Environmental Visage

HEALTH IMPACT ASSESSMENT FOR A PROPOSED ENERGY RECOVERY FACILITY, NEAR IRVINE, SCOTLAND

WEP PARTNERS LIMITED
41 DOVER STREET
LONDON
W1S 4NS

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Report Author: [redacted]

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 proposed Energy Recovery Facility (ERF) to be developed by WEP Partners Limited on the Oldhall West Industrial Estate, near Irvine, Scotland. Detailed atmospheric dispersion modelling of emissions from the 60-metre high chimney was undertaken using the ADMS Version 5.2 model to predict increases in pollutant concentrations at nearby sensitive receptors such as residential properties, schools and locations where people may congregate for significant periods of time. The assessment involved a comparison of model-predicted Process Contributions against health-based air quality standards and relevant Environmental Assessment Levels recommended by SEPA.

The modelling showed that increases in background pollutant concentrations of species such as NO_2, SO_2, PM_{10}, HCl, HF and CO at nearby residential properties were low and would not have a significant impact on the health of people living and working nearby. Process Contributions for pollutants such as VOCs and heavy metals were also very low and their potential health effects screened out as insignificant in relation to health-based air quality standards and relevant EALs recommended by SEPA. The exception was when considering Process Contributions of Chromium$^{(VI)}$ which, as detailed in the modelling report, predicted a worst-case Process Contribution of 1.4 % of the EAL, although the point of maximum impact does not occur at any sensitive human health receptor.

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 locality of the proposed ERF due to emissions of Dioxins and Furans, and Dioxin-like PCBs. The assessment considered the potential health risks associated with the intake of Dioxins from the consumption of potentially contaminated foodstuffs due to emissions to atmosphere from the chimney of the proposed ERF. The assumptions used within the assessment are conservative and combined. As such, the study was undertaken on a conservative, worst-case basis.

The assessment indicates that the risk to health of the local population due to exposure to Dioxins in emissions from the facility is likely to be low, typically less than 1 % of the adult Tolerable Daily Intake (TDI) of 2 pg kg^{-1}. The inclusion of Dioxin-like PCBs into the assessment resulted in a marginal increase in the resulting Process Contributions, which remained a very small proportion of the 2 pg kg^{-1} TDI.

The assessment for health risks associated with exposure to emissions of PAH demonstrated that Process Contributions would generally be less than 1 % of the health-based air quality standard of 0.25 ng m^{-3}, and could be screened out as insignificant either at the initial or secondary assessment stage.

In conclusion, the results from the health impact assessment confirm that there is no significant health risk associated with potential exposure to emissions of pollutants from the proposed ERF to be developed by WEP Partners in Oldhall, near Irvine, Scotland.

Contents

Issue and Revision Record

Issue	Date	Author	Review / Authorise	Description
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2	05/04/2019	[redacted]		Version 1
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1. Introduction

WEP Partners Limited (WEP Partners) proposes to develop an Energy Recovery Facility (ERF) to process up to 180,000 tonnes per annum of residual commercial and industrial (C and I) waste and residual municipal solid waste (MSW). The ERF will generate an estimated 15 MW_e of electricity per annum, of which approximately 12 MW_e would be available for export to the National Grid, with the remainder used by the facility itself. The proposed development would also be capable of supplying electricity and heat directly to local businesses or residential areas. The amount of electricity and heat distributed would be determined by potential customers' energy requirements and commercial terms.

Detailed atmospheric dispersion modelling of process emissions from the ERF chimney has been undertaken in support of planning and PPC permit applications for the facility[1]. The objective of the modelling exercise was to assess the potential impact of the process emissions from the ERF on local air quality, in terms of ground level concentrations of pollutants designated by Scottish Air Quality Regulations and other relevant Environmental Assessment Levels (EALs) recommended by the Scottish Environment Protection Agency (SEPA). Modelling was based upon emissions and process data, and site drawings supplied by Fichtner Consulting Engineers Limited who are preparing the permit application, and Castellum Consulting Limited, planning advisors to WEP Partners.

All of the activities associated with the ERF will take place within fully enclosed buildings, minimising the potential for the fugitive release of pollutants from process areas. The principal sources of emissions to atmosphere are those from the waste incineration process with an associated discharge to atmosphere via the 60-metre high chimney.

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 will be no exceedances of any AQS objective value or Environmental Assessment Level. Accordingly, it is expected that the operation of the proposed facility is unlikely to pose a significant risk to the health of the local population living in the surrounding area. However, 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 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 proposed ERF, and should be read in conjunction with the associated air quality assessment report.

1.1 Health Issues Associated with Emissions from the Proposed ERF

The primary source of pollutant emissions from the proposed ERF is the release of flue-gases to atmosphere from the 60-metre high chimney. 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) including Nitrogen Dioxide (NO_2);
- Sulphur Dioxide (SO_2);
- Particulates;
- Carbon Monoxide (CO);
- Hydrogen Chloride (HCl);
- Hydrogen Fluoride (HF).

<u>Chronic Effects</u>

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

The assessment considered the direct health risks associated with the inhalation and consumption of substances released from the chimney of the proposed ERF.

For most of the pollutants considered, the assessment is based upon the incremental increase in background concentration, referred to as the Process Contribution (PC), associated with emissions to atmosphere from the proposed ERF. 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.

The HIA considers the potential impact of emissions of pollutants on the health of local residents living in the vicinity of the proposed ERF.

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

- Comparison with the relevant health-based Scottish Air Quality Standards or Environmental Assessment Levels (EALs) recommended by SEPA;
- The US EPA Human Health Risk Assessment Protocol (HHRAP) for Dioxins, Dioxin-like PCBs and PAH.

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

2. Determining Significance

The descriptive terms for the impact significance of NO_2 and PM_{10} are based on those published in Land Use Planning and Development Control: Planning for Air Quality (2017 Update) prepared by Environmental Protection UK (EPUK) and the Institute of Air Quality Management (IAQM)[2]. Impact description involves expressing the "*magnitude of incremental change as a proportion of a relevant assessment level and then examining this change in the context of the new total concentration and its relationship with the assessment criterion*". The EPUK / IAQM descriptor matrix is shown in the Table below:

Table 1 Definition of Impact Magnitude for Changes in Annual Mean Nitrogen Dioxide and PM_{10} Concentration

Long term average Concentration at receptor in assessment year	% Change in concentration relative to Air Quality Assessment Level (AQAL)			
	1	2-5	6-10	>10
75% or less of AQAL	Negligible	Negligible	Slight	Moderate
76-94% of AQAL	Negligible	Slight	Moderate	Moderate
95-102% of AQAL	Slight	Moderate	Moderate	Substantial
103-109% of AQAL	Moderate	Moderate	Substantial	Substantial
110% or more of AQAL	Moderate	Substantial	Substantial	Substantial

The EPUK / IAQM guidance states that impacts on air quality, whether adverse or beneficial, will have an effect on human health that can be judged as "significant" or "not significant".

The above assessment criteria apply to increases in annual average NO_2 and PM_{10} concentrations due to the operation of the proposed ERF.

2.1 Other Assessment Criteria

SEPA provides guidance[3] for screening the significance of air quality impacts associated with the operation of industrial processes. For long-term impacts, the guidance recommends a 1 % insignificance threshold of Process Contributions relative to a long-term AQS or environmental assessment level, with a corresponding 10 % insignificance threshold for the assessment of short-term Process Contributions.

SEPA goes on to note that modelling of long-term effects may be appropriate if the long-term PEC is above 70 % of the relevant environmental benchmark (EQS or EAL), and the modelling of short-term effects may be appropriate if the short-term PC is more than 20 % of the difference between the (long-term) background concentration and the relevant short term environmental benchmark. However, the guidance goes on to note that, the detailed assessment of short-term effects is often complex and the error in estimating short-term releases can be a factor of 4 to 5. Therefore, a pragmatic approach is suggested that unless the short-term PC exceeds 30 % of the short term EAL then the emissions may be considered to be tolerable and detailed modelling may not be needed.

This report details the assessment of comprehensive modelling undertaken for the proposed Oldhall ERF development. The significance or otherwise of the results are therefore assessed using a two-stage approach, whereby:

- a long-term PC of less than 1 % of the assessment level, or a PEC of less than 70 % of the assessment level is screened as insignificant; and
- a short-term PC of less than 10 % of the assessment level, or a PC of less than 20 % of the assessment level minus the long-term background is screened as insignificant.

3. Health Impact Assessment for Pollutants with Acute Effects

3.1 Introduction

The following assessment relates to those pollutants identified in Section 1.2 that are associated with short-term acute health impacts.

3.2 Nitrogen Dioxide (NO_2)

The potential impact on human health of NO_2, arising from emissions of NO_X from the proposed ERF, has been considered in relation to both the hourly peak and annual predictions.

Table 2 Relationship Between Model Predictions for NO_2 and AQS Values

Averaging Period	Maximum PC (100 %)	Existing Background Concentration	AQS	Insignificance Threshold - PC (PEC)
Hourly	48.34 µg m^{-3}	14.24 µg m^{-3} (2 x the annual average)	200 µg m^{-3}	> 10 % and > 20% of (AQS – LT Background)
Annual	2.22 µg m^{-3}	7.12 µg m^{-3}	40 µg m^{-3}	> 1% (< 70%)

As can be seen, the maximum (100 %) hourly average PC of approximately 48 µg m^{-3} is about 24 % of the hourly average health-based AQS of 200 µg m^{-3}, and cannot therefore be screened as insignificant in relation to the either the first or second stage screening of SEPA guidance. It should be noted however, that the hourly average AQS objective is based upon the 99.79th percentile value (18 permissible exceedances per year) and therefore, consideration of the 100th percentile value represents a worst-case basis for assessment. Assessment of the maximum 99.79th percentile value (approximately 14 µg m^{-3}) would be screened as insignificant at the first assessment stage.

The annual average Process Contribution of about 2 µg m^{-3} is above SEPA's 1 % insignificance threshold, although the resulting PEC value of 9.3 µg m^{-3} is well within the 70 % insignificance threshold and can therefore be screened out as insignificant.

At Receptor No.1, representing one of the nearest downwind residential properties to the site, being 1.33 km to the east, and experiencing the highest reported annual average contributions of each of the receptors, the annual Process Contribution was predicted to be 0.46 µg m^{-3}, which represents a value equivalent to about 1.2 % of the health-based AQS objective, and can be considered **negligible** in relation to EPUK / IAQM assessment criteria. The maximum (100 %) hourly average NO_2 PC at Receptor No.1 (4.41 µg m^{-3}) would also be screened as insignificant, equating to approximately 2.2 % of the short-term assessment level.

3.3 Sulphur Dioxide (SO_2)

The potential impact on human health of SO_2, arising from emissions from the ERF, has been considered in relation to both the hourly peak and annual predictions.

Table 3 Relationship Between Model Predictions for SO_2 and AQS Values

Averaging Period	Maximum PC (100 %)	Existing Background Concentration	AQS	Insignificance Threshold - PC (PEC)
Hourly	24.2 µg m^{-3}	4.44 µg m^{-3} (2 x the annual average)	350 µg m^{-3}	< 10 % and < 20% of (AQS – LT Background)
Annual	0.55 µg m^{-3}	2.22 µg m^{-3}	20 µg m^{-3}	> 1% (< 70%)

As can be seen, the maximum (100 %) hourly average PC of approximately 24 µg m^{-3} is less than 10 % of the hourly average health-based AQS of 350 µg m^{-3}, and can be screened as insignificant in relation to SEPA guidance. It should be noted that the hourly average AQS objective is based upon the 99.73rd percentile value (24 permissible exceedences per year), therefore, consideration of the 100th percentile value represents a worst-case basis for assessment.

The corresponding annual average PC is about 2.8 % of the AQS objective value and cannot be screened out as insignificant in relation to the first stage screening in the SEPA guidance. However, when considered in relation to the annual average background[4] of 2.22 µg m^{-3}, the resulting PEC value is approximately 14 % of the assessment level and is therefore well below SEPA's 70 % insignificance threshold.

At Receptor No.1, the annual average Process Contribution was predicted to be about 0.114 µg m^{-3}, which represents a value equivalent to about 0.6 % of the AQS objective value, and should not have a significant impact on the health of local residents.

3.4 Particulates

The potential impact on human health, of particulates arising from emissions from the single chimney of the proposed ERF, has been considered in relation to both the daily peak and annual predictions.

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

Averaging Period	Maximum PC (100 %)	Existing Background Concentration	AQS	Insignificance Threshold - PC (PEC)
Daily	1.15 µg m^{-3}	15.8 µg m^{-3} (2 x the annual average)	50 µg m^{-3}	< 10 % and < 20% of (AQS – LT Background)
Annual	0.093 µg m^{-3}	7.9 µg m^{-3}	18µg m^{-3}	< 1% (< 70%)

The maximum (100 %) daily average Process Contribution of approximately 1.15 µg m^{-3} is less than 10 % of the daily average health-based AQS of 50 µg m^{-3}, and can be screened out as insignificant in relation to SEPA guidance. Additionally, the corresponding annual average PC of 0.093 µg m^{-3} is less than 1 % of the AQS objective value and can also be considered insignificant in relation to SEPA guidance. Contributions can be considered **negligible** in relation to EPUK / IAQM assessment criteria.

It should be noted that the hourly average AQS objective is based upon the 98.08th percentile value (7 permissible exceedences per year) and therefore, consideration of the 100th percentile value represents a worst-case basis for assessment. It should also be noted that the AQS applies to PM_{10} whereas the emissions from the proposed ERF are based upon total particulate emissions. Therefore, the assessment may over-estimate the significance of particulate emissions.

At Receptor No.1, the annual average Process Contribution for PM_{10} was predicted to be approximately 0.02 µg m^{-3}, which represents a value equivalent to about 0.1 % of the Scottish AQS objective value, and should not have a significant impact on the health of local residents.

3.5 Hydrogen Chloride (HCl)

The health effects associated with exposure to Hydrogen Chloride are primarily acute impacts on the respiratory system and accordingly, the assessment is based upon the short-term modelling predictions.

The maximum hourly PC for Hydrogen Chloride, approximately 4.8 µg m^{-3}, is less than 10 % of the short-term EAL of 750 µg m^{-3}, and can be screened out as insignificant in relation to SEPA guidance. Consequently, no significant effects on the health of the nearby residents are expected as a result of the emission of HCl from the proposed ERF.

3.6 Hydrogen Fluoride (HF)

The health effects associated with exposure to Hydrogen Fluoride are primarily acute impacts on the respiratory system and accordingly, the assessment is based upon the short-term modelling predictions.

The maximum hourly PC for Hydrogen Fluoride is approximately 0.81 µg m^{-3}, which is less 10 % of the short-term EAL of 160 µg m^{-3}, and can be screened out as insignificant in relation to SEPA guidance. The corresponding annual average PC is also less than 1 % of the long-term EAL and can be considered insignificant in relation to SEPA guidance. Consequently, no significant effects on the health of the local community are expected as a result of the emission of HF from the proposed ERF.

4. Health Impact Assessment for Pollutants with Chronic Effects

4.1 Introduction

The following assessment relates to those pollutants identified in Section 1.1 that are associated with long-term chronic health impacts.

4.2 Volatile Organic Compounds (VOCs)

There are no Environmental Assessment Levels for total VOCs, and therefore, to provide a conservative assessment, the PC values for VOCs were compared against the Scottish AQS for Benzene, which is 3.25 µg m^{-3} expressed as an annual average. The health effects associated with exposure to Benzene in the ambient air are primarily chronic impacts and so 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 less than 5 %) of the total VOC emission, and therefore this assessment represents a gross over-estimation of the true impact of VOC emissions.

The maximum annual average PC for VOCs was 0.185 µg m^{-3}, which is approximately 5.7 % of the annual AQS for Benzene. In view of the low proportion of Benzene which could be expected in the total VOC emission, there are unlikely therefore, to be any significant effects on the health of the community as a result of exposure to emissions of VOCs from the ERF.

4.3 Group 3 Metals

A detailed assessment for the significance of Group 3 Metal emissions was undertaken in relation to Environment Agency guidance[5], which is presumed to be acceptable to SEPA. The results are presented in Section 4.14 of the detailed atmospheric dispersion model prepared in conjunction with this health impact assessment, and demonstrated that emissions of heavy metals from the proposed ERF could generally be screened out as insignificant in relation to relevant Air Quality Standards and Environmental Assessment Levels specified for the protection of human health. The one exception was the Process Contribution of Chromium$^{(VI)}$ which, when considering a worst-case species-specific assessment, predicted a Process Contribution of 1.4 % of the EAL at the maximum point across the modelled grid. Whilst not screened as insignificant, this contribution does not occur at a sensitive human health receptor and remains very low.

4.4 Dioxins and Furans

The maximum annual PC for Dioxins associated with emissions from the proposed ERF was approximately 0.7 fg m^{-3}, at the point of maximum Process Contribution, which occurs about 290 metres to the north-east of the chimney of the ERF. The maximum daily average PC for Dioxins was predicted to be about 9.1 fg m^{-3}. Emissions from the facility are therefore not expected to significantly increase the airborne concentrations or deposition rate of Dioxins and Furans over what may be currently experienced in the vicinity of the development site.

In the absence of any Air Quality Standards or Environmental Assessment Levels, Section 5 of this report presents a full health risk assessment of emissions of Dioxins from the ERF.

5. Dioxin Health Risk Assessment

5.1 Introduction

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

The basis for the Dioxin health risk assessment is predictive modelling using the ADMS atmospheric dispersion model to estimate likely ground level concentrations and deposition rates for Dioxins as a result of emissions to atmosphere from the proposed ERF. The assessment is based upon the incremental increase in Dioxin concentrations due to emissions from the chimney of the facility and does not take account of any existing Dioxin contamination at the location of the specific receptors. The assessment does, however, consider ambient Dioxin levels in the atmosphere using measured data from the TOMPS network of monitoring stations operated by DEFRA[6].

The location of the proposed ERF is within a predominantly industrial / commercial area to the south-east of Irvine, with the majority of the surrounding land dedicated to a mixture of industrial and commercial use, and with farmland and residential properties farther afield. Accordingly, the average Dioxin concentration for urban locations was used in the calculations.

5.2 Potential Pathways for Exposure

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

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

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

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

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

5.3 Pathways Relevant to the Proposed ERF

Inhalation

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 proposed ERF for the proportion of the time that they spend there.

Accordingly, this pathway is considered relevant to the current assessment, and the default values recommended by the US EPA were used as the basis for assessment.

Ingestion of Soil

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

Consumption of Fruit and Vegetables

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

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

Consumption of Local Dairy Produce

The development site is located in a mixed use area, and there is limited potential for grazing animals to forage on pasture land in the vicinity of the development site that could be contaminated by Dioxins deposited from the proposed ERF. Nevertheless, to provide a worst-case basis for assessment the consumption of locally sourced dairy produce has been considered in this assessment.

A separate assessment is made of the potential for infants up to 1-year old to be exposed to Dioxins through the consumption of breast milk. The consumption of breast milk by infants may be a potentially significant pathway for the dietary intake of Dioxins due to absorption from contaminated foodstuffs by the mother’s lactate system. However, where an infant is consuming breast milk it is unlikely that it will also be consuming cow’s milk or other significant food stuffs. As such, the assessment for potential exposure to Dioxins via breast milk is reported as a sub-section of Section 5.12.

Consumption of Meat and Eggs

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

Drinking Water

The likelihood of contamination of groundwater aquifers occurring due to the deposition of Dioxins associated with emissions from the facility is considered highly unlikely given the very low solubility of Dioxins in water. Furthermore, the likelihood of local residents collecting 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.

5.4 Exposure Scenarios

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

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

General Population Exposure

Land use in the immediate vicinity of the development site area is predominantly industrial / commercial with a major pharmaceutical manufacturing facility to the east, and a large paper mill to the south of the site. The residential outskirts of Irvine are approximately 1.5 km to the north and north-west, while about 2 km to the west is the Irish Sea, and to the east are extensive areas of farmland, with the town of Kilmarnock about 15 km east of the site.

Seven specific receptors were included in the Dioxin health risk assessment representing nearby locations, within approximately 3 km of the site, where members of the general public may be present for significant periods of time. People living and working in the vicinity of the development site may be exposed to emissions of Dioxins from the facility via the inhalation route, although the proposed ERF will not be the only source of airborne Dioxins in the wider area.

The area covered by the modelling assessment is shown in Figure 1 over page, which also shows the location of the specific receptors included in the assessment, these being Receptor No's. 1 – 3 and 6 – 9 from the Air Quality Assessment.

Ingestion of Soil

This scenario could apply to workers on nearby agricultural land and local residents working in their gardens or allotments, who may be exposed to soil that could be contaminated by Dioxins deposited from the emissions from the proposed ERF.

Exposure via the Consumption of Fruit and Vegetables

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

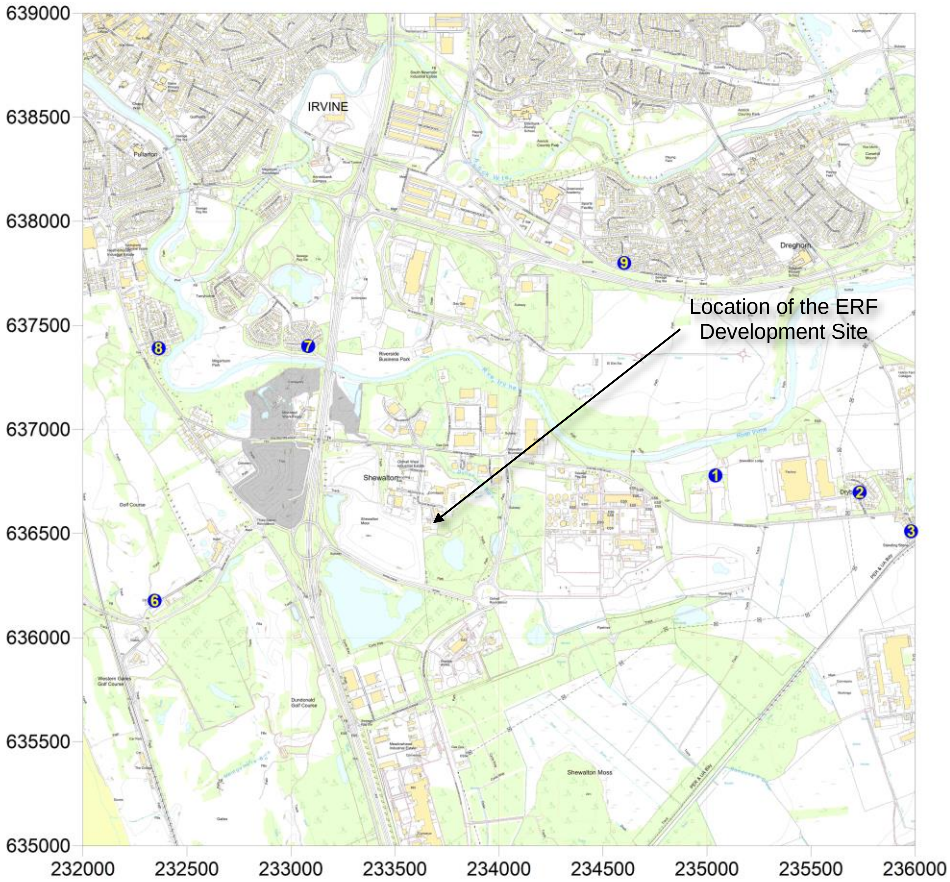
Exposure via the Consumption of Milk

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

Exposure by the Consumption of Meat and Eggs

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

Figure 1 The Local Setting Showing the Vicinity of the Proposed ERF Development Site



5.5 Exposure Factors

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

Inhalation Rates

For a 70 kg adult the daily respiration volume was taken as about 20 m^3 day^{-1} which is in line with US EPA recommendations. This corresponds to an average value of about 0.012 m^3 kg^{-1} hr^{-1}. The corresponding value for a child weighing about 20 kg was 7.2 m^3 day^{-1}, or about 0.015 m^3 kg^{-1} hr^{-1}.

Consumption of Meat and Eggs

Information on the intake of meat and eggs was obtained from the Food Standards Agency website[7] and is summarised in the following table.

Table 5 UK Official Figures for the Consumption of Meat and Eggs (grams day^{-1})

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

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

For home-reared or allotment-reared eggs and poultry meat, it is unlikely that meat consumption rates would be as high as those for eggs, as the birds are the source of the eggs in preference to a meat source. Accordingly, and in the absence of a local poultry farm, the majority of poultry meat consumed in the vicinity of the ERF 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

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

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

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

Consumption of Milk

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

Table 7 UK Official Figures for the Consumption of Milk (grams day^{-1})

Milk Category	UK Adult Mean (g day^{-1})	UK Child Mean (g day^{-1})
Whole Milk	24	73.7

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

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

Ingestion of Soil

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

Table 8 US EPA HHRAP Estimates for Soil Ingestion (kg day^{-1})

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

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

5.6 Emissions Scenario

The proposed ERF will be subject to regulation by SEPA in line with the emission limit values (ELVs) for Dioxins and Furans for incineration plant as defined by the EU Industrial Emissions Directive (IED) and the associated BAT-Conclusions document. Accordingly, atmospheric dispersion modelling was undertaken on the basis of normal operation with emissions of Dioxins at the 0.04 ng Nm^{-3} ELV specified in the BAT-Conclusions, which is the design point and performance guarantee for the proposed ERF.

Exposure via the dietary route was assessed by modelling Dioxin deposition in both the gaseous and particulate phases. Partitioning of Dioxins between the vapour phase and the particulate phase was assumed to be in the proportions 66.4:33.6 as provided by HHRAP guidance[8], and the modelling results were adjusted accordingly. The results from deposition modelling were then taken in conjunction with the US EPA Human Health Risk Assessment Protocol for Hazardous Waste Combustion for calculating the intake of Dioxins into the soil, fruit and vegetables, dairy products, meat and eggs to provide an estimate of dietary intake of Dioxins as a result of the operation of the new facility. The potential intake of breast milk by infants aged 0 – 1 years has also been calculated using the US EPA HHRAP, although this assessment is reported in isolation from the dietary uptake by adults and older children. The results were compared against the Tolerable Daily Intake (TDI) value of 2 pg kg^{-1} day^{-1} recommended by the UK Committee on Toxicity[9].

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.

Area Covered and Specific Receptors Included in the Assessment

Atmospheric dispersion modelling using ADMS Version 5.2 was undertaken to estimate likely ground level concentrations of Dioxins at nearby sensitive receptors arising from emissions from the proposed ERF. Meteorological data for the Prestwick Airport measurement station for 2015 to 2019 were used in the modelling and the results reported are based upon the maximum Process Contributions over the five-year period. The model was run separately in dispersion and in dry deposition mode to provide the maximum Dioxin vapour concentration and likely Dioxin deposition rates in the vicinity of the development site.

5.7 Results from Detailed Modelling - Concentration Mode

The results from modelling emissions of Dioxins from the facility, based upon the anticipated ELV of 0.04 ng Nm^{-3} gave a maximum Process Contribution of about 9.1 fg m^{-3} (9 x 10^{-15} g m^{-3}) expressed as a daily average value, and located approximately 290 metres to the north-east of the chimney of the proposed ERF. The corresponding annual average Process Contribution was about 0.7 fg m^{-3}.

5.8 Deposition Mode

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

The ADMS model was run in dry deposition mode only with total deposition calculated as per SEPA's IPPC H1 guidance note[3], which 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 results from deposition modelling of emissions from the proposed ERF, assuming continuous emissions at the maximum ELV of 0.04 ng Nm^{-3}, gave a maximum value for total (dry and wet) Dioxin deposition of 3.9 x 10^{-13} µg m^{-2} s^{-1} for Dioxins in the gaseous and particulate phases, which equates to 0.012 ng m^{-2} annum. The results showed deposition rates for Dioxins decreasing markedly with distance from the point of release.

Specific Receptor Locations and Exposure Pathways

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

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 Number	Receptor Location	OS Coordinates		Distance from Source (metres)
		X	Y	
1	Residence - Drybridge, KA11 5BX	235041	636779	1,329
2	Residence - Shewalton Moss, KA11 5BW,	235734	636697	2,013
3	Residence - Main Street, Drybridge, KA11 5BX	235981	636511	2,260
6	Glasgow Golf Club / Gailes Links, Irvine	232345	636177	1,443
7	Residence - Muirfield Court, Irvine, KA11 4DG	233083	637400	1,018
8	Residence - Carson Drive, Irvine, KA12 8HR	232364	637390	1,568
9	Residence - Monarch Gardens, Dreghorn, KA11 4EB	234602	637800	1,482

5.9 Results and Discussion

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

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

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

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

5.10 Exposure via Inhalation

The following equation is taken from the US EPA HHRAP and was used in the calculation of the Maximum Daily Intake due to inhalation of Dioxins as a result of exposure to emissions from the proposed ERF:

Equation 1 Maximum Daily Intake Due to Inhalation

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

Where:

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

The following input data were assumed:

- The inhalation rate (IR) was 19.92 m^3 day^{-1} for an adult and 7.2 m^3 day^{-1} for a child (US EPA recommended value);
- Body weight (BW) was taken as 70 kg for an adult (US EPA HHRAP and UK Human Health Toxicological Report[10] recommended value) and 20 kg for a child (UK Human Health Toxicological Report).

The maximum daily adult intake of Dioxins due to inhalation was calculated to be 0.0011 pg kg^{-1} day^{-1}. For children the corresponding figure was 0.0014 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 approximately 0.05 % of the TDI, while the estimated value for children is about 0.07 % of the TDI.

The calculated daily inhalation rates above do not include any existing background figure. Monitoring of Dioxins is undertaken at a small number of sites around the country representing rural and urban background locations. For the purpose of this study, reference was made to the latest available average urban background concentration for Dioxins and Furans of 0.0165 pg m^{-3} in 2016, as measured by the Toxic Organic Micro Pollutants (TOMPs) monitoring network[11] at sites in Manchester and London. This figure was therefore applied as the background and adds an additional 0.0047 pg kg^{-1} day^{-1} to adult inhalation and 0.0059 pg kg^{-1} day^{-1} to child inhalation. The overall inhalation rates therefore equate to 0.29 % of the TDI for adults and 0.37 % of the TDI for children.

5.11 Potential Increase in Concentration of Dioxins in Soil Due To Emissions from the Proposed ERF

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 proposed ERF.

Deposition modelling of Dioxins, in the particulate and gaseous phases, was carried out using ADMS Version 5.2. The likelihood is that the majority of Dioxins released from the facility would be associated with the particulates in the emission to atmosphere. Accordingly, the model predictions for Dioxin deposition associated with the particulates with a diameter of 1 µm represents an appropriate worst-case value for assessment of Dioxin deposition to soils in the vicinity of the proposed ERF. The following deposition rates were predicted at the seven 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 ELV of 0.04 ng Nm^{-3}

Receptor Number	Distance from Source (metres)	Total Deposition Rate* - Gaseous and Particulate (μg m^{-2} s^{-1})	Annual Deposition Rate (ng m^{-2} $annum^{-1}$)
Maximum	290	3.91×10^{-13}	0.012
1	1,329	3.31×10^{-13}	0.01
2	2,013	1.93×10^{-13}	0.006
3	2,260	1.62×10^{-13}	0.005
6	1,443	8.47×10^{-14}	0.003
7	1,018	1.86×10^{-13}	0.006
8	1,568	7.96×10^{-14}	0.003
9	1,482	2.49×10^{-13}	0.008

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 of Dioxins in water.

The following assessment is based upon the maximum deposition rate at the location of the maximum Process Contribution, approximately 290 metres to the north-east of the single chimney of the proposed ERF.

Increase in Soil Concentration

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

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

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

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

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

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 $soil^{-1}$ yr^{-1};
- 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;
- Dywp = Unitised annual average dry deposition from particulate phase – derived from ADMS output.

Using the above equations and input parameters, gave a value for the increase in soil Dioxin concentration due to deposition of approximately 0.00016 ng kg^{-1}. This value represents the case at the location of the maximum Process Contribution based upon the emission limit value for normal operating conditions of 0.04 ng Nm^{-3}, and is about 0.002 % of the maximum concentration of Dioxin in soils in urban locations (about 9.2 ng kg^{-1}) reported by the Environment Agency[12]. As discussed earlier, the urban land classification is considered to be appropriate for the area surrounding the proposed ERF development site.

The value reported above is based upon the maximum deposition rate at the location of the maximum Process Contribution which occurs approximately 290 metres to the north-east of the chimney of the facility, while deposition at specific receptors farther afield is predicted to occur at lower rates as indicated by the deposition results reported in Table 10.

Exposure from Dietary Intake of Meat and Eggs

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

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

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

The results presented in the following section relate to the deposition rate at the location of the maximum Process Contribution, approximately 290 metres to the north-east of the chimney of the proposed ERF.

Dioxin Concentration in Beef

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

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

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

Where:

- A_{beef} = Concentration of Dioxin in beef (mg kg^{-1} FW tissue);
- F_i = Fraction of plant type i grown on contaminated soil and ingested by the cattle (unitless);
- Qp_i = Quantity of plant type i eaten by the cattle per day (kg DW plant day^{-1});

- P_i = Concentration of Dioxin in each plant type i eaten by the cattle (mg kg^{-1} DW);
- Q_s = Quantity of soil eaten by the cattle each day (kg day^{-1});
- C_s = Average soil concentration over exposure duration (mg kg^{-1} soil);
- B_s = Soil bio-availability factor (unitless);
- Ba_{beef} = Dioxin bio-transfer factor for beef (day kg^{-1} FW tissue);
- MF = Metabolism factor (unitless).

Using the above equation, a value of approximately 5.99 x 10^{-09} mg kg^{-1} (about 6 pg kg^{-1}) of fresh meat was derived for the Dioxin concentration in beef due to the ingestion of contaminated feed and soil with an incremental annual average increase in Dioxin concentration, due to the operation of the proposed ERF, of 0.00016 ng kg^{-1}.

Dioxin Concentration in Pork

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

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

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

Where:

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

Using the above equation, a value of approximately 1.3 x 10^{-11} mg kg^{-1} (about 0.013 pg kg^{-1}) of fresh meat was derived for the Dioxin concentration in pork due to the ingestion of contaminated feed and soil with an incremental annual average increase in Dioxin concentration, due to the operation of the proposed ERF, of 0.00016 ng kg^{-1}.

Dioxin Concentration in Eggs

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

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

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

Where:

- A_{egg} = Concentration of Dioxin in egg;
- F_i = Fraction of grain grown on contaminated soil and ingested by chickens – assumed to be 1.0;
- Qp_i = Quantity of grain ingested by chickens – assumed to be 0.2 (US EPA HHRAP value);
- P_i = Concentration of Dioxin in grain – derived from separate equation below;
- Q_s = Quantity of soil ingested by chicken – assumed to be 0.022 kg day^{-1} (US EPA HHRAP value);
- C_s = Maximum annual average incremental increase in Dioxin concentration in soil – estimated by modelling to be 0.00016 ng kg^{-1};

- B_s = Soil bio-availability factor – assumed to be 1.0 (US EPA HHRAP value);
- Ba_{egg} = Bio-transfer factor for chicken eggs – assumed to be 1.09984 (US EPA HHRAP Database).

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

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

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

Where:

- P_i = Concentration of Dioxin in grain;
- C_s = Annual average increase in Dioxin concentration in soil – estimated by modelling to be 0.00016 ng kg^{-1};
- Br_{forage} = Plant-soil bio-concentration factor for grain – assumed to be 0.00455 (US EPA HHRAP Database).

Using the above equations, a value of 3.98 x 10^{-12} mg kg^{-1} Fresh Weight (FW) basis (approximately 0.004 pg kg^{-1}) was derived for the Dioxin concentration in eggs due to the consumption of grain and foraging of chickens on soil with an incremental annual average increase in Dioxin concentration in the soil of 0.00016 ng kg^{-1}, due to the operation of the proposed ERF.

Dioxin Concentration in Chicken Meat

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

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

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

Where:

- $A_{Chicken}$ = Concentration of Dioxin in chicken meat;
- F_i = Fraction of grain grown on contaminated soil and ingested by chickens – assumed as 1.0;
- Qp_i = Quantity of grain ingested by chickens – assumed to be 0.2 (US EPA HHRAP value);
- P_i = Concentration of Dioxin in grain – derived from the equation above;
- Q_s = Quantity of soil ingested by chickens – assumed to be 0.022 kg day^{-1} (US EPA HHRAP value);
- C_s = Maximum annual average incremental increase in Dioxin concentration in soil – estimated by modelling to be 0.00016 ng kg^{-1};
- B_s = Soil bio-availability factor – assumed to be 1.0 (US EPA HHRAP value);
- Ba_{egg} = Bio-transfer factor for chicken carcase – assumed to be 1.09984 (US EPA HHRAP Database).

Using the above equations, a value of approximately 6.97 x 10^{-12} mg kg^{-1} (about 0.007 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 ERF, of 0.00016 ng kg^{-1}.

Dietary Intake Due to the Combined Consumption of Meat and Eggs

Data published by the Food Standards Agency was presented in Table 5 and provides the dietary intakes of meat and eggs for adults and children in the UK. The data are based upon the average values for men and women, and boys and girls, to give an overall average for an adult or child member of the population. The values relate to the average daily consumption of meat and eggs normalised to include non-consumers, to give an overall average for an adult or child member of the population.

When the dietary intake data presented in Table 5 are combined with the estimated Dioxin concentration data for meat and eggs calculated above, the following daily intake values were derived for adults with a body weight of 70 kg, and children with a body weight of 20 kg:

Table 11 Dietary Intake of Dioxins via the Consumption of Meat and Eggs Reared at the Location of the Maximum Process Contribution

Food Category	UK Adult Mean	UK Child Mean
	pg day^{-1}	
Beef	0.00374	0.00631
Pork	0.0000023	0.0000029
Chicken	0.000007	0.000014
Eggs	0.0000014	0.0000022
	Percentage of Tolerable Daily Intake (2 pg kg^{-1})	
Beef	0.2%	0.3%
Pork	0.0001%	0.0001%
Chicken	0.0004%	0.0007%
Eggs	0.00007%	0.00011%

As can be seen in the above table, the estimated daily intake of Dioxins due to the consumption of beef is substantially higher than that from pork or chicken. As only a single full portion of meat is likely to be consumed by each individual on any day, the intake rate from the consumption of beef is carried forward in the assessment of the total, in addition to the contribution from the consumption of eggs. The intake values for beef represent approximately 0.2 % of the Tolerable Daily Intake value of 2 pg kg^{-1} day^{-1} for adults, and 0.3 % of the TDI for children. The values for egg consumption are much lower, equating to 0.00007 % and 0.00011 % of the TDI for adults and children respectively.

5.12 Exposure from Dietary Intake of Milk

The potential link between human receptors in the vicinity of the proposed ERF and the consumption of locally produced milk is not known. Nevertheless, to provide a worst-case basis for assessment, exposure to Dioxins via the consumption of milk has been undertaken.

The US EPA Human Health Risk Assessment Protocol (HHRAP) for Hazardous Waste Combustion Facilities methodology was used to assess the potential exposure to Dioxins arising from emissions from the facility. The equation in Table B-3-11 in Appendix B of the HHRAP was used to determine the concentration of Dioxins in milk at locations in the vicinity of the proposed ERF development.

The results presented in the following section relate to the deposition rate at the point of maximum Process Contribution, approximately 290 metres to the north-east of the development site.

Dioxin Concentration in Milk

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

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

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

Where:

- A_{milk} = Concentration of Dioxin in milk;
- F_i = Fraction of forage grown on contaminated soil and ingested by cows – assumed to be 1.0;
- Qp_i = Quantity of forage ingested by cows – assumed to be 13.2 (US EPA HHRAP value);
- P_i = Concentration of Dioxin in 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 value);
- C_s = Maximum annual average incremental increase in Dioxin concentration in soil – estimated

by modelling to be 0.00016 ng kg^{-1};
- B_s = Soil bioavailability factor – assumed to be 1.0 (US EPA HHRAP value);
- Ba_{milk} = Biotransfer factor for milk – assumed to be 5.499 (US EPA HHRAP Database).

The value of P_i was derived 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

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

Where:

- P_i = Concentration of Dioxin in forage;
- C_s = Annual average increase in Dioxin concentration in soil – estimated by modelling to be 0.00016 ng kg^{-1};
- Br_{forage} = Plant-soil bioconcentration factor for forage – assumed to be 0.00455 (US EPA HHRAP Database);

Using the above equations, a value of 1.86 x 10^{-8} mg kg^{-1} Fresh Weight (FW) basis (approximately 19 pg kg^{-1}) was derived for the Dioxin concentration in milk due to the grazing of cows on grass and soil with an incremental annual average increase in Dioxin concentration in the soil of 0.00016 ng kg^{-1}, due to the operation of the proposed ERF.

Dietary Intake Due to the Consumption of Milk

Data published by the Food Standards Agency was presented in Table 5 and provides the dietary intakes of milk for adults and children in the UK. The data are based upon the average values for men and women, and boys and girls, to give an overall average for an adult or child member of the population. The values relate to the average daily consumption of milk normalised to include non-consumers, to give an overall average for an adult or child member of the population.

When the dietary intake data presented in Table 5 are combined with the estimated Dioxin concentration data for whole milk calculated above, the following daily intake values were derived for adults with a body weight of 70 kg, and children with a body weight of 20 kg:

Table 12 Dietary Intake of Dioxins via the Consumption of Milk Produced at the Location of the Maximum Process Contribution

Food Category	**UK Adult Mean**	**UK Child Mean**
Whole Milk	**pg day^{-1}**	
	0.0064	0.0685
	Percentage of Tolerable Daily Intake (2 pg kg^{-1})	
	0.3 %	3.4 %

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 0.00016 ng kg^{-1}, represents values that are about 0.3 % of the Tolerable Daily Intake for adults and about 3.4 % for children. These values are significantly higher than those for meat and eggs and reflect the fact that Dioxins tend to concentrate in fats and fatty tissues, which includes an animal's lactate system. The above assessment is based upon the consumption of whole milk, and as such the results probably overestimate considerably the significance of Dioxin intake via the consumption of milk for many people.

Dietary Intake of Infants Due to the Consumption of Breast Milk

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

The following formulae were used to estimate the potential Dioxin concentration in breast milk due to ingestion by the mother (Equation 10 below taken from Table C-3-1 of Appendix C of the HHRAP), and then the uptake of Dioxin by the feeding infant (Equation 11, taken from Table C-3-2 of Appendix C of the HHRAP):

Equation 10 The Concentration of Dioxin in Breast Milk Due to maternal Ingestion

$$C_{milkfat} = \frac{m \cdot 1\times10^{9} \cdot h \cdot f_1}{0.693 \cdot f_2}$$

Where:

- C milk/fat = Concentration of Dioxins in breast milk (pg kg^{-1} of milk fat);
- m = 1.59E^{-11} - the calculated average maternal Dioxin intake via the dietary route (mg kg^{-1} BW day^{-1});
- 1 x 10^9 = Conversion factor (pg mg^{-1});
- H = 2,555 - the half-life of dioxins in adults (days) – (US EPA HHRAP value);
- f_1 = 0.9 - Fraction of ingested dioxins stored in fat – (US EPA HHRAP value);
- f_2 = 0.3 - Fraction of mother's weight that is fat – (US EPA HHRAP value).

Equation 11 The Uptake of Dioxin by the Feeding Child

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

Where:

- ADD infant = Average daily dose for infant exposed to contaminated breast milk;
- C milk/fat = Concentration of dioxins in breast milk as calculated (pg kg^{-1} of milk fat);
- f_3 = 0.04 - Fraction of mother's milk that is fat – (US EPA HHRAP value);
- f_4 = 0.9 - Fraction of dioxin that is absorbed – (US EPA HHRAP value);
- IR milk = 0.688 - Ingestion rate of breast milk by infant (kg day^{-1}) – (US EPA HHRAP value);
- ED = 1 - Exposure duration (years) – (US EPA HHRAP value);
- BW infant = 9.4 - Body weight of infant (kg) – (US EPA HHRAP value);
- AT= 1 - Averaging time (years) – (US EPA HHRAP value).

Using the above equations, a maximum value of 176 pg kg^{-1} milk fat was derived for the Dioxin concentration in breast milk, with an incremental increase in daily Dioxin uptake by the infant of 0.463 pg kg^{-1}, due to the operation of the proposed ERF. This equates to a daily dietary intake by infants from the consumption of breast milk, of approximately 23 % of the Tolerable Daily Intake.

5.13 Exposure from Dietary Intake Due to Ingestion of Soil

The formula in Table C-1-1 in Appendix C of the US EPA HHRAP was used to estimate the potential intake of Dioxins due to ingestion of soil in the locality of the proposed ERF:

Equation 12 The Intake of Dioxin Due to Ingestion of Soil

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

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 0.00016 ng kg^{-1};
- CR_{Soil} = Consumption rate of soil (US EPA HHRAP Values);
- F_{Soil} = Fraction of soil contaminated by Dioxins – US EPA HHRAP recommends the use of 1.0;
- BW = Body weight.

Using the above equation, a Dioxin intake as a result of soil ingestion of 0.00000023 pg kg^{-1} day^{-1} for adults and 0.00000158 pg kg^{-1} day^{-1} for children was predicted, due to the operation of the proposed ERF. These values represent approximately 0.00001 % and 0.00008 % respectively of the TDI of 2 pg day^{-1} and are considered to be negligible.

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

An assessment for exposure to Dioxins has been undertaken for the consumption of fruit and vegetables in order to represent a scenario where local residents are obtaining their dietary intake of fruit and vegetables from plants grown in soil that could potentially be contaminated by Dioxins in the emissions from the proposed ERF.

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

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

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 P_d

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

Equation 14 The Increase in Dioxin Concentration in Aboveground Produce Due to Deposition

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

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.

Using the above equation, a value of 2.44 x 10^{-12} mg Dioxin per kg Dry Weight was obtained for P_d.

Calculation of P_v

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

Equation 15 The Increase in Dioxin Concentration in Aboveground Produce Due to Air-Plant Transfer

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

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 for 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}).

Using the above equation, a value of 2.48 x 10^{-10} mg Dioxin per kg Dry Weight was obtained for P_v.

Calculation of Pr_{ag}

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

Equation 16 The Increase in Dioxin Concentration in Aboveground Produce Due to Root Intake

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

Where:

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

Using the above equation, a value of 7.2×10^{-13} mg Dioxin per kg Dry Weight was obtained for Pr_{ag}.

Calculation of Pr_{bg}

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

Equation 17 The Increase in Dioxin Concentration in Belowground Produce Due to Deposition

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

Where:

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

Using the above equation, a value of 1.6×10^{-12} mg Dioxin per kg Dry Weight was obtained for Pr_{bg}.

Calculation of Dioxin Intake from the Consumption of Fruit and Vegetables

Equation C-1-2 in Appendix C of the US EPA HHRAP methodology was used to calculate the overall intake of Dioxins due to the consumption of fruit and vegetables:

Equation 18 The Daily Intake of Dioxins Due to the Consumption of Fruit and Vegetables

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

Where:

- I_{ag} = Daily intake of Dioxins from the consumption of fruit and vegetables;
- P_d = Aboveground exposed fruit and vegetables concentration due to direct deposition onto plant surfaces – calculated using Equation B-2-7 in Appendix B of HHRAP methodology = 2.44 x 10^{-12} mg kg^{-1} day^{-1} DW;
- P_v = Aboveground exposed fruit and vegetables concentration due to air-to-plant transfer – calculated using Equation B-2-8 in Appendix B of HHRAP methodology = 2.48 x 10^{-10} mg kg^{-1} day^{-1} DW;
- Pr_{ag} = Aboveground exposed and protected fruit and vegetables concentration due to root intake – calculated using Equation B-2-9 in Appendix B of HHRAP methodology = 7.2 x 10^{-13} mg kg^{-1} day^{-1} DW;

- Pr_{bg} = Belowground exposed and protected fruit and vegetables concentration due to root intake – calculated using Equation B-2-10 in Appendix B of HHRAP methodology = 1.6 x 10^{-12} mg kg^{-1} day^{-1} DW;
- CR_{ag} = Consumption rate of aboveground fruit and vegetables (US EPA HHRAP Value) = 0.00047 kg kg^{-1} day^{-1} DW for adults and 0.00113 kg kg^{-1} day^{-1} DW for children;
- CR_{pp} = Consumption rate of protected aboveground fruit and vegetables (US EPA HHRAP Value) = 0.00064 kg kg^{-1} day^{-1} DW for adults and 0.00157 kg kg^{-1} day^{-1} DW for children;
- CR_{bg} = Consumption rate of belowground fruit and vegetables (US EPA HHRAP Value) = 0.00017 kg kg^{-1} day^{-1} DW for adults and 0.00028 kg kg^{-1} day^{-1} DW for children;
- F_{ag} = Fraction of fruit and vegetables that is contaminated – assumed to be 1.0

Using the above equation, a value of 0.0000017 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 0.000014 pg kg^{-1} Dioxin per kg Dry Weight for children.

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

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

Table 13 Intake of Dioxins at the Location of Maximum Process Contribution

Food Category	UK Adult Mean (pg kg^{-1})	UK Child Mean (pg kg^{-1})
Beef (for all meat)	0.00374	0.00631
Eggs	0.0000014	0.0000022
Whole Milk	0.0064	0.0685
Soil Ingestion	0.00000023	0.00000158
Fruit and Vegetables	0.0000017	0.000014
Inhalation (PC plus background)	0.0058	0.0073
Total	**0.0159**	**0.0822**

Table 14 Intake of Dioxins at the Location of Maximum Process Contribution as a Percentage of the Tolerable Daily Intake

Food Category	UK Adult Mean	UK Child Mean
Beef (for all meat)	0.2 %	0.3 %
Eggs	0.00007 %	0.00011 %
Whole Milk	0.3 %	3.4 %
Soil Ingestion	0.00001 %	0.00008 %
Fruit and Vegetables	0.0001 %	0.0007 %
Inhalation (PC plus background)	0.29 %	0.37 %
Total	**0.8 %**	**4.1 %**

The results presented in Tables 13 and 14 represent a worst case estimate, based upon Dioxin deposition rates due to continuous emissions at the ELV of 0.04 ng Nm^{-3}, at the location of the maximum Process Contribution which is about 290 metres to the north-east of the chimney of the proposed ERF. It also assumes that total dietary intake of meat, eggs, milk, and fruit and vegetables is derived from produce grown at that specific location.

Nevertheless, the results show that the potential impact of Dioxin release from the proposed ERF on Dioxin concentrations in the soil, and on the associated increase in dietary intake through the consumption of meat, eggs, fruit and vegetables, as well as via the ingestion of soil through the working of the land, and through inhalation, is likely to be considerably below the recommended Tolerable Daily Intake of 2 pg kg^{-1} day^{-1}. The overall potential intake of Dioxins for adults represents about 0.8 % of the TDI, with that for children equating to approximately 4.1 % of the TDI. It should be noted that in defining a TDI of 2 pg kg^{-1} for Dioxins, the Committee on Toxicity acknowledged the uncertainties associated with the approach:

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

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

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

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

The corresponding values for the seven nearby specific receptors were lower in relation to their distance from the site, as shown in Table 15.

Table 15 Exposure to Dioxins at Specific Receptors in the Vicinity of the Oldhall ERF

Receptor Number	Distance from the Facility (metres)	Percentage of Tolerable Daily Intake (Adult)	Percentage of Tolerable Daily Intake (Child)
1	1,329	0.7 %	3.5 %
2	2,013	0.5 %	2.2 %
3	2,260	0.5 %	1.9 %
6	1,443	0.4 %	1.1 %
7	1,018	0.5 %	2.1 %
8	1,568	0.4 %	1.1 %
9	1,482	0.6 %	2.7 %

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

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

Table 16 Cancer Risk Due to Exposure to Dioxins at Residential Receptors in the Vicinity of the Oldhall ERF

Receptor	Distance from the Facility (metres)	Cancer Risk (Adult)		Cancer Risk (Child)	
Maximum	290	1.02×10^{-06}	1 in 978,091	5.28×10^{-06}	1 in 189,341
1	1,329	8.87×10^{-07}	1 in 1,126,771	4.50×10^{-06}	1 in 222,007
2	2,013	6.47×10^{-07}	1 in 1,544,883	2.80×10^{-06}	1 in 357,310
3	2,260	5.93×10^{-07}	1 in 1,687,663	2.41×10^{-06}	1 in 414,958
6	1,443	4.71×10^{-07}	1 in 2,124,861	1.46×10^{-06}	1 in 684,397
7	1,018	6.53×10^{-07}	1 in 1,531,690	2.73×10^{-06}	1 in 366,299
8	1,568	4.56×10^{-07}	1 in 2,192,084	1.39×10^{-06}	1 in 719,220
9	1,482	7.56×10^{-07}	1 in 1,322,925	3.5×10^{-06}	1 in 285,766

The above Cancer Risk estimates represent the incremental probability that an individual, living continuously at a particular receptor location, will develop cancer over that person's lifetime as a result of a specific exposure to Dioxins emitted from the chimney of the proposed ERF. The position in the UK at present is that a risk level of 1 x 10^{-05} is considered to be appropriate for use as the basis for assessment for carcinogenic contaminants such as Dioxins[13,14]. Accordingly, the above results can be screened out as insignificant.

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

1. Emissions of Dioxins are continuously discharged at the ELV of 0.04 ng Nm^{-3} for waste incineration plants.
2. It is assumed that all of the food consumed by individuals is grown at that location, which is highly unlikely given the likelihood that for the majority of the population food is purchased from supermarkets, or other outlets, and is grown outside of the area; and,
3. All of the milk consumed is produced by cows grazing at the specific receptor location for the entire year, which is highly unlikely. Furthermore, the consumption of milk accounts for between approximately 38 % and 83 % of the estimated dietary intake due to the propensity for Dioxins to accumulate in fatty body tissue and pass through into the cows' lactate system

Accordingly, the above results are considered to provide a worst-case and an overly conservative assessment of the potential exposure to Dioxins in the vicinity of the proposed ERF.

To put the Cancer Risk data into perspective, information is presented below relating to risk of death from a range of causes[15].

Table 17 Risk of an Individual Dying in Any One Year

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

These values are not absolute, but indicative, and enable the Cancer Risk estimates to be viewed in perspective with other activities that individuals may be associated with. As can be seen, when compared to the Cancer Risk scores for Receptor No. 1, representing one of the nearest downwind residential properties to the site, being 1.33 km to the east and with the highest Dioxin deposition rate of each of the receptors, the risk of dying in a road traffic accident (1 in 8,000) is about one hundred and forty times higher than the risk of developing cancer (approximately 1 in 1,126,771), due to exposure to Dioxins released from the proposed ERF.

6 The Impact of Emissions of PAH and Dioxin-like PCBs

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

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

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

The Waste Incineration BREF[16] does not specify an individual achievable emission level for PCBs, instead specifying that the combined emissions of Dioxins, Furans and PCBs from waste incineration plant should remain within 0.06 ng Nm^{-3}, or 1.5 times the Dioxin and Furan ELV. However, the BREF does provide a range of values for PCB emissions, suggesting that the annual average total PCB release is likely to be less than 0.005 mg Nm^{-3} and therefore, an assumed PCB release rate of 0.005 mg Nm^{-3} has been modelled.

6.1 Results and Discussion

Detailed atmospheric dispersion modelling of emissions of PAH and PCBs from the proposed ERF was undertaken, and the reported maximum annual average Process Contribution for the years 2015 to 2019, are presented in the following table for the seven local human health receptor locations considered in this report.

Table 18 Maximum Exposure to PAH and PCBs at Specific Receptors in the Vicinity of the Oldhall ERF

Receptor Number	Annual Average B[a]P Concentration (ng m^{-3})	% AQS	Annual Average PCB Concentration (µg m^{-3})	% EAL
1	0.00380	**1.5 %**	1.90E-05	0.0095 %
2	0.00229	0.9 %	1.14E-05	0.0057 %
3	0.00201	0.8 %	1.00E-05	0.0050 %
6	0.00113	0.5 %	5.64E-06	0.0028 %
7	0.00236	0.9 %	1.18E-05	0.0059 %
8	0.00095	0.4 %	4.75E-06	0.0024 %
9	0.00280	**1.1 %**	1.40E-05	0.0070 %

As can be seen, the maximum annual average Process Contributions to PAH levels at most of the modelled receptor sites equate to less than 1 % of the Air Quality Standard. The exceptions are at Receptor Nos. 1 and 9, which are predicted to receive up to 1.5 % and 1.1 % of the AQS respectively. However, applying a background figure of 0.10833 ng m^{-3}, obtained from monitoring undertaken through 2019 in Glasgow at the Townhead monitoring station[17], results in a maximum Predicted Environmental Concentration at the receptor sites of 0.112 ng m^{-3}, which is approximately 45 % of the AQS, and can be screened as insignificant at the second assessment stage.

Annual average Process Contributions of PCBs are all considerably below 1 % the Environmental Assessment Level, and can therefore be screened as insignificant at all of the specific receptor locations.

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

The Dioxin Tolerable Daily Intake value of 2 pg kg^{-1} body weight used as the basis for assessment for Dioxins, was also applied to the Process Contribution of the PCBs.

Table 19 Maximum Exposure to Dioxins and PCBs at Specific Receptors in the Vicinity of the Facility

Receptor Number	Distance from Source (metres)	Dioxins Alone		Dioxins and PCBs	
		Percentage of Tolerable Daily Intake (Adult)	Percentage of Tolerable Daily Intake (Child)	Percentage of Tolerable Daily Intake (Adult)	Percentage of Tolerable Daily Intake (Child)
Maximum	290	0.8 %	4.1 %	1.2 %	6.2 %
1	1,329	0.7 %	3.5 %	1.1 %	5.3 %
2	2,013	0.5 %	2.2 %	0.8 %	3.3 %
3	2,260	0.5 %	1.9 %	0.8 %	2.9 %
6	1,443	0.4 %	1.1 %	0.6 %	1.7 %
7	1,018	0.5 %	2.1 %	0.8 %	3.2 %
8	1,568	0.4 %	1.1 %	0.6 %	1.7 %
9	1,482	0.6 %	2.7 %	0.9 %	4.1 %

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

7. Conclusions

A health impact assessment has been undertaken to assess the risk to the health of people living and working in the vicinity of the proposed Energy Recovery Facility to be developed by WEP Partners Limited in Oldhall, near Irvine, Scotland. Detailed atmospheric dispersion modelling of emissions from the 60-metre high chimney was undertaken using the ADMS Version 5.2 model to predict increases in pollutant concentrations at nearby sensitive receptors such as residential properties, schools and locations where people may congregate for significant periods of time. The assessment involved a comparison of model-predicted Process Contributions against health-based air quality standards and relevant Environmental Assessment Levels recommended by SEPA.

The modelling showed that increases in background pollutant concentrations of species such as NO_2, SO_2, PM_{10}, HCl, HF and CO at nearby residential properties were low and would not have a significant impact on the health of people living and working nearby. Process Contributions for pollutants such as VOCs and heavy metals were also very low and their potential health effects screened out as insignificant in relation to health-based air quality standards and relevant EALs recommended by SEPA. The exception was when considering Process Contributions of Chromium$^{(VI)}$ which, as detailed in the modelling report, predicted a worst-case Process Contribution of 1.4 % of the EAL, although the point of maximum impact does not occur at any sensitive human health receptor.

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 locality of the proposed ERF due to emissions of Dioxins and Furans, and Dioxin-like PCBs. The assessment considered the potential health risks associated with the intake of Dioxins from the consumption of potentially contaminated foodstuffs due to emissions to atmosphere from the chimney of the proposed ERF. The assumptions used within the assessment are conservative and therefore the study is considered to represent a worst-case.

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

The assessment for health risks associated with exposure to emissions of PAH demonstrated that Process Contributions would also generally be less than 1 % of the health-based Air Quality Standard of 0.25 ng m^{-3}, and could be screened out as insignificant, either at the initial or secondary assessment stage.

In conclusion, the results from the health impact assessment confirms that there is no significant health risk associated with potential exposure to emissions of pollutants from the proposed ERF to be developed by WEP Partners Limited, at Oldhall, near Irvine, Scotland.

8. References

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