence Woodland Park	13	294824	207560	1,240 (NE)
Pontbren Llwyd School	14	295057	208264	1,900 (NE)
Ffynnon Ddu	15	292273	208364	2,210 (NW)
Ton-y-Gilfach	16	289565	208712	4,680 (NW)
Rose Cottage	17	291284	208150	2,890 (NW)
The Don Bungalow	18	291512	207044	2,340 (W)
Werfa Farm	19	291944	206721	1,900 (W)
Willows Farm	20	294223	205972	920 (SE)
John Street Allotments, Hirwaun	21	296180	205605	2,630 (SE)

4. Results and Discussion

4.1 Introduction

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

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

4.1.2 The results from the dioxin health risk assessment reported here represent the maximum potential increase for each of the pathways included, and therefore represent a worst case based upon emissions of dioxins at the WID limit of 0.1 ng m^{-3}.

4.1.3 Uptake of dioxins was assessed in relation to 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 proposed Enviroparks facility.

4.2 Exposure via Inhalation

4.2.1 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 new Enviroparks facility. The equation is taken from *HMIP Report, "Risk Assessment of Dioxin Releases from Municipal Waste Incineration Processes", 1996*:

Equation 1 Maximum Daily Intake Due to Inhalation

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

where :

C = Maximum daily average dioxin concentration (pg/m^3)

B = Estimated background concentration (pg/m^3)

IR = Inhalation Rate (m^3/day)

BW = Body Weight (kg)

4.2.2 The following input data were assumed:

- The model predicted a maximum daily average ground level dioxin concentration (C) of ~0.02 pg m^{-3}.
- The estimated background dioxin concentration (B) was taken to be 0.014 pg m^{-3}. This is the average of the 2006 annual average values for Urban stations (London, Middlesbrough and Manchester) in the TOMPS (Toxic Organic Micropollutants) monitoring stations within the UK network. It is not known how representative this value is of the situation in Hirwaun as there are no data available for this area, but it is considered to represent the basis for a worst case assessment;
- 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).

4.2.3 Using these data, the maximum daily intake of dioxins due to inhalation by adults was calculated to be 0.009 pg kg^{-1} day^{-1}. For infants the corresponding figure was 0.01 pg kg^{-1} day^{-1}.

4.2.4 The Tolerable Daily Intake (TDI) for dioxins is 2 pg kg^{-1} day^{-1}; accordingly the estimated exposure via inhalation for adults represents ~0.4% of the TDI, while the estimated value for infants is ~0.6% of the TDI.

4.2.5 The corresponding figures for the house at Penderyn Reservoir, the nearest property where individuals might be exposed to emissions from the proposed Enviroparks facility (~530 m to the north of the development site), were 0.005 pg kg^{-1} day^{-1} for adults (~0.2% of TDI) and for infants the corresponding figure was 0.006 pg kg^{-1} day^{-1} (~0.3% of TDI).

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

4.3.1 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 from the emissions associated with the proposed Enviroparks facility.

4.3.2 Deposition modelling of dioxins, as both particles and in the gaseous phase, was carried out using ADMS Version 4.1. The results are summarised in the following table:

Table 2 Model Predictions for Deposition of Dioxins in the Gaseous and Particulate Phases

Form of Dioxin	Maximum Dry Deposition Rate ($\mu g\ m^{-2}\ s^{-1}$)	Maximum Total Deposition Rate (H1 Equivalent) ($\mu g\ m^{-2}\ s^{-1}$)	Annual Total Deposition Rate ($ng\ m^{-2}\ annum^{-1}$)
Gaseous	2.26×10^{-12}	6.78×10^{-12}	0.21
Particulate (0.1 μm)	3.30×10^{-12}	9.90×10^{-12}	0.31
Particulate (1 μm)	7.56×10^{-12}	2.27×10^{-11}	0.72
Particulate (10 μm)	1.83×10^{-10}	5.49×10^{-10}	17.31

4.3.3 As can be seen the particulate deposition rate is significantly higher than the gaseous deposition rate, and increases markedly with particle size.

4.3.4 The above results indicate that coarser particles will result in higher deposition rates, which will also occur closer to the site. There is little information available on the particle size distribution of emissions from reciprocating engines, however, a reference in the US EPA Emissions Inventory to particulate emissions from natural gas combustion[3] indicates that the majority of particles are likely to be less than 1 um in diameter.

4.3.5 The likelihood is that the majority of any dioxins released from the proposed 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 proposed Enviroparks facility.

4.3.6 The maximum deposition rate for dioxins, based on 1 μm particles, would add ~0.7 ng m^{-2} $annum^{-1}$ to the surface of exposed soils in the vicinity of the proposed Enviroparks facility. Therefore, the total deposition due to gaseous and particulate deposition is expected to be ~0.9 ng m^{-2} $annum^{-1}$ at the location of the maximum Process Contribution. The maximum value is predicted to occur close to the site boundary (~330 metres to the north-east of the chimneys) with values decreasing rapidly with distance.

4.3.7 The following deposition rates were predicted at several locations near to the development site, where there is the potential for fruit and vegetables to be grown and where the rearing of poultry could become significant:

[3] http://www.epa.gov/ttn/chief/ap42/ch01/final/c01s04.pdf

Table 3 Deposition Modelling of Dioxins in the Gaseous and Particulate Phases Based Upon Normal Operating Conditions at the WID Emissions Limits

Receptor	Distance from the Chimney (metres)	Total Deposition Rate* (Gaseous & Particulate) ($\mu g\ m^{-2}\ s^{-1}$)	Annual Deposition Rate ($ng\ m^{-2}\ annum^{-1}$)
Maximum Process Contribution	~330 (NE)	2.95×10^{-11}	0.93
Castell Farm	970 (SW)	2.96×10^{-12}	0.09
House at Penderyn Reservoir	530 (NE)	4.96×10^{-12}	0.16
Ty Newydd Hotel	770 (E)	1.53×10^{-11}	0.48
Cors Bryn y Gaei	670 (E)	1.22×10^{-11}	0.38
Caer Llwyn Cottage	680 (W)	3.34×10^{-12}	0.11
Rhombic Farm	890 W)	3.85×10^{-12}	0.12
Ty Newydd Cottage	730 (E)	6.08×10^{-13}	0.02
Residence Woodland Park	1,240 (NE)	3.88×10^{-12}	0.12
Pontbren Llwyd School	1,900 (NE)	1.30×10^{-12}	0.04
Ffynnon Ddu	2,210 (NW)	6.25×10^{-13}	0.02
Ton-y-Gilfach	4,680 (NW)	2.13×10^{-13}	0.01
Rose Cottage	2,890 (NW)	4.67×10^{-13}	0.02
The Don Bungalow	2,340 (W)	8.42×10^{-13}	0.03
Werfa Farm	1,900 (W)	1.33×10^{-12}	0.04
Willows Farm	920 (SE)	5.42×10^{-13}	0.02
John Street Allotments, Hirwaun	2,630 (SE)	1.89×10^{-12}	0.06

Note: * Total Deposition Rate calculated according to IPPC H1 guidance (3 x dry deposition rate)

4.3.8 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.

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

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

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

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

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

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.

4.3.10 Using the above equations and input parameters, gave a value for the increase in soil dioxin concentration due to deposition of ~0.006 ng kg^{-1}. This value represents the case at the location of the maximum deposition rate predicted by ADMS modelling based upon Normal Operating Conditions at the WID emissions limit, and is <0.1% of the maximum concentration of dioxin in soils in rural locations (~17 ng kg^{-1}) reported by DEFRA[4]. The "rural maximum" category of land classification is considered to be appropriate for area in the vicinity of the Enviroparks development site.

4.3.11 The value reported above is based upon the maximum deposition rate which occurs within ~200 metres of the engine exhausts, while deposition at receptors farther afield is predicted to occur at lower rates as indicated in Table 3.

4.3.12 The following assessment of dietary uptake of dioxins is based upon the maximum Process Contribution, and represents the absolute worst case scenario for the area.

4.4 Exposure from Dietary Intake of Poultry and Eggs

4.4.1 The potential link between human receptors and the consumption of locally reared poultry meat or eggs is not known, and it is unclear whether 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 nearby industrial processes if they did. This could be a key pathway for dioxin exposure and as such should be thoroughly investigated.

4.4.2 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.

4.4.3 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.

4.4.4 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 Hirwaun area, and the equation in Table B-3-14 was used to determine the corresponding concentration of dioxins in poultry meat. The results presented in the following section relate to the estimated dioxin deposition rate at the location of the maximum Process Contribution identified by modelling.

[4] Dioxins and dioxin-like PCBs in the UK environment. Consultation Document, DEFRA (2002)

Dioxin Concentration in Eggs

4.4.5 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 3 The Uptake of Dioxin in Eggs Due to Foraging on Contaminated Soil

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

4.4.6 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 0.006 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)

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

Equation 4 The Uptake of Dioxin in Grain Due to Increase in Soil Concentration

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

4.4.8 Where:

- P_i = Concentration of dioxin in grain;
- C_s = Annual average increase in dioxin concentration in soil – estimated by modelling to be 0.006 ng kg^{-1};
- Br_{forage} = Plant-soil bioconcentration factor for grain – assumed to be 0.00455 (US EPA HHRAP Database);

4.4.9 Using the above equations, a value of 1.45 x 10^{-10} mg kg^{-1} Fresh Weight (FW) basis (~0.14 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 0.006 ng kg^{-1}, due to the operation of the proposed Enviroparks facility.

Dioxin Concentration in Chicken Meat

4.4.10 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 5 The Uptake of Dioxin in Chicken Meat Due to Foraging on Contaminated Soil

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

4.4.11 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 4.4.7 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 0.006 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)

4.4.12 Using the above equations, a value of 2.53 x 10^{-10} mg kg^{-1} (~0.25 pg kg^{-1}) of fresh meat was derived for the dioxin concentration in chicken meat due to the foraging for food on soil with an incremental annual average increase in dioxin concentration, due to the operation of the proposed Enviroparks facility, of 0.006 ng kg^{-1}.

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

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

Table 4 UK Data on the Consumption of Eggs and Chicken

Food Category	UK Adult Mean	UK Infant Mean
Poultry Meat	0.84	2.64
Eggs	0.35	1.09

4.4.14 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 National Nutrition and Diet Survey covers adults between the ages of 19 and 64, and it has been assumed that infants may consume about 65% of the amount of food consumed by adults. This may be an overestimation, but provides a basis for a worst case assessment.

4.4.15 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 5 Dietary Uptake of Dioxins via the Consumption of Eggs and Chicken Reared at the House at the Location of the Maximum Process Contribution

Food Category	UK Adult Mean	UK Infant Mean
	pg day^{-1}	
Chicken	0.015	0.010
Eggs	0.0035	0.0023
	Percentage of Tolerable Daily Intake (2 pg kg^{-1})	
Chicken	0.74	0.48
Eggs	0.18	0.11

4.4.16 As can be seen in the above table, the estimated daily intake of dioxins due to the consumption of chicken, arising from the maximum incremental annual average increase in dioxin concentration in the soil of 0.006 ng kg^{-1}, represent values that are between ~0.7% and ~0.5% of the Tolerable Daily Intake value of 2 pg kg^{-1} day^{-1}. The values for egg consumption are generally about four times lower than those for the consumption of chicken meat.

4.4.17 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 resourced from outside of the area.

4.5 Exposure from Dietary Intake Due to Ingestion of Soil

4.5.1 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 proposed Enviroparks development:

Equation 6 The Uptake of Dioxin Due to Ingestion of Soil

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

4.5.2 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 0.006 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

4.5.3 Using the above equation, a dioxin intake as a result of soil ingestion of 0.000008 pg kg^{-1} day^{-1} for adults and 0.00008 pg kg^{-1} day^{-1} for infants was predicted, due to the operation of the proposed Enviroparks facility. These values represent ~0.0004% and ~0.0038% respectively of the TDI of 2 pg day^{-1} and are considered to be negligible.

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

4.6.1 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 proposed Enviroparks facility.

4.6.2 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 7 The Uptake of Dioxin in Produce Due to Increase in Concentration in the Soil

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

4.6.3 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 uptake – 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 uptake – 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

4.6.4 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 8 The Increase in Dioxin Concentration in Aboveground Produce Due to Deposition

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

4.6.5 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;
- Tp = 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.

4.6.6 Using the above equation, a value of 3.44 x 10^{-10} mg dioxin per kg Dry Weight was obtained for Pd.

Calculation of Pv

4.6.7 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 9 The Increase in Dioxin Concentration in Aboveground Produce Due to Air-Plant Transfer

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

4.6.8 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;
- ρ_a = Density of air (1,293 g m^{-3}).

4.6.9 Using the above equation, a value of 7.76 x 10^{-10} mg dioxin per kg Dry Weight was obtained for Pv.

Calculation of Pr_{ag}

4.6.10 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 10 The Increase in Dioxin Concentration in Aboveground Produce Due to Root Uptake

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

4.6.11 Where:

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

4.6.12 Using the above equation, a value of 2.61 x 10^{-11} mg dioxin per kg Dry Weight was obtained for Pr_{ag}.

Calculation of Pr_{bg}

4.6.13 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 11 The Increase in Dioxin Concentration in Belowground Produce Due to Deposition

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

4.6.14 Where:

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

4.6.15 Using the above equation, a value of 5.91 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

4.6.16 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 12 The Daily Intake of Dioxins Due to the Consumption of Fruit & Vegetables

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

4.6.17 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 = 3.44 x 10^{-10} 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 = 7.76 x 10^{-10} mg/kg-day DW;
- Pr_{ag} = Aboveground exposed and protected fruit and vegetables concentration due to root uptake – calculated using Equation B-2-9 in Appendix B of HHRAP methodology = 2.61 x 10^{-11} mg/kg-day DW;
- Pr_{bg} = Belowground exposed and protected fruit and vegetables concentration due to root uptake – calculated using Equation B-2-10 in Appendix B of HHRAP methodology = 5.91 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

4.6.18 Using the above equation, a value of 0.00057 pg kg^{-1} dioxin per kg Dry Weight for adults was obtained for I_{ag}, and a value of 0.00135 pg kg^{-1} dioxin per kg Dry Weight for children.

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

4.6.19 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 6 Uptake of Dioxins at the Location of Maximum Process Contribution

Food Category	UK Adult Mean (pg kg^{-1})	UK Infant Mean (pg kg^{-1})
Chicken	0.015	0.010
Eggs	0.0035	0.0023
Soil Ingestion	0.000008	0.000077
Fruit & Veg.	0.00057	0.00135
Inhalation	0.0088	0.0109
Total	**0.0278**	**0.0243**

Table 7 Uptake of Dioxins at the Location of Maximum Process Contribution as a Percentage of the Tolerable Daily Intake

Food Category	UK Adult Mean	UK Infant Mean
Chicken	0.74	0.48
Eggs	0.18	0.11
Soil Ingestion	0.0004	0.0038
Fruit & Veg.	0.028	0.068
Inhalation	0.44	0.55
Total	**1.39**	**1.22**

4.6.20 The results presented in Table 7 represent a worst case estimate, based upon dioxin deposition rates at the location of the maximum Process Contribution, which is ~330 metres to the north-east of the chimneys of the Enviroparks facility. It is also assumed that total dietary intake of eggs chicken meat and fruit and vegetables is derived from locally-reared produce, which is unlikely.

4.6.21 Nevertheless, the results show that the potential impact of dioxin release from the proposed Enviroparks facility on dioxin concentrations in the soil, and on the associated increase in dietary intake through the consumption of eggs, chicken meat and fruit and vegetables via the ingestion of soil through the working of the land, is likely to be low in terms of the recommended TDI of 2 pg kg^{-1} day^{-1}, and should be regarded as insignificant.

4.6.22 When combined with the potential intake of dioxins via inhalation the highest value for adults represents ~1.4% of the TDI, with that for infants at ~1.2% 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.*

4.6.23 Accordingly, the results from this assessment, which are based upon 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.

4.6.24 The corresponding values for nearby specific receptors were as follows:

Table 8 Exposure to Dioxins at Specific Receptors in the Vicinity of the Proposed Enviroparks Facility at Hirwaun

Receptor	Distance from Chimneys (km)	Percentage of Tolerable Daily Intake * (Adult)	Percentage of Tolerable Daily Intake * (Infant)
Maximum Process Contribution	~330 (NE)	1.39%	1.22%
Castell Farm	970 (SW)	0.40%	0.41%
House at Penderyn Reservoir	530 (NE)	0.50%	0.48%
Ty Newydd Hotel	770 (E)	0.96%	0.82%
Cors Bryn y Gaei	670 (E)	0.46%	0.48%
Caer Llwyn Cottage	680 (W)	0.41%	0.42%
Rhombic Farm	890 W)	0.57%	0.52%
Ty Newydd Cottage	730 (E)	1.01%	0.85%
Residence Woodland Park	1,240 (NE)	0.40%	0.40%
Pontbren Llwyd School	1,900 (NE)	0.27%	0.30%
Ffynnon Ddu	2,210 (NW)	0.24%	0.28%
Ton-y-Gilfach	4,680 (NW)	0.21%	0.26%
Rose Cottage	2,890 (NW)	0.23%	0.27%
The Don Bungalow	2,340 (W)	0.26%	0.30%
Werfa Farm	1,900 (W)	0.29%	0.32%
Willows Farm	920 (SE)	0.25%	0.30%
John Street Allotments, Hirwaun	2,630 (SE)	0.31%	0.34%

Note: * Based upon Total Deposition Rate calculated according to IPPC H1 guidance (3 x dry deposition rate)

4.6.25 The assessment indicates that the risk to the health of the local population due to exposure to dioxins in emissions from the proposed Enviroparks facility is likely to be very low.

5. Conclusions

5.1 Introduction

5.1.1 The US EPA Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities has been used to assess the potential risk to health of residents living in the locality of the proposed Enviroparks facility near Hirwaun. The assessment considered the potential risk associated with the uptake of dioxins due to emissions from reciprocating engines associated with the proposed development.

5.1.2 The assessment considered the potential risk to health due to inhalation of dioxins. The basis for assessment was Normal Operating Conditions based upon emissions of dioxins at the WID limit of 0.1 ng m^{-3}. The maximum daily dioxin inhalation rate for a 70 kg adult was estimated to be 0.008 pg kg^{-1} day^{-1}, and the corresponding figure for a 14.5 kg infant was estimated to be 0.0109 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 represents ~0.4% of the TDI, while the estimated value for infants is ~0.6% of the TDI. Corresponding values for people living and working in the vicinity of the site were considerably lower in relation to their distance from the chimneys of the Enviroparks facility.

5.1.3 Deposition modelling of emissions of dioxins from the proposed Enviroparks facility showed that the maximum rate of deposition for dioxins when considered in the gaseous phase was ~6.78 x 10^{-12} µg m^{-2} s^{-1}, which corresponds to an annual deposition rate of ~0.21 ng m^{-2} $annum^{-1}$. The corresponding deposition rates for dioxin release in the particulate phase were ~9.90 x 10^{-12} µg m^{-2} s^{-1}, ~2.27 x 10^{-11} µg m^{-2} s^{-1} and ~5.49 x 10^{-10} µg m^{-2} s^{-1} for particles sizes of 0.1 µm, 1 µm and 10 µm. The corresponding annual deposition rates were ~0.31 ng m^{-2} $annum^{-1}$, ~0.72 ng m^{-2} $annum^{-1}$ and ~17.3 ng m^{-2} $annum^{-1}$.

5.1.4 There is a clear indication that if particulate sizes were >10 µm then the associated dioxin deposition rates would increase dramatically. There is little information available on the particle size distribution of emissions from reciprocating engines, however, a reference in the US EPA Emissions Inventory to particulate emissions from natural gas combustion indicates that the majority of particles are likely to be less than 1 um in diameter. The likelihood is that the majority of any dioxins released from the proposed 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 proposed Enviroparks facility.

5.1.5 Using equations from the US EPA HHRAP (Human Health Risk Assessment Protocol), a value was calculated for the incremental annual average increase in dioxin concentrations in soils within the vicinity of the proposed Enviroparks facility. Based upon the dioxin emissions limit in the EC Waste incineration Directive, a value of 0.006 ng kg^{-1} for the increase in concentration due to deposition in the vicinity of the site. The corresponding value at the nearest downwind residential receptors was about one third of the maximum value.

5.1.6 The uptake of dioxins by free-range chickens foraging at the location of maximum deposition predicted by modelling was estimated using the US EPA HHRAP methodology. Estimates of the intake of dioxins by members of the local population deriving all of their dietary requirements for eggs and chicken meat from this location indicate that daily values for adults and children would be well within the Tolerable Daily Intake of 2 pg kg^{-1}.

5.1.7 The estimated daily intake of dioxins arising from the consumption of eggs and chicken meat, based upon the maximum incremental annual average increase in dioxin concentration in the soil due to the operation of the proposed Enviroparks facility, represent values that are between ~0.9% and ~0.6% of the Tolerable Daily Intake for adults and infants respectively.

5.1.8 The estimated daily intake of dioxins arising from the ingestion of soil, based upon the maximum incremental annual average increase in dioxin concentration in the soil due to the

operation of the proposed Enviroparks facility, represent values that are <0.001% of the Tolerable Daily Intake.

5.1.9 The estimated daily intake of dioxins arising from the consumption of fruit and vegetables, based upon the maximum incremental annual average increase in dioxin concentration in the soil due to the operation of the proposed Enviroparks facility, represent values that are between ~0.3 and ~0.7% of the Tolerable Daily Intake for adults and infants respectively.

5.1.10 The results from the assessment indicate that the operation of the proposed Enviroparks facility is likely to have a low impact on the exposure of the surrounding population to dioxins via inhalation and dietary consumption. The worst case intake from this combination of pathways would represent ~1.4% of the TDI of 2 pg kg^{-1} day^{-1} for adults and ~1.2% of the TDI for infants. This value corresponds to the location of maximum Process Contribution which is located ~330 metres to the north-east of the site. Corresponding values predicted for residential receptors and allotment areas in the vicinity of the site were three to four times lower than the maximum value, and decreased rapidly with distance from the site.

5.1.11 The assessment indicates that the risk to health of the local population due to exposure to dioxins in emissions from the reciprocating engines associated with the proposed Enviroparks facility is likely to be low.