Proposed Aire Valley Clean Energy Facility

Environmental Permit Application – Human Health Risk Assessment

Report for Endless Energy Ltd

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Executive summary

Introduction

A detailed human health risk assessment to identify potential health risks associated with exposure to emissions from the proposed Clean Energy Facility at Aire Valley Road, Keighley has been completed in line with best practice methodologies.

This report sets out the analysis of the health risks associated with the treatment of approximately 148,000 tonnes per annum of commercial and industrial waste at the proposed facility, based on the estimated throughput at design point.

Methodology

The study was carried out in accordance with guidance provided by the Department for Environment, Food and Rural Affairs (Defra) and focussed on assessing the health effects of dioxin and furan concentrations.

A simplified conceptual model was built for the site identifying all relevant sources, receptors and pathways of exposure relevant to each of the receptors. In the absence of specific information in relation to the nature of the local receptors, all default pathways of exposure were assumed to exist for each receptor, to ensure that all potentially significant exposure pathways were assessed.

Dioxin and furan concentrations in the different receiving media were calculated from the particle phase and vapour phase air concentrations and deposition to the soil, using the "Industrial Risk Assessment Program-Human Health" system. The estimated concentrations were based on a number of conservative assumptions to ensure that the study provided a worst-case assessment.

The level of exposure to dioxins and furans emitted from the proposed facility was quantified at selected sensitive receptors within the vicinity of the site. In residential locations, the key exposure pathways include the ingestion of soils and home-grown produce. On agricultural premises and at allotments, potential exposure through the ingestion of home-grown produce, and ingestion of beef, milk, pork, poultry and eggs was included. Throughout this assessment, where there is uncertainty in respect of the data, a precautionary (conservative) approach has been used to estimate the possible risks from exposure to emissions from the proposed facility. The approach ensures that allowance is made for uncertainties in the interpretation of the data provided in order to be protective of human health.

Assessment Criteria

Estimated intake of dioxins and furans, and associated health risks, were assessed against relevant standards and guidelines and against background exposure levels.

For the assessment of lifetime cancer risk, a health benchmark value of 1 in 100,000 lifetime risk was used. This is more demanding than a widely used UK benchmark, which is equivalent to 1 in 14,300 lifetime risk.

For the assessment of health impacts due to individual contaminants, the total health quotient was assessed against a criterion of 1.

For the assessment of exposure to dioxins and furans, the risk posed by the proposed facility was evaluated by comparing estimated worst-case forecast intake against the UK Tolerable Daily Intake (TDI) value of 2 picograms per kilogram body weight per day. Infant intake in breast milk was assessed against UK data on background infant intakes of dioxins and furans in breast milk.

Background exposure to dioxins and furans is dependent on a wide range of complex individual factors, and will vary from one individual to another. For context, the levels of dioxins and furans in soil due to the proposed facility were evaluated against the average rural and urban soil concentration of dioxins and furans as reported in the UK Soil and Herbage Pollutant Survey.

Baseline Conditions

The health profile of the population of Keighley was taken from health profile data for Bradford Metropolitan District Council. Keighley is situated approximately 7.5 miles north west of the city of Bradford. The health of people in Bradford is generally worse than the England average, with life expectancy 9.6 years lower for men and 7.2 years lower for women in the most deprived areas. Levels of child obesity are also higher than the England average, with 21.5% of children classified as obese in 2016.

The rates of alcohol related hospital stays, self-harm and smoking related deaths are also higher than the England average, whilst levels of physical activity are lower. The rate of tuberculosis is also worse than the national average.

Public Health England lists the health priorities for the Bradford area as addressing health inequalities, reducing infant deaths and reducing harm caused by tobacco, obesity, alcohol and substance abuse.

Assessment of Effects

The focus of this assessment was to assess the risks to health posed by emissions during the operational phase. The risks to health were found to comply with the relevant benchmarks at all potentially sensitive locations.

The greatest intake was predicted to result if an individual could theoretically consume only beef, pork, poultry, eggs, milk and vegetables produced at a farm close to the site. The highest theoretically possible intake of dioxins and furans was predicted to be 0.0147 picograms per kilogram body weight per day (pg/kg-day). Despite the worst-case approach adopted in the assessment, this incremental intake associated with the proposed facility is a small fraction (0.74 %) of the recommended tolerable daily intake for dioxins of 2 pg/kg-day, and would not be detectable in practice. Similarly, the potential exposure of infants via breast milk was assessed, and it was found that the proposed facility would have no significant or detectable influence on exposure in this way.

Mitigation

The proposed facility includes extensive measures to control emissions to air, ensuring compliance with the demanding standards set out in the Industrial Emissions Directive. The health risk assessment found no requirement for further mitigation, over and above that described in the Environmental Statement.

Conclusions

It was concluded that emissions to air from the proposed Aire Valley Clean Energy Facility will not pose unacceptable health risks to the residential or allotment locations identified in the vicinity of the proposed facility.

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1 Introduction

A detailed human health risk assessment to identify potential health risks associated with exposure to emissions from the proposed Clean Energy Facility, Aire Valley Road, Keighley has been completed in line with best practice methodologies.

The study has been carried out in accordance with guidance published by the Department for Environment, Food and Rural Affairs (Defra),[1] which includes guidelines setting out the basic principles which the regulatory authorities would normally intend to use in the assessment and management of environmental risks and which are recommended for all public domain risk assessments, including:

- Stage I: Identify the hazard(s)
- Stage II: Assess the consequences
- Stage III: Assess their probabilities
- Stage IV: Characterise risk and uncertainty

Following a brief review of information relating to the health status of the local population, the four stages set out in the Defra guidance were followed in the present project.

[1] Defra, "Guidelines for Environmental Risk Assessment and Management: Green Leaves III," report ref. PB13670 prepared by Cranfield University, 2011

2 Existing conditions

The health profile of the population of Keighley was taken from health profile data for Bradford Metropolitan District Council. Keighley is situated approximately 7.5 miles to the north west of the City of Bradford. The health of people in Bradford is generally worse than the England average, with life expectancy 9.6 years lower for men and 7.2 years lower for women in the most deprived areas. Levels of child obesity are also higher than the England average, with 21.5% of children classified as obese in 2016.[2]

The rates of alcohol related hospital stays, self-harm and smoking related deaths are also higher than the England average, whilst levels of physical activity are lower. The rate of tuberculosis is also worse than the national average.

Public Health England lists the health priorities for the Bradford area as addressing health inequalities, reducing infant deaths and reducing harm caused by tobacco, obesity, alcohol and substance abuse.

[2] Bradford Unitary Authority, Health Profile 2016, September 2016, available via http://fingertipsreports.phe.org.uk/health-profiles/2016/e08000032.pdf&time_period=2016 [accessed June 2017]

3 Methodology

3.1 Background

In its review of environmental and health effects of waste management, Defra reported that a direct measurement of exposure attributable to facilities such as the proposed Aire Valley Clean Energy Facility cannot be made due to the complexity of the pollutant mixture, the possibility of exposure through multiple pathways, wider environmental and lifestyle influences and the generally non-specific health outcomes.[3]

In order to address the difficulties of directly measuring effects and to provide a predictive analysis, this assessment is based on modelling the various exposure routes, along with applying outputs from the air quality assessment which takes account of the influence of meteorological conditions and characteristics such as the proposed stack height, discharge velocity and temperature. Such modelling is a means of establishing a worst-case exposure attributable to the sources and forms the basis of this health risk assessment.

Exposure to emissions from waste thermal treatment facilities can be through a number of pathways, with exposure via inhalation and the food chain being the most critical. For certain persistent pollutants, such as dioxins and furans, the cumulative indirect exposure via the ingestion of contaminated food is of paramount importance. Therefore potential exposure through this important pathway has been taken into account, in addition to exposure via inhalation.

3.2 Risk assessment

Guidance on environmental risk assessment and management was published by Defra in updated form in 2011.[4] The Defra guidelines were used as the basis for the assessment and appraisal of potential impact on human health from the proposed facility. These guidelines set out the basic principles which the regulatory authorities would normally intend to use in the assessment and management of environmental risks and which are recommended for all such risk assessments. They are intended to provide decision-makers, practitioners and the public with a consistent language and approach for environmental risk assessment and management.

The framework provides for a tiered approach to environmental risk assessment and management where the level of effort put into assessing each risk is proportionate to its priority (in relation to other risks) and its complexity (in relation to an understanding of the likely impacts).

The updated guidance sets out the following framework for environmental risk assessment:

- Stage I: Identify the hazard(s)
- Stage II: Assess the consequences
- Stage III: Assess their probabilities
- Stage IV: Characterise risk and uncertainty

This study was carried out in accordance with this staged approach.

3.2.1 Stage I: Identify the hazards(s)

The potential hazards which require consideration as part of this risk assessment were identified. This assessment focused on the risks posed by emissions to air from the proposed facility. The assessment of hazards comprised an identification of the substances of potential concern; consideration of how they could be released and transferred into the environment; and identification of those who could potentially be affected by these hazards.

As part of the identification of hazards, a conceptual model of risks was developed and refined. The source-pathway-receptor concept was adopted in order to construct a Site Conceptual Model (SCM)

[3] Defra, "*Review of Environmental and Health Effects of Waste Management*," (2004) via http://archive.defra.gov.uk/environment/waste/statistics/documents/health-report.pdf

[4] Defra, "Guidelines for Environmental Risk Assessment and Management: Green Leaves III," report ref. PB13670 prepared by Cranfield University, 2011

and to assess potential risks to health. The source-pathway-receptor 'pollutant linkage' scenario provides a useful basis for developing a site conceptual model, which can be used to identify critical pathways on which a quantitative analysis may be undertaken. The SCM provides a qualitative description of:

- The principal sources of contamination on the site: namely the emissions to air from the proposed waste facility;
- The contaminants of potential concern;
- The behaviour of contaminants within contaminated media, considering potential exposure via airborne pathways, deposition on soils, and uptake by home grown vegetables and other agricultural products;
- Relevant receptors in the local area; and
- Plausible pathways connecting sources of contamination and sensitive receptors, including consumption of home-grown produce, accidental ingestion of soil, and other routes of exposure through the food chain.

3.2.2 Stage II: Assess the consequences

The hazards and potential source-pathway-receptor linkages identified in Stage I were evaluated in more detail. This evaluation had regard to the findings of the accompanying Air Quality Impact Assessment.[5]

The outcome of Stage II was a list of potential hazards for which the estimation and evaluation of risk was required in more detail. As discussed in Section 5 below, this process led to attention being focused on emissions to air of dioxins and furans from the stack.

3.2.3 Stage III: Assess their probabilities

The objective of this stage was to quantify the potential exposure of local people to the contaminants of potential concern. The forecast exposure levels were then assessed against relevant standards and guidelines in order to provide protection for public health.

Public exposure can take place by a variety of possible exposure pathways including direct exposure by inhalation of dioxins/furans as gases and as fine particulates, and indirect exposure following the deposition of trace contaminants to land and subsequent transfer by biogeochemical processes through soils and vegetation into the food chain. The assessment has evaluated potential impact on human health from the proposed facility's emissions, both in terms of the inhalation pathway, and the overall long-term exposure through additional viable routes such as the food chain.

This included identification of:

- The type and spatial distribution of relevant hazardous substances;
- The media containing such hazardous materials;
- The concentration of the hazardous substance in the identified media;
- Exposure scenarios, whether residential, agricultural, etc.;
- Exposure routes – inhalation; ingestion of soil; ingestion of beef; potential exposure of breast feeding infants through the exposure of their mothers, etc.; and
- Exposure factors for each scenario and route.

The geographic scope of the study is based on assessment of a range of receptors representative of the highest potential exposure, located up to 3 km from the proposed facility. The risk estimation was designed to estimate exposure through direct inhalation of affected air, and indirect exposure through ingestion of affected food, locally grown on soil impacted by the emissions through deposition and accumulation. Based on the preceding stages of the assessment, the only relevant sources of emissions considered in this assessment are the stack emissions. At this stage, attention was focused primarily on substances which have the potential to accumulate in the environment over the operational life of the facility.

[5] Proposed Aire Valley Clean Energy Facility, Environmental permit application – Air Quality Impact Assessment, Report for Endless Energy Ltd, prepared by Ricardo Energy & Environment, July 2017.

In the absence of UK protocols for estimating the level of human exposure to Compounds of Potential Concern (COPC) through all relevant pathways of exposure, the United States Environmental Protection Agency (USEPA) "*Human Health Risk Assessment Protocol HHRAP 2005*"[6] was used to estimate all exposures utilising the predicted air concentration and deposition rates provided by the air dispersion modelling. The Industrial Risk Assessment Program-Human Health (IRAP-h View – version 4.0.3) was used for this assessment. This system was used to calculate the transport and fate of dioxins and furans emitted in the stack exhaust gases. The model drew on the results of the air quality assessment[7] carried out using the Atmospheric Dispersion Modelling System (ADMS). The results of this modelling study were copied into the IRAP-h View system.

The USEPA default exposure parameters and toxicological data were replaced by those recommended by Defra and the Environment Agency's reports CLR10 and R&D Publication TOX reports.[8,9] These modified parameters include averaging times for carcinogens and non-carcinogens, body weight, consumption and inhalation rates, exposure frequencies and durations.

UK data for consumption of home grown vegetables and, in the absence of UK data, US data for consumption of other foodstuffs were included in the exposure modelling. In this respect, UK consumption patterns will not be greatly dissimilar to US patterns, and uptake mechanisms are identical. Using US data where UK data are not available is normal practice for studies of this nature.

The IRAP-h View model used for the assessment is equipped with a database of physical and chemical parameters used to calculate the media concentrations for dioxins and furans. These are chemical specific values based on current international knowledge of chemicals.

In addition to the default values, which were used for this assessment, IRAP-h requires specific parameters to be identified. These include the following:

- Annual average evapotranspiration – i.e. the amount of water which is removed from the (crop + soil) combination into the air, taken to be 51 cm/year[10];
- Annual average precipitation, 102.41 cm/yr[11];
- Annual average runoff - i.e. annual average precipitation less evapotranspiration is known as the hydrologically effective rainfall, including that recharged to groundwater and flow to rivers (runoff). This is calculated to be 51.41 cm/year; and
- Annual average wind speed at 10 m above ground level – a value of 3.88 m/s was used based on the local meteorology data recorded in 2014 (used for the air dispersion modelling).

The IRAP-h View model calculates the average annual volume of water available for generating leachate as the mass balance of all water inputs (includes precipitation and irrigation) and outputs (runoff and evaporation) from the area under consideration. In the absence of information on the proportion of the runoff and the recharge to groundwater to the total hydrologically effective rainfall, the total was divided equally between runoff and recharge (25.71 cm/year).

3.2.3.1 Concentration in soil

COPC concentrations in soil are calculated from the wet and dry deposition of particulates and vapour to the soil. Soil conditions such as pH, structure, organic matter content and moisture content will affect the distribution and mobility of contaminants. Losses from the soil by mechanisms such as leaching, erosion, runoff, degradation and volatilisation may reduce the concentrations of COPC in soil over time. These are utilised in the model, where appropriate, by using rates that depend on the physical and chemical characteristics of the soil.

3.2.3.2 Concentration in produce

Indirect exposure resulting from ingestion of produce depends on the total concentration of COPC in the leaves, fruit, and tuber portions of the plant.

[6] United States Environmental Protection Agency (2005) "Human Health Risk Assessment Protocol (HHRAP) for Hazardous Waste Combustion Facilities", available via https://www.weblakes.com/products/iraph/protocol.html

[7] Ricardo Energy & Environment (2017) Proposed Aire Valley Clean Energy Facility – Environmental permit application – Air Quality Impact Assessment (Ref. ED 10527)

[8] Defra & Environment Agency "The Contaminated Land Exposure Assessment Model (CLEA): Technical basis and algorithms" (2002)

[9] Defra & Environment Agency 2009 , Contaminants in soil: updated collation of toxicological data and intake values for humans Dioxins, furans and dioxin-like PCBs (Science report: SC050021/TOX 12)

[10] Tim Hess "*Evapotransporation estimates for water balance scheduling in the UK*" Irrigation News, 25: 31-36 (1996)

[11] Met Office: Keighley annual average rainfall, 1981-2010 via http://www.metoffice.gov.uk/

Due to general differences in contamination mechanisms, it is generally recommended to separate produce into two broad categories for the purposes of risk assessment: above-ground produce and below-ground produce. In addition, above-ground produce can be further subdivided into exposed and protected above-ground produce.

Above-ground exposed produce is typically assumed to be contaminated by the following main mechanisms:

- Direct deposition of particles — wet and dry deposition of particle phase COPC on the leaves and fruits of plants;
- Vapour transfer uptake of vapour phase COPC by plants through their foliage; and
- Root uptake of COPC available from the soil and their transfer to the above ground portions of the plant.

The USEPA methodology estimates the total COPC concentration in above-ground exposed produce as the sum of contamination occurring through all of these mechanisms. However, edible portions of above-ground protected produce, such as peas and corn, are enclosed within an outer covering. They are therefore protected from contamination from deposition and vapour transfer. Root uptake of COPC is the primary mechanism through which above-ground protected produce becomes contaminated.

3.2.3.3 Concentration in beef and milk

The USEPA methodology recommends that COPC concentrations are estimated in beef tissue and milk products on the basis of the amount of COPC that cattle consume through their diet. The human health risk assessment (HHRA) assumes that the cattle's diet consists of:

- Forage (primarily pasture grass and hay);
- Silage (forage that has been stored and fermented); and
- Grain.

Additional contamination may occur through the cattle ingestion of soil. The HHRA calculates the total COPC concentration in the feed items (e.g., forage, silage, and grain) as a sum of contamination occurring through the following mechanisms:

- Direct deposition of particles – wet and dry deposition of particle phase COPC onto forage and silage;
- Vapour transfer – uptake of vapour phase COPC by plants through their foliage; and
- Root uptake – root uptake of COPC available from the soil and their transfer to the above-ground portions of forage, silage, and grain.

It is also assumed, as recommended by the USEPA, that 100% of the plant materials eaten by cattle are grown on soil contaminated by emission sources. This is likely to be a highly pessimistic assumption for UK farming practice. COPC concentrations in forage and silage result from deposition onto exposed plant surfaces; the same is assumed for above-ground produce.

COPC concentration in beef tissue is calculated from the daily amount of a COPC that is consumed by cattle through the ingestion of contaminated feed items (plant) and soil by including bio-transfer and metabolism factors. These transform the daily animal intake of a COPC (mg/day) into an animal COPC tissue concentration (mg COPC/kg tissue).

The metabolism factor (*MF*) estimates the amount of COPC that remains in fat and muscle. In the absence of data to support the derivation of chemical-specific *MF*s, it is recommended by the USEPA HHRAP that a conservative *MF* of 1.0 for all chemicals be used. A *MF* of 1.0 was used for this assessment.

COPC concentration in milk is calculated from the daily amount of a COPC that is consumed by dairy cattle through the ingestion of contaminated feed items (plant) and soil by including bio-transfer and metabolism factors to transform the daily animal intake of a COPC (mg/day) into an animal COPC milk concentration (mg COPC/kg milk).

3.2.3.4 Concentration in pork

COPC concentrations in pork tissue are estimated on the basis of the amount of COPC that pigs consume through a diet consisting of silage and grain. Additional COPC contamination of pork tissue may occur through their ingestion of soil.

3.2.3.5 Concentration in poultry and eggs

Estimates of the COPC concentrations in chicken and eggs are based on the amount of COPC that chickens consume through ingestion of grain and soil. The HHRA assumes that chickens are husbanded in a manner that allows contact with soil, i.e. free range. Consequently, chickens are assumed to consume 10% of their diet as soil, consistent with a study by Stephens et al.[12] Although highly unlikely in practice, for the screening assessment it is assumed, as recommended, that the remainder of the diet (90%) consists of grain grown at the exposure scenario location. Therefore, it was appropriate to assume that 100% of the grain consumed is contaminated.

3.2.3.6 Other parameters

Soil bio-availability (*Bs)* is the ratio between bio-concentrations for soil and vegetation. The efficiency of transfer from soil may differ from the efficiency of transfer from plant material for some COPC. If the transfer efficiency is lower for soils, then the ratio would be less than 1.0. If it is equal to or greater than that of vegetation, the *Bs* value would be equal to or greater than 1.0. A value of 1.0 is recommended by USEPA and was used for calculating all the above-presented concentrations.

Data used for calculating the concentration of COPC in each medium and the human ingestion rates for different food are presented in the air quality assessment.

3.2.3.7 Assessment locations

The level of exposure to substances emitted from the proposed facility was quantified at selected sensitive locations in the vicinity of the site. In residential locations, the key exposure pathways include the ingestion of soils and home-grown produce. Allotments were modelled using the same conservative assumptions as would be used to represent exposure of farmers in a rural setting. Hence, on allotment premises, potential exposure through the ingestion of home-grown produce, and ingestion of beef, milk, pork, poultry and eggs, produced at allotments within the vicinity of the site has been included, as appropriate.

3.2.4 Stage IV: Characterise risk and uncertainty

3.2.4.1 Assessment criteria

Toxic effects associated with chemical exposure are divided into two categories: threshold toxicity and non-threshold toxicity. Threshold toxic effects apply to chemicals for which there is a level of exposure below which no adverse effects will be observed. That is, there is a quantity of exposure below which no adverse effect is observed.

For non-threshold toxicity, some substances act in a way which indicates that no threshold for effects would be expected to occur– for example, in the case of many genotoxic carcinogens and mutagens. Assessment of these substances is carried out on the basis that any exposure to these substances, no matter how small, will carry some level of risk.

Non-threshold risks to human health were assessed using specified Index Dose values. In the UK the Health Protection Agency and the Department of Health are advised on the health effects by the independent expert advisory committee, the Committee on the Toxicity of Chemicals in Food, Consumer Products and the Environment (COT). The COT has recommended a tolerable daily intake (TDI) for dioxins and furans[13], which is the amount that can be ingested daily over a lifetime without appreciable health risk. This TDI is based on a detailed consideration of the extensive toxicity data on the most well studied dioxin, TCDD, but may be used to assess the toxicity of mixtures of dioxins and dioxin-like PCBs by use of Toxic Equivalency Factors, which allow concentrations of the less toxic compounds to be expressed as an overall equivalent concentration of TCDD. These toxicity-weighted concentrations are then summed to give a single concentration expressed as a Toxic Equivalent (TEQ). Thus, the COT has recommended a tolerable daily intake for dioxins of 2

[12] Stephens, R., Petreas, M., Hayward, D., "Biotransfer and bioaccumulation of dioxins and furans from soil: Chickens as a model for foraging animals," The Science of the Total Environment 175 (1995) 253-273.

[13] Committee on Toxicity of chemicals in food, consumer products and the environment, "*Statement on the Tolerable Daily Intake for Dioxins and dioxinlike polychlorinated biphenyls,*" http://cot.food.gov.uk/pdfs/cot-diox-full.pdf

picograms TEQ/kg body weight/day based on the most sensitive effect of TCDD in laboratory animals, namely, adverse effects on the developing foetus resulting from exposure *in utero*.

If required, index doses are available for other relevant substances – primarily, trace metals. Tolerable daily intake values are also available for threshold substances.

Risk characterisation involves combining the exposure quantities and the toxicity benchmarks to evaluate the cancer risks and non-cancer hazards for each of the relevant hazards, pathways and receptors. A value of 1×10^{-5} for lifetime cancer risk and a hazard quotient of 1 is used in the HHRAP model as a benchmark for the assessment of individual contaminants. In the UK, a benchmark of 1 in 1 million (1×10^{-6}) annual risk is frequently adopted, following advice from the Royal Commission on Environmental Pollution, Health and Safety Executive and World Health Organisation.[14] Assuming a 70 year lifetime, this is equivalent to a lifetime risk of 1 in 14,300 (7×10^{-5}). In order to provide an additional margin of safety, the HHRAP benchmark for lifetime cancer risk of 1 in 100,000 (1×10^{-5}) was used in this study.

Cancer risk estimates represent the incremental probability that an individual will develop cancer over a lifetime as a result of a specific exposure to a carcinogenic chemical. The UK approach to risk assessment from land contamination for non-carcinogen compounds is based on the health criteria with considerations given to potential background exposure through other sources such as food and water. Where background exposure is equal or greater than 80% of the health criterion or is unknown, 20% of the health criterion is used as the acceptable level from exposure to land contamination with the remaining 80% left to other sources to allow for exposure through the ingestion of food, water and other sources. Defra has proposed to change the above mentioned value of 20% to 50% in a consultation paper.[15]

Background exposure to dioxins and furans is dependent on a wide range of complex individual factors, and will vary from one individual to another. Key issues include individual lifestyle, diet and baseline land quality, especially the background level of dioxins and furans within the locality of the proposed facility. For baseline land quality, an individual exposure cannot feasibly be quantified due to the heterogeneous nature of the soil as a natural medium caused by the anthropogenic influence from the varying use of land over time, and geological/hydrogeological factors. Consequently, the study focused on an assessment of the potential impact of the proposed facility, rather than on the combined effect of the proposed facility and other potential sources of exposure. For context, the levels of dioxins and furans in soil due to the proposed facility were evaluated against the average rural and urban soil concentration of dioxins and furans as reported in the UK Soil and Herbage Pollutant Survey.[16]

3.2.4.2 Uncertainty

Throughout this assessment, where there was uncertainty in respect of the data, a precautionary approach (conservative) was used to estimate the possible risks from exposure to emissions from the proposed facility. The approach ensured that allowance is made for uncertainties in the available data in order to be protective of human health.

In accordance with the tiered approach to environmental risk assessment, this study has considered worst-case scenarios for all receptors in assuming multiple exposure conditions where all pathways of exposure in each land use scenario were considered to be potentially viable. The assessment relies on assumptions that are both extremely conservative and also very unlikely, resulting in a substantial margin of safety in the results obtained. These worst case assumptions have been used in the first instance as part of a screening study, to identify receptors that can be excluded from further assessment. In the event of a receptor failing the screening assessment, a further assessment could be carried out with the exposure assumptions refined to reflect the specific circumstances of the relevant locations (referred to as a detailed quantitative risk assessment[4]).

3.3 Risk evaluation

The information developed during the preceding stages of assessment was drawn together and a judgment made with regard to the significance of any risks identified. Any necessary remedial action was identified and implemented, and the assessment revised as appropriate. This assessment had

[14] PR Hunter and L Fewtrell, "Acceptable Risk," in World Health Organization (WHO). "Water Quality: Guidelines, Standards and Health," 2001
[15] CLAN 6/06 *Assessing Risks From Land Contamination – A proportionate approach, Soil Guideline Values: The Way Forward, 2006*
[16] Environment Agency, "*UK Soil and Herbage pollutant Survey, Report 10: Environmental concentrations of polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans in UK soil and herbage,*" Product code: SCHO0607BMTD-E-P, 2007

regard to the standards required under the relevant legislative regimes, and took account of uncertainty in the assessment and how this had been addressed throughout the risk assessment process. This evaluation and the supporting information is provided to assist the decision-making authorities in reaching their permitting decisions.

3.4 Risk management

At this stage of the assessment, strategies to control and manage potential risks through appropriate mitigation measures are identified if needed. This may be achieved through the management of the source or the exposure pathways to prevent the exposure of the receptors, where needed.

3.5 Cumulative impacts

Carrying out a risk assessment study which takes account of all factors which could affect people's health is not practicable and would be subject to substantial uncertainties. Consequently, the approach adopted in studies of this nature is to evaluate the potential impact on health associated with the proposed facility. Provided this impact is not significant, there is no need to consider wider health issues.

Because the approach is to demonstrate an insignificant health risk due to emissions from the proposed facility, there is no requirement to consider cumulative health risks associated with other existing or proposed sources. Cumulative impacts were therefore not specifically addressed in this report. The air quality assessment found that there were no significant cumulative impacts on air quality from other local development proposals, which indicates that there is minimal likelihood of any potentially significant cumulative health risks from potential future development.

4 Stage I: Identify the hazards(s)

The development of a site conceptual model (SCM) is required to identify the potential sources, critical pathways and receptors that require assessment as described in the following paragraphs.

4.1 Sources

For the purpose of assessing potential health impacts associated with the effect of emissions from the proposed Aire Valley Clean Energy Facility, the relevant source of emissions is the complete combustion technology, discharging via a 60 metre stack.

The substances of potential concern emitted from this source include:

- Particulate matter
- Volatile organic compounds
- Hydrogen chloride
- Hydrogen fluoride
- Carbon monoxide
- Sulphur dioxide
- Oxides of nitrogen
- Metals group 1: Cadmium and Thallium
- Metals group 2: Mercury
- Metals group 3: Antimony, Arsenic, Lead, Chromium, Cobalt, Copper, Manganese, Nickel, Vanadium
- Dioxins and furans, and dioxin-like PCBs
- Polycyclic aromatic hydrocarbons (PAHs)
- Ammonia

4.2 Pathways of exposure

The two primary pathways of exposure considered in this assessment are inhalation and ingestion.

On the basis of the significance of exposure and consequently risks associated with the exposure, the following pathways were identified as the relevant pathways of exposure:

- Inhalation;
- Ingestion of soil; and
- Ingestion of locally produced food.

Exposure through food consumption from the following products was considered:

- Home-grown produce – farms/allotments and residential properties;
- Eggs produced and used on receptor farms – farms/allotments;
- Chicken produced and used on receptor farms – farms/allotments;
- Beef produced and used on receptor farms – farms/allotments;
- Pork produced and used on receptor farms – farms/allotments;
- Milk produced and used on receptor farms – farms/allotments; and
- Breast milk – assessed for the residential and farm/allotment receptors at which the highest exposures were forecast to occur.

Potential exposure through the ingestion of drinking water requires the contamination of the local drinking water sources. The USEPA HHRAP includes the ingestion of locally abstracted surface water as a potential pathway of exposure to allow for modelling of special sites in situations where such a pathway of exposure is likely to be of potential concern (e.g. water storage ponds and lakes). The ingestion of groundwater as a potential source of exposure is not considered in this methodology as a feasible pathway of exposure and therefore is not included in the assessment procedure. No surface water abstraction points for drinking water are likely to be present in the vicinity of the site. Therefore, potential exposure through this pathway was not considered in this assessment.

4.3 Receptors

The air quality study found that the highest levels of released substances were forecast to occur within 1 km of the proposed facility. Consequently, the assessment of potential health risks associated with the forecast levels of released substances was focused on the areas surrounding the emission sources, and extending out to about 3 km. The purpose of characterising the exposure setting is to identify the type of human activities or land uses which determine the exposure scenarios that may result due to exposure to emissions from the proposed facility.

Within the assessment area around the proposed facility, the locations of potential sensitive receptors were identified. Following the identification of potentially sensitive locations, the highest yearly average value for each modelled air parameter (e.g. air concentration, dry deposition, wet deposition) for each phase (e.g. vapour, particle, particle-bound) was determined at each location.

The assessment was carried out at 31 representative locations, comprising 25 “residential” locations and 6 allotments (modelled as “farm” locations) within 3 km of the proposed facility. Three of the “residential” locations were identified as representative of farmland in the vicinity of the proposed development, and were therefore modelled as “farm” locations. Table 1 below sets out details of the assessment locations.

Table 1: Locations at which exposure to emissions was assessed

Ref.	Receptor name	Assessed as	Easting (m)	Northing (m)	Approx. distance from stack (km)
S1	The Croft 1 Residential/Farm	Farm	407828	441370	0.18
S2	The Croft 2 Residential/Farm	Farm	407773	441334	0.25
S3	Thwaites Brow Road Commercial 1	Residential	407731	441375	0.27
S4	Thwaites Brow Road Commercial 2	Residential	407588	441386	0.40
S5	The Orchard Residential	Residential	407568	441281	0.45
S6	Rose Street Residential	Residential	407519	441270	0.50
S7	Primrose Street (south) Residential	Residential	407517	441163	0.55
S8	Clay Hall Farm Residential/Farm	Farm	407724	441016	0.51
S9	Thwaites Brow Road Residential	Residential	407637	441067	0.52
S10	Airedale Road Commercial	Residential	407727	441539	0.27
S11	Gasworks Road Commercial	Residential	407773	441482	0.22
S12	Middle Way Residential	Residential	407194	441412	0.79
S13	Thwaites Lane Commercial	Residential	407473	441427	0.51
S14	Garforth Road Residential	Residential	407391	441813	0.69
S15	Aireworth Road Residential	Residential	407298	441716	0.74
S16	King George V Playing Field 1 Recreational	Residential	407863	441613	0.20
S17	King George V Playing Field 2 Recreational	Residential	407984	441560	0.11
S18	King George V Playing Field 3 Recreational	Residential	408050	441509	0.08
S19	King George V Playing Field 4 Recreational	Residential	408031	441613	0.16

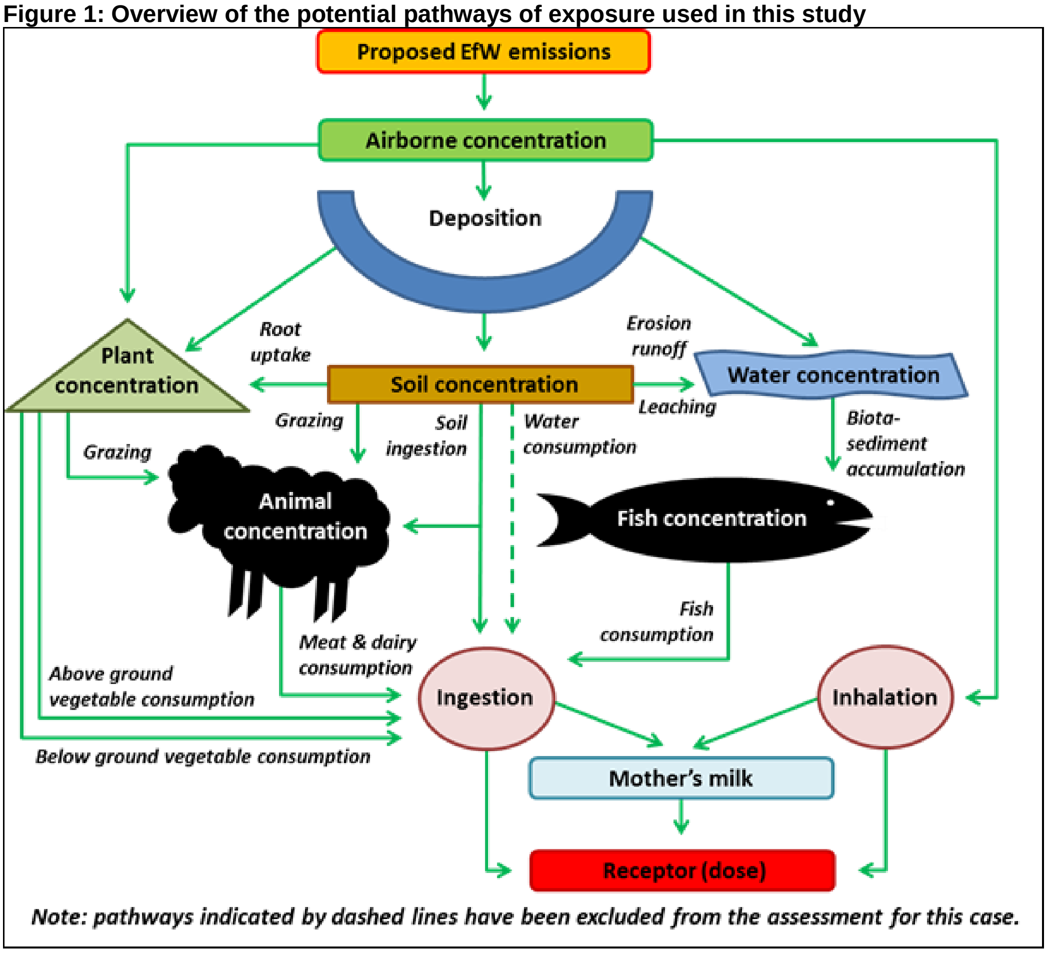
Ref.	Receptor name	Assessed as	Easting (m)	Northing (m)	Approx. distance from stack (km)
S20	King George V Playing Field 5 Recreational	Residential	408121	441534	0.16
S21	Aire Valley Road Commercial	Residential	408177	441372	0.21
S22	Marley Cottages Residential	Residential	408428	441210	0.50
S23	Airedale Cricket Club Recreational	Residential	408235	441819	0.44
S24	Bradford Road Riddlesden Residential	Residential	408481	441871	0.65
S25	East Riddlesden Hall Residential	Residential	407896	442054	0.61
S26	Westlea Avenue Riddlesden Residential	Residential	407809	442100	0.67
S27	Kinara Close Residential	Residential	407548	442015	0.71
S28	Airedale Road Commercial 2	Residential	407402	441565	0.59
S29	Haworth Allotments 1	Farm	403174	437234	0.18
S30	Haworth Allotments 2	Farm	402877	437285	0.25
S31	Silsden Allotments	Farm	403747	446032	0.27

For residential and farm scenarios, in accordance with the UK guidelines as published in CLR10,[8] the critical receptor is considered to be a female child aged 0-6.

4.4 Site conceptual model

The conceptual model for consideration of the potential health effects associated with emissions to air from the proposed facility is summarised in Figure 1.

Figure 1: Overview of the potential pathways of exposure used in this study



5 Stage II: Assess the consequences

The substances which would be emitted to air from the proposed facility are listed in Section 4.1. The air quality assessment report provides a detailed assessment of these emissions to air, with the exception of dioxins and furans, and dioxin-like PCBs, because of the nature of this group of chemicals. The air quality assessment includes a modelling study to forecast levels of these substances against air quality standards and guidelines which have been specified for the protection of health. The levels of released substances are forecast to comply with all relevant air quality standards and guidelines. In the single case of chromium VI, where baseline levels are above the relevant standards and guidelines, the proposed development would make an insignificant contribution to environmental levels. Assessment of these substances against the established air quality standards and guidelines is protective of human health via both direct and indirect pathways. On this basis, it is concluded that further assessment of these hazards is not required as part of this health risk assessment.

This is consistent with the approach adopted by the Environment Agency in relation to applications for thermal treatment processes. For example, in relation to the proposed Beddington Lane Energy Recovery Facility, London Borough of Sutton, the Environment Agency commented: "*As regards metal emissions, it should be noted that the environmental standards for ground level concentrations are considered to be sufficiently protective of human health, consequently the HHRA* [Human Health Risk Assessment] *should be concerned solely with dioxins and furans.*"[17] A similar approach was recommended by the Environment Agency in relation to the proposed Willows Power and Recycling Centre, Kings Lynn, Norfolk: "*For other pollutants such as heavy metals, in principle, we consider each EQS' as protective of human health. It is not therefore necessary to model the human body uptake of metals.*"[18]

Dioxins and furans, and dioxin-like PCBs, could not be assessed in this way because the main issues are associated with indirect exposure pathways. Consequently, it is important for this risk assessment chapter to estimate public exposure to levels of dioxins and furans, and dioxin-like PCBs, more fully. This is described in Stage III below.

Hence, the detailed assessment of risks to health posed by the facility has focused on emissions of dioxins and furans, and dioxin-like PCBs, and, in accordance with Environment Agency guidance does not provide further calculations of indirect exposure to other substances.

Emissions of dioxins and furans, and dioxin-like PCBs, from the proposed Aire Valley Clean Energy Facility are presented in Table 2 below.

Table 2: Dioxin and furan, and dioxin-like PCBs, congener emissions from the proposed facility

Congener	Annual mean emission concentration (ng I-TEQ/m^3) [19]	I-Toxic equivalent factor (as in Waste Incineration Directive)	Annual mean emission concentration (ng/m^3)	Emission rate (g I-TEQ/s)
2,3,7,8-TCDD	0.0031	1	0.0031	8.54×10^{-11}
1,2,3,7,8-PeCDD	0.0123	0.5	0.025	3.37×10^{-10}
1,2,3,4,7,8-HxCDD	0.0029	0.1	0.029	7.90×10^{-11}
1,2,3,6,7,8-HxCDD	0.0026	0.1	0.026	7.10×10^{-11}
1,2,3,7,8,9-HxCDD	0.0021	0.1	0.021	5.64×10^{-11}
1,2,3,4,6,7,8 HpCDD	0.0017	0.01	0.17	4.69×10^{-11}
OCDD	0.0004	0.001	0.4	1.11×10^{-11}
2,3,7,8-TCDF	0.0028	0.1	0.027	7.63×10^{-11}
1,2,3,7,8-PCDF	0.0014	0.05	0.028	3.81×10^{-11}
2,3,4,7,8-PCDF	0.0268	0.5	0.054	7.37×10^{-10}

[17] Environment Agency Air Quality Modelling and Assessment Unit, "Beddington Lane ERF: Response to NPS Request," Ref. AQMAU_C952_RP01
[18] Environment Agency Air Quality Modelling and Assessment Unit, "Willows Power & Recycling Centre," Ref. C791
[19] Congener profile adapted from Her Majesty's Inspectorate of Pollution (1996). "*Risk assessment of dioxin releases from municipal waste incineration processes*."

Congener	Annual mean emission concentration (ng I-TEQ/m^3) [19]	I-Toxic equivalent factor (as in Waste Incineration Directive)	Annual mean emission concentration (ng/m^3)	Emission rate (g I-TEQ/s)
1,2,3,4,7,8-HxCDF	0.0218	0.1	0.22	6.00×10^{-10}
1,2,3,6,7,8-HxCDF	0.0081	0.1	0.081	2.22×10^{-10}
1,2,3,7,8,9-HxCDF	0.0004	0.1	0.0042	1.16×10^{-11}
2,3,4,6,7,8-HxCDF	0.0087	0.1	0.087	2.40×10^{-10}
1,2,3,4,6,7,8-HpCDF	0.0044	0.01	0.44	1.21×10^{-10}
1,2,3,4,7,8,9-HpCDF	0.0004	0.01	0.043	1.18×10^{-11}
OCDF	0.0004	0.001	0.36	9.82×10^{-11}
Total (dioxins and furans)	0.1	-	2.02	2.75×10^{-9}
Aroclor 1016	0.0092	0.0001	92	2.53×10^{-10}
Total (dioxins and furans, and dioxin-like PCBs)	0.1092	-	94	3.01×10^{-9}

6 Stage III: Assess their probabilities

In summary, the risk assessment presented in this report results in the following outputs:

- Estimates of the combined cancer risks and non-cancer risks (Hazard Quotients) for all identified receptors;
- Estimates of risk and hazards associated with exposure to relevant COPC;
- Estimates of risk and hazards associated with pathways of exposure;
- Evaluation of infant exposure via breast milk to COPC with appropriate bio-transfer factors; and
- Estimates of the soil concentrations at most affected receptors to compare with urban and rural soil concentrations.

6.1 Risk estimates

The total cancer risk (TCR) and total hazard quotient (THQ) estimated by the model, based on the air dispersion modelling prediction of air concentrations and depositions by ADMS, for the proposed facility for all identified receptors are presented in Table 3 and Table 4 below. The highest modelled risk estimates for farm/allotment and residential receptors are highlighted in yellow.

Table 3: Risk summary at all "residential" locations considered

Ref.	Receptor name	Residential adult		Residential child	
		TCR	THQ	TCR	THQ
S3	Thwaites Brow Road Commercial 1	8.46×10^{-9}	5.81×10^{-6}	2.26×10^{-8}	1.61×10^{-5}
S4	Thwaites Brow Road Commercial 2	1.72×10^{-8}	1.18×10^{-5}	4.60×10^{-8}	3.26×10^{-5}
S5	The Orchard Residential	1.51×10^{-8}	1.04×10^{-5}	4.04×10^{-8}	2.87×10^{-5}
S6	Rose Street Residential	1.51×10^{-8}	1.03×10^{-5}	4.03×10^{-8}	2.86×10^{-5}
S7	Primrose Street (south) Residential	1.14×10^{-8}	7.85×10^{-6}	3.06×10^{-8}	2.17×10^{-5}
S9	Thwaites Brow Road Residential	1.08×10^{-8}	7.44×10^{-6}	2.90×10^{-8}	2.06×10^{-5}
S10	Airedale Road Commercial	6.20×10^{-9}	4.25×10^{-6}	1.66×10^{-8}	1.18×10^{-5}
S11	Gasworks Road Commercial	3.39×10^{-9}	2.33×10^{-6}	9.08×10^{-9}	6.44×10^{-6}
S12	Middle Way Residential	1.38×10^{-8}	9.44×10^{-6}	3.68×10^{-8}	2.61×10^{-5}
S13	Thwaites Lane Commercial	1.87×10^{-8}	1.28×10^{-5}	4.99×10^{-8}	3.54×10^{-5}
S14	Garforth Road Residential	1.09×10^{-8}	7.47×10^{-6}	2.91×10^{-8}	2.07×10^{-5}
S15	Aireworth Road Residential	1.19×10^{-8}	8.18×10^{-6}	3.19×10^{-8}	2.26×10^{-5}
S16	King George V Playing Field 1 Recreational	6.29×10^{-9}	4.32×10^{-6}	1.68×10^{-8}	1.19×10^{-5}
S17	King George V Playing Field 2 Recreational	4.47×10^{-10}	3.07×10^{-7}	1.19×10^{-9}	8.47×10^{-7}
S18	King George V Playing Field 3 Recreational	2.17×10^{-10}	1.49×10^{-7}	5.80×10^{-10}	4.12×10^{-7}
S19	King George V Playing Field 4 Recreational	1.15×10^{-8}	7.90×10^{-6}	3.08×10^{-8}	2.18×10^{-5}
S20	King George V Playing Field 5 Recreational	3.39×10^{-8}	2.33×10^{-5}	9.07×10^{-8}	6.43×10^{-5}
S21	Aire Valley Road Commercial	1.01×10^{-8}	6.94×10^{-6}	2.70×10^{-8}	1.92×10^{-5}
S22	Marley Cottages Residential	1.79×10^{-8}	1.23×10^{-5}	4.78×10^{-8}	3.39×10^{-5}
S23	Airedale Cricket Club Recreational	4.78×10^{-8}	3.28×10^{-5}	1.28×10^{-7}	9.07×10^{-5}
S24	Bradford Road Riddlesden Residential	3.96×10^{-8}	2.72×10^{-5}	1.06×10^{-7}	7.51×10^{-5}
S25	East Riddlesden Hall Residential	1.06×10^{-8}	7.26×10^{-6}	2.83×10^{-8}	2.01×10^{-5}
S26	Westlea Avenue Riddlesden Residential	8.33×10^{-9}	5.71×10^{-6}	2.23×10^{-8}	1.58×10^{-5}

Ref.	Receptor name	Residential adult		Residential child	
		TCR	THQ	TCR	THQ
S27	Kinara Close Residential	1.05×10^{-8}	7.22×10^{-6}	2.81×10^{-8}	2.00×10^{-5}
S28	Airedale Road Commercial 2	1.65×10^{-8}	1.13×10^{-5}	4.40×10^{-8}	3.12×10^{-5}

Table 4: Risk summary at all "farmer" locations considered

Ref.	Receptor name	Farmer adult		Farmer child	
		TCR	THQ	TCR	THQ
S1	The Croft 1 Residential/Farm	2.40×10^{-7}	1.80×10^{-4}	3.41×10^{-7}	2.58×10^{-4}
S2	The Croft 2 Residential/Farm	4.71×10^{-7}	3.53×10^{-4}	6.68×10^{-7}	5.05×10^{-4}
S8	Clay Hall Farm Residential/Farm	5.89×10^{-7}	4.42×10^{-4}	8.36×10^{-7}	6.33×10^{-4}
S29	Haworth Allotments 1	4.02×10^{-8}	3.02×10^{-5}	5.70×10^{-8}	4.31×10^{-5}
S30	Haworth Allotments 2	3.92×10^{-8}	2.94×10^{-5}	5.56×10^{-8}	4.20×10^{-5}
S31	Silsden Allotments	4.86×10^{-8}	3.65×10^{-5}	6.90×10^{-8}	5.22×10^{-5}

As stated previously, a value of 0.00001 (1×10^{-5}) was used as the benchmark for cancer risk and a hazard quotient of 1 was used as a benchmark for the assessment of individual contaminants. The data in Table 3 and Table 4 presents the combined risks from exposure to all contaminants to identify the most affected receptor.

It can be seen from the above results that the highest identified cancer risk and hazard quotient at a residential receptor is at 'Airedale Cricket Club Recreational' with highest predicted values of 1.28×10^{-7} for cancer risk and 9.07×10^{-5} (0.000091) for the hazard quotient. This evaluation is based on the assumption that an individual could be resident at or near this location, and would consume only vegetables produced at this location, and would also experience exposure via soil at this location. This will result in a substantial overestimate of the exposure that could conceivably arise in practice.

The highest identified cancer risk and hazard quotient for a "farm"/allotment receptor is at location 'Clay Hall Farm Residential/Farm' with predicted values of 8.36×10^{-7} for cancer risk and 6.33×10^{-4} (0.00063) for the hazard quotient. This evaluation is based on the assumption that an individual living at this location would consume only beef, pork, poultry, eggs, milk and vegetables produced from the allotment at this location. This will result in a substantial overestimate of the exposure that could conceivably arise in practice – for example, it is most unlikely that an individual would keep beef or dairy cattle at an allotment.

These values are well within the benchmarks of 0.00001 (1×10^{-5}) for cancer risk and 1 for the hazard quotient, and also comply with the value of 20% - 50% of these benchmarks, used when background exposure is not known.

6.2 Intake of dioxins and furans

The tolerable daily intake (TDI) for dioxins estimated by the model, based on the air dispersion modelling prediction of air concentrations and depositions by ADMS, for the proposed facility for the two locations at which the highest exposures were forecast are presented in Table 5 below.

Table 5: Predicted oral intake at the two most affected locations

Receptor	Airedale Cricket Club Recreational		Clay Hall Farm Residential/Farm	
	Resident adult	Resident child	Farmer adult	Farmer child
	Predicted oral intake (pgTEQ/kg body weight/day)			
Intake above ground vegetables	1.33×10^{-3}	3.07×10^{-3}	3.48×10^{-4}	8.06×10^{-4}
Intake beef	-	-	2.25×10^{-3}	1.38×10^{-3}
Intake chicken	-	-	8.24×10^{-6}	5.62×10^{-6}
Intake eggs	-	-	5.35×10^{-6}	3.85×10^{-6}

Receptor	Airedale Cricket Club Recreational		Clay Hall Farm Residential/Farm	
Intake milk	-	-	7.32×10^{-3}	1.21×10^{-2}
Intake pork	-	-	2.50×10^{-4}	1.91×10^{-4}
Intake soil	1.93×10^{-4}	9.02×10^{-4}	3.96×10^{-5}	1.85×10^{-4}
Total intake	1.52×10^{-3}	3.97×10^{-3}	1.02×10^{-2}	1.47×10^{-2}
Threshold	2 pg/kg-day			
% of threshold	0.08%	0.20%	0.51%	0.74%

The greatest intake at any assessed location is predicted to occur at 'Clay Hall Farm Residential/Farm'. On the basis that an individual at this location could theoretically consume vegetables, meat and dairy produce grown in that location, the maximum predicted intake is 1.47×10^{-2} pg/kg-day (0.0147 pg/kg-day). Despite the worst-case approach adopted in the assessment, the maximum incremental intake associated with the proposed facility is a small fraction (0.74 %) of the recommended tolerable daily intake for dioxins of 2 pg/kg-day, and would not be detectable in practice. At residential locations, the highest forecast increment would be 0.20 % or lower of the tolerable daily intake.

As noted above, where background exposure is unknown or relatively high, Defra suggests the use of a benchmark of 20% to 50% of the health criteria. Background exposure to dioxins and furans is dependent on individual environmental, lifestyle and physiological factors, and no single representative value can be derived for background exposure. This indicates that a benchmark of 20% to 50% of the health criterion would be appropriate for the assessment of the proposed facility. The highest modelled exposure level is 0.74 % of the relevant criterion, well below both these benchmarks.

6.3 Infant exposure to dioxins and furans through breast milk

IRAP-h View calculates the exposure through breast milk by calculating infant exposures, and risks associated with such exposures for 2,3,7,8-TCDD TEQ. There is no UK or USEPA target level for acceptable infant exposure. However, one approach USEPA has taken to evaluate forecast exposure to dioxins and furans is to compare the estimated exposure levels to national average background exposure levels. The Defra and Environment Agency R&D publication TOX 12[20], reported a UK background adult exposure of 1.8 pg TEQ/kg-day. The Former Ministry of Agriculture, Forestry and Fisheries (MAFF) calculated dietary intake by breast-fed infants to be 170 pg TEQ/kg-day at two months, dropping to 39 pg TEQ/kg-day at 10 months. Despite the relatively high intakes of dioxins experienced by nursing infants (about 100-fold those of an adult per kilogram body mass), the impact of breast-feeding on infant body burden of dioxins and furans is markedly less dramatic. Peak infant body burdens are around twice those of an adult, a consequence of the infant's rapidly expanding body weight and lipid volume, as well as a possibly faster elimination rate.

Table 6 below presents the estimated infant Additional Daily Dose (ADD) values for 'Airedale Cricket Club Recreational' and 'Clay Hall Farm Residential/Farm', at which the highest exposures due to the proposed facility were forecast to occur.

Table 6: Estimated infant additional daily doses (pgTEQ/kg body weight per day)

Receptor		Additional daily dose (pgTEQ/kg body weight/day)
Airedale Cricket Club Recreational	**Residential**	0.017
Clay Hall Farm Residential/Farm	**Allotment**	0.127

[20] Defra – Dioxins, Furans and dioxin-like PCBs published April 2003 R&D Publication – TOX 12

All of the estimated values at all locations are well below the range of UK infant background exposures discussed above with the highest being 0.127 pgTEQ/kg/day at Clay Hall Farm Residential/Farm.

Based on the above presented data the proposed facility will not pose a significant risk via the ingestion of contaminated breast milk even at the most affected receptors.

6.4 Soil concentration

As discussed previously, the background level of dioxins and furans within the locality of the proposed facility is an unknown quantity and is not practically feasible to quantify at a receptor scale. Table 7 below presents the highest estimated concentration of dioxins and furans in soil due to the proposed facility, in comparison to UK rural and urban soil concentration of the assessed contaminants as provided in "The UK Soil and Herbage Pollutant Survey".[16]

Table 7: Concentration of dioxins and furans in soils at 'Airedale Cricket Club Recreational' and 'Clay Hall Farm Residential/Farm'

Location	Maximum predicted soil level due to proposed facility (ng TEQ/kg)	Rural soil level (mean – ng TEQ/kg)	Urban soil level (mean – ng TEQ/kg)
Airedale Cricket Club Recreational	0.135	4.7	9.19
Clay Hall Farm Residential/Farm	0.028	4.7	9.19

The highest predicted soil level is 1.5% of the urban mean soil level identified in the 2007 survey, and would not constitute a significant additional burden in the context of the variability of soil levels of dioxins and furans between locations.

7 Stage IV: Characterise risk and uncertainty

7.1 Summary of exposure assessment

This chapter provides an assessment of possible effects on the health of humans due to emissions from the proposed Aire Valley Clean Energy Facility. As set out at Stage II, this focused on dioxins and furans, and dioxin-like PCBs, for which any effects are likely to be chronic arising from prolonged exposure. Potential secondary exposures, following the deposition of dioxins and furans, and dioxin-like PCBs, through the ingestion of affected soils, home-grown produce, beef, milk, pork, poultry and eggs at receptors within the vicinity of the site were also considered in the assessment.

The USEPA methodology "Human Health Risk Assessment Protocol 2005" was used to carry out the study. The USEPA default exposure parameters and toxicological data were replaced by those recommended by Defra and the EA reports CLR10 and R&D Publication TOX reports where available.

A simplified conceptual model was built for the site identifying all viable sources, receptors and pathways of exposure relevant to each of the receptors. In the absence of specific information in relation to the nature of the local receptors, all default pathways of exposure were assumed to exist, for each receptor scenario, to screen receptors with potentially significant exposure and consequently greater risks.

Dioxin and furan, and dioxin-like PCB, congener concentrations in the different receiving media were calculated from the particle phase and vapour phase air concentrations and deposition to the soil. The estimated concentrations were based on a number of conservative assumptions to ensure that worst-case scenarios were assessed.

To identify the level of potential risk from exposure to each individual chemical in all relevant pathways of exposure, the hazard quotients for each medium were calculated. Potential cancer risk was also estimated and compared with relevant acceptable risk levels and recommended tolerable daily intake.

The risks to health were found to comply with the relevant benchmarks at all potentially sensitive locations. Intakes were predicted to be higher if an individual could theoretically consume vegetables, meat and dairy produce grown at the location of highest concentration. Levels of released substances at allotments in the vicinity of the proposed facility were taken into account in the study. The highest theoretically possible intake of dioxins and furans was predicted to be 0.0147 pg/kg body weight/day. Despite the worst-case approach adopted in the assessment, this incremental intake associated with the proposed facility is a small fraction (0.74 %) of the recommended tolerable daily intake for dioxins of 2 pg/kg-day, and would not be detectable in practice. Similarly, the potential exposure of infants via breast milk was assessed, and it was found that the proposed facility would have no significant or detectable influence on exposure in this way.

There is uncertainty associated with the assessment of emissions to air from facilities such as the proposed Aire Valley Clean Energy Facility. These uncertainties relate to aspects such as the variability in exposures of individuals resulting from differences in diet and lifestyle. There are also uncertainties in the dispersion modelling of emissions from combustion processes.

To account for these uncertainties, a worst-case approach was adopted throughout the study. This means that, wherever there is uncertainty in an aspect of the study, the most pessimistic available assumption was adopted. Hence, for example, it was assumed that the proposed facility would operate continuously at the maximum limit set down in the Industrial Emissions Directive. Information provided in the air quality study indicates that emissions of dioxins and furans may be significantly less than the emissions limit. It was assumed that individuals could be present at the locations of highest exposure continuously, resulting in a pessimistic view of potential exposure to released substances.

7.2 Significance of risks to health

On the basis of the information set out above, it was concluded that emissions to air from the proposed Aire Valley Clean Energy Facility will not pose unacceptable health risks to residents or allotment-holders in the vicinity of the proposed facility.

7.3 Remedial action

On the basis of this assessment, no further remedial action or mitigation measures are required to further reduce the forecast impact of emissions to air from the proposed facility on health. The focus should be on ensuring that the detailed design, construction, operation and decommissioning of the proposed facility are carried out in accordance with Best Available Techniques and in accordance with the assumptions used to develop this risk assessment.

7.4 Risk management for the proposed development

On the basis of this assessment, no further risk management measures are required to further reduce the forecast impact of emissions to air from the proposed facility on health. As highlighted above, the focus should be on ensuring that the detailed design, construction, operation and decommissioning of the proposed facility are carried out in accordance with Best Available Techniques and in accordance with the assumptions used to develop this risk assessment.

7.5 Communication

It will also be important to ensure that the assessment of risks is clearly presented to decision-makers, local communities and other stakeholders. This discussion may need to be widened to encompass more widespread public concern with regard to the risks to health posed by waste incineration in general. In this regard, reference should be made to the Defra publication "Energy from waste: A guide to the debate,"[21] which includes a summary in relation to health impacts based on research carried out by Public Health England (formerly the Health Protection Agency):[22]

> *"The potential health implications of emissions are often a major focus of concern, hence the tight regulation of the emissions and the high priority Government gives to the ongoing process of conducting, evaluating and disseminating high quality science. Public Health England (PHE) has reviewed research undertaken to examine the suggested links between emissions from municipal waste incinerators and effects on health. It notes that modern, well-managed incinerators make only a small contribution to local concentrations of air pollutants. The PHE's view is that while it is possible that such small additions could have an impact on health, such effects, if they exist, are likely to be very small and not detectable."*

A more detailed review of health risks was carried out by Health Protection Scotland and SEPA.[23] This study concluded:

> "*Based on the limitations of available research literature, attempting to provide an overall conclusion on the health effects of incineration in total is particularly difficult.*
>
> *For waste incineration as a whole topic, the body of evidence for an association with (non-occupational) adverse health effects is both inconsistent and inconclusive. However, more recent work suggests, more strongly, that there may have been an association between emissions (particularly dioxins) in the past from industrial, clinical and municipal waste incinerators and some forms of cancer, before more stringent regulatory requirements were implemented.*

[21] Department of Environment, Food and Rural Affairs, "*Energy from waste: A guide to the debate*," February 2014 (revised edition)
[22] Health Protection Agency, "*The Impact on Health of Emissions to Air from Municipal Waste Incinerators,*" RCE-13, 2010
[23] Health Protection Scotland/Scottish Environmental Protection Agency, "*Incineration of Waste and Reported Human Health Effects*." Health Protection Scotland, Glasgow, 2009.

For individual incineration waste streams (clinical, hazardous, industrial and municipal), the evidence for an association with (non-occupational) adverse health effects is inconclusive.

The magnitude of any past health effects on residential populations living near incinerators that did occur is likely to have been small.

The majority of research work in this field is of historical relevance but tells us little about the current risk of (non-occupational) adverse effects potentially associated with incineration plants in operation now.

Levels of airborne emissions from individual incinerators should be lower now than in the past, due to stricter legislative controls and improved technology. Hence, any risk to the health of a local population living near an incinerator, associated with its emissions, should also now be lower."

The findings of the health risk assessment for the proposed Aire Valley Clean Energy Facility described in this report are consistent with the conclusions of these authoritative reviews.

Appendices

Appendix 1: Model input data

Appendix 1 – Model input data

Description	Resident adult	Resident child	Farmer adult	Farmer child	Units
Averaging time for carcinogens	30	6	40	6	Yr
Averaging time for noncarcinogens	30	6	40	6	Yr
Consumption rate of BEEF	0.0	0.0	0.00122	0.00075	kg/kg-day FW
Body weight	70	15	70	15	Kg
Consumption rate of POULTRY	0.0	0.0	0.00066	0.00045	kg/kg-day FW
Consumption rate of ABOVEGROUND PRODUCE	0.00032	0.00077	0.00047	0.00113	kg/kg-day DW
Consumption rate of BELOWGROUND PRODUCE	0.00014	0.00023	0.00017	0.00028	kg/kg-day DW
Consumption rate of DRINKING WATER	1.4	0.67	1.4	0.67	l/day
Consumption rate of PROTECTED ABOVEGROUND PRODUCE	0.00061	0.0015	0.00064	0.00157	kg/kg-day DW
Consumption rate of SOIL	0.0001	0.0001	0.0001	0.0001	kg/day
Exposure duration	30	6	40	6	Yr
Exposure frequency	350	365	350	350	Day/yr
Consumption rate of EGGS	0.0	0.0	0.00075	0.00054	kg/kg-day FW
Fraction of contaminated ABOVEGROUND PRODUCE	1.0	1.0	1.0	1.0	--
Fraction of contaminated DRINKING WATER	1.0	1.0	1.0	1.0	--
Fraction contaminated SOIL	1.0	1.0	1.0	1.0	--
Consumption rate of FISH	0.0	0.0	0.0	0.0	kg/kg-day FW
Fraction of contaminated FISH	1.0	1.0	1.0	1.0	--
Inhalation exposure duration	30	6	40	6	Yr
Inhalation exposure frequency	350	350	350	350	Day/yr
Inhalation exposure time	24	24	24	24	Hr/day
Fraction of contaminated BEEF	1.0	1.0	1.0	1.0	--
Fraction of contaminated POULTRY	1.0	1.0	1.0	1.0	--
Fraction of contaminated EGGS	1.0	1.0	1.0	1.0	--
Fraction of contaminated MILK	1.0	1.0	1.0	1.0	--
Fraction of contaminated PORK	1.0	1.0	1.0	1.0	--
Inhalation rate	0.83	0.49	0.83	0.49	m^3/hr
Consumption rate of MILK	0.0	0.0	0.01367	0.02268	kg/kg-day FW
Consumption rate of PORK	0.0	0.0	0.00055	0.00042	kg/kg-day FW
Time period at the beginning of Combustion	0	0	0	0	Yr
Length of exposure duration	30	6	40	6	Yr

'*kg/kg-day FW/DW = typical daily intake by kilogram of produce per kilogram of body weight per day, FRESH WEIGHT or DRY WEIGHT of plant or animal foodstuff

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