



## **Human Health Risk Assessment: Houghton Main Energy Centre**

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October 2018



Experts in air quality  
management & assessment

## Document Control

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## Executive Summary

- 1.1 A human health risk assessment has been carried out in order to identify any potential health risks associated with emissions of dioxins and furans from the proposed Houghton Main Energy Centre in Barnsley. The assessment draws on the dispersion modelling presented in the Air Quality Technical Report included as an appendix to the Environmental Statement for the scheme, and additionally uses the United States Environmental Protection Agency's Human Health Risk Assessment Protocol (HHRAP). A range of worst-case assumptions has been applied and thus the assessment is very precautionary.
- 1.2 The assessment has shown that the risks to health comply with the relevant benchmarks. All of the impacts are assessed to be insignificant. No specific mitigation measures are required.

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# 1 Introduction

- 1.1 A detailed human health risk assessment has been carried out in order to identify any potential health risks associated with emissions from the Houghton Main Energy from Waste scheme. The assessment has been carried out by Air Quality Consultants Ltd on behalf of Enzygo Ltd. It accompanies an Air Quality Technical Report included as an appendix to the Environmental Statement for the proposed development.
- 1.2 The pollutants of concern to this assessment (as defined in paragraph 2.1) are termed 'persistent', which means that they have the potential to remain and accumulate in the local environment over the operational life of the facility, including bioaccumulation through the food chain. The assessment is based on the United States Environmental Protection Agency (USEPA) Human Health Risk Assessment Protocol (HHRAP). This approach is current best-practice in the UK and is often recommended by the UK Environment Agency. The assessment has used the Industrial Risk Assessment Program-Human Health (IRAP) model, which is based on the HHRAP
- 1.3 The HHRAP method was developed to assess risks in areas where much of the population derives a substantial portion of its diet from local produce. Because of the potential for accumulation in the food chain, animal husbandry (particularly the raising of pigs and cattle) forms a key part of HHRAP. In practice, many areas near to the proposed Energy Centre are urban and thus the HHRAP method will provide an extremely conservative (i.e. worst-case) assessment.

## 2 Scope

- 2.1 Following standard Environment Agency practice for studies of this nature, the health risk assessment focuses on the uptake of polychlorinated dibenzo-para-dioxins and polychlorinated dibenzofurans, often abbreviated to 'dioxins and furans'. While other substances such as metals, acid gases, and particulate matter would be emitted from the proposed Energy Centre, these can be adequately assessed by comparing the predicted ambient concentrations against relevant assessment criteria. A detailed assessment of these other pollutants is presented in the Air Quality Technical Report for the proposed development.
- 2.2 Exposure to emissions of dioxins and furans can be through a number of pathways, with inhalation and the food chain being most critical. This assessment covers exposure through the direct inhalation of dioxins and furans as gases and fine airborne particles, as well as indirect exposure following the deposition of contaminants to land and subsequent transfer by biogeochemical processes through soils and vegetation into the food chain.
- 2.3 The assessment has not considered the potential for significant impacts associated with ingestion of drinking water, or dermal contact with soil or water. Other studies have shown that absorption through dermal contact with soil is significantly less efficient than absorption by inhalation and can thus safely be discounted (Pasternach, 1989). Dermal contact with standing water in the area will also be sporadic and unlikely to lead to significant exposure. Exposure via drinking water requires contamination of drinking water sources local to the point of consumption. Mains water for the local area comes from reservoirs throughout the Yorkshire Water region. The nearest reservoirs are located approximately 18 km west of the proposed Energy Centre. This is sufficiently far from the development site that mains water will not be significantly affected by emissions from the Energy Centre.
- 2.4 The assessment has also discounted the potential for local residents to derive a large proportion of their diet from locally-caught fish. Any fish caught in the local area are unlikely to provide a substantial part of people's diets, therefore this pathway has not been included in this assessment.

### 3 Assessment Approach

#### Baseline Conditions

- 3.1 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, baseline land quality, and background levels of dioxins and furans. This study has thus focused on the potential impact of the proposed Energy Centre, rather than on the combined effect of the proposed Energy Centre and other potential sources of exposure. If it is possible to demonstrate that the impacts of the proposed Energy Centre will be insignificant, then it is not necessary to calculate the total exposure.

#### Emissions of Dioxins and Furans from the proposed Energy Centre

- 3.2 The general term 'dioxins and furans' describes a large number of compounds, which are individually known as 'congeners'. Each congener has a different toxicity and physical properties with regard to atmospheric behaviour.
- 3.3 As explained in the Air Quality Technical Report, the Industrial Emissions Directive (IED) (2010/75/EU, 2010) allows a maximum emission rate for total dioxins and furans of  $0.1 \text{ ng/Nm}^3$  (averaged over a sampling period between 6 and 8 hours). The IED also provides a range of congener-specific international toxic equivalence (TEQ) factors by which the mass concentrations of specific congeners should be multiplied before summing. In other words,  $0.1 \text{ ng/Nm}^3$  refers not to the total mass emission, but to the toxic-equivalent emission. In practice, the proposed Energy Centre is unlikely to emit anywhere near  $0.1 \text{ ng/Nm}^3$ , but it has nevertheless been assumed that  $0.1 \text{ ng TEQ/Nm}^3$  would be emitted during every hour of every year. This provides a worst-case assessment.
- 3.4 Her Majesty's Inspectorate of Pollution (HMIP) previously published a dioxin and furan congener profile based on measurements at municipal waste incinerators (HMIP, 1996). This provides the most robust dataset to describe the proposed Energy Centre at this time and has thus been used to define the relative quantities of each congener that would be emitted.
- 3.5 The congener profile from HMIP has been combined with the IED toxic equivalence factor and the volumetric emission rate from the proposed Energy Centre to calculate g/s mass emissions of the individual congeners. These calculations are shown in Table 1.

**Table 1: Assumed Dioxin and Furan Emissions from the proposed Energy Centre**

Congener	Sum of Emissions (ng-TEQ/Nm <sup>3</sup> )	% of Total Toxic-Equivalent Conc from Each Congener	Toxic Eq Factor (ng TEQ / ng)	Mass Emission Conc (ng/Nm <sup>3</sup> ) <sup>a</sup>	Mass Emission Rate (g/s) <sup>b</sup>
2,3,7,8-TCDD	-	3.1%	1	0.0031	1.26 x 10 <sup>-10</sup>
1,2,3,7,8-PeCDD	-	12.4%	0.5	0.025	1.02 x 10 <sup>-9</sup>
1,2,3,4,7,8-HxCDD	-	2.9%	0.1	0.029	1.18 x 10 <sup>-9</sup>
1,2,3,7,8,9-HxCDD	-	2.1%	0.1	0.021	8.53 x 10 <sup>-10</sup>
1,2,3,6,7,8-HxCDD	-	2.6%	0.1	0.026	1.06 x 10 <sup>-9</sup>
1,2,3,4,6,7,8-HpCDD	-	1.7%	0.01	0.17	6.90 x 10 <sup>-9</sup>
OCDD	-	0.4%	0.001	0.4	1.62 x 10 <sup>-8</sup>
2,3,7,8-TCDF	-	2.7%	0.1	0.027	1.10 x 10 <sup>-9</sup>
2,3,4,7,8-PeCDF	-	26.8%	0.5	0.054	2.19 x 10 <sup>-9</sup>
1,2,3,7,8-PeCDF	-	1.4%	0.05	0.028	1.14 x 10 <sup>-9</sup>
1,2,3,4,7,8-HxCDF	-	21.8%	0.1	0.22	8.93 x 10 <sup>-9</sup>
1,2,3,7,8,9-HxCDF	-	0.4%	0.1	0.0042	1.71 x 10 <sup>-10</sup>
1,2,3,6,7,8-HxCDF	-	8.0%	0.1	0.081	3.29 x 10 <sup>-9</sup>
2,3,4,6,7,8-HxCDF	-	8.6%	0.1	0.087	3.53 x 10 <sup>-9</sup>
1,2,3,4,6,7,8-HpCDF	-	4.4%	0.01	0.44	1.79 x 10 <sup>-8</sup>
1,2,3,4,7,8,9-HpCDF	-	0.4%	0.01	0.043	1.75 x 10 <sup>-9</sup>
OCDF	-	0.4%	0.001	0.36	1.46 x 10 <sup>-8</sup>
<b>Sum</b>	<b>0.1</b>	<b>100%</b>	<b>-</b>	<b>2.1</b>	<b>8.19 x 10<sup>-8</sup></b>

<sup>a</sup> i.e. 0.1 ng TEQ/Nm<sup>3</sup> divided by the toxic equivalence factor and multiplied by the percentage of total toxic-equivalent concentration from each congener. Calculated from unrounded numbers.

<sup>b</sup> i.e. mass emission concentration (ng/Nm<sup>3</sup>) divided by 1 billion, multiplied by the volume flow rate (146,160 Nm<sup>3</sup>/hr – see the Air Quality Technical Report) divided by 3,600.

## Dispersion Modelling

- 3.6 The transport of emissions through air has been modelled using the ADMS-5 dispersion model. The model, and the input parameters used for this assessment, are described in the Air Quality Technical Report.
- 3.7 Dry and wet deposition of particle-bound and vapour-phase congeners has been simulated within the ADMS-5 model. In terms of the dry deposition of particles, because large particles will be filtered out from the stack emissions, particulate emissions are expected to be predominantly in the



1-2  $\mu\text{m}$  diameter range. For particles of this size, deposition velocities are likely to be in the range of 0.001 m/s to 0.1 m/s. For dry deposition of particle-bound congeners, a fixed worst-case deposition velocity of 0.01 m/s has thus been assumed. The dry deposition of vapour-phase congeners has been modelled using the ADMS default parameters for non-reactive gases.

- 3.8 The ADMS model has been run using five separate yearly meteorological datasets (2011 to 2015 inclusive) from Robin Hood Airport. These are the data used in the Air Quality Technical Report and are described therein. For each receptor, the maximum predicted concentration, dry deposition flux, and wet deposition flux during any year was taken and used for the health risk assessment. Where these maxima come from different years, the approach is worst-case since, in practice, one form of deposition depletes the potential for the other.

### ***Receptors for Dispersion Modelling***

- 3.9 Modelling has been carried out across three nested Cartesian grids of receptors, centred on the proposed development site:
- A 2 km x 2 km inner grid, with points spaced 20 m apart;
  - A middle grid, extending 3 km from the proposed development site, with points spaced 50 m apart; and
  - An outer grid, extending 5 km from the proposed development site, with points spaced 100 m apart.
- 3.10 The gridded receptors have been modelled at a height of 1.5 m, to represent ground-level human exposure.

## **Human Health Risk Assessment**

- 3.11 The assessment has used the IRAP model, which is based on HHRAP.

### ***Receptors for IRAP Model***

- 3.12 Within the IRAP model, there are four receptor types of relevance to this assessment:
- resident adult;
  - resident child;
  - farmer adult; and
  - farmer child.

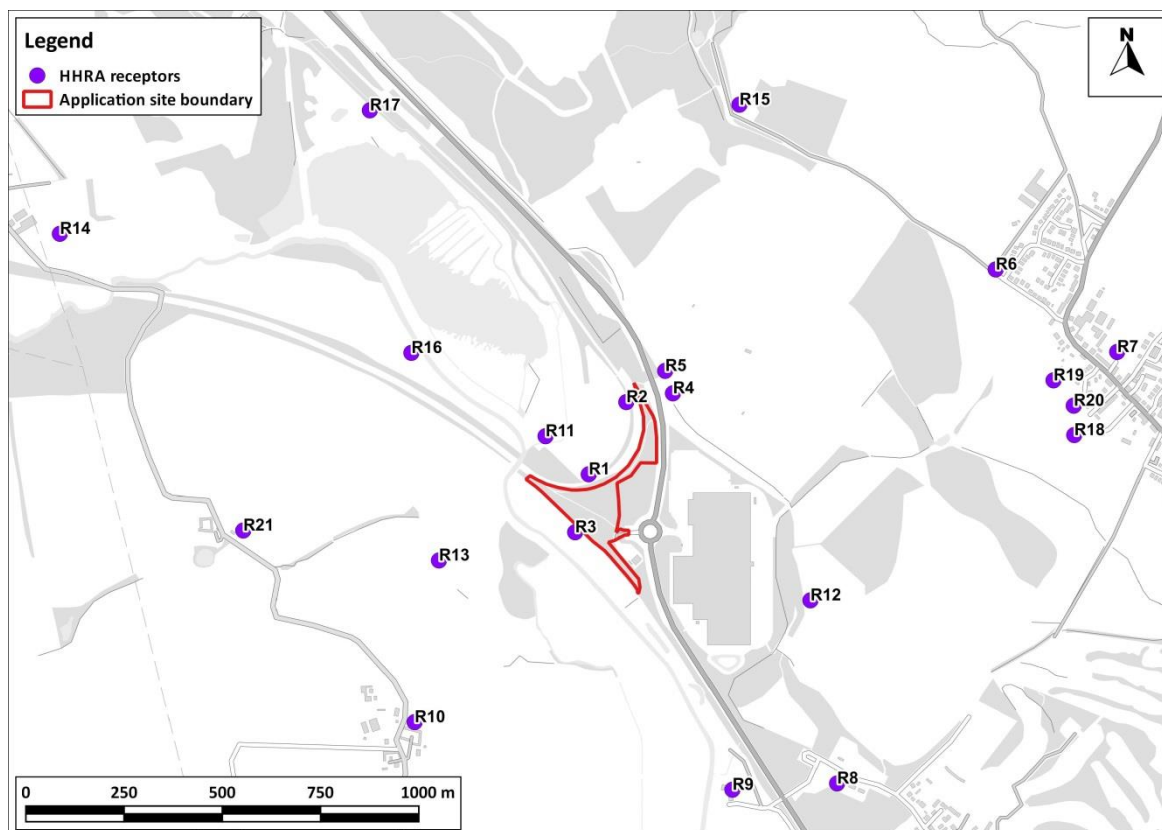
- 3.13 Resident receptors are assumed to have the potential to intake pollutants via inhalation, by eating above-ground home-grown vegetables and by eating soil<sup>1</sup>.
- 3.14 Farmer receptors are assumed to intake pollutants by these same pathways, but also from eating home-reared beef, chicken and pork, drinking milk from cows kept at home, and eating home-produced eggs. It is important to recognise that, when a receptor is included as a farmer, the assumption is made that the location is an active farm at which only beef, pork, poultry, eggs, milk and vegetables produced at that farm are consumed. It is unlikely that there are any such locations in the vicinity of the proposed Energy Centre. Allotments have been included as farm receptors. It should, though, be stressed that allotments are used for growing vegetables and not for animal husbandry and so are not really appropriate. Including them provides a worst-case assessment.
- 3.15 Occasionally, residents keep animals in domestic gardens. Where this occurs, it is highly unlikely that these animals would provide the dominant source of consumed food. While it is possible that, for example, chickens kept at home could provide the only source of eggs consumed, it is relatively unlikely that a dominant proportion of the chickens' food would be grown within the study area.
- 3.16 The results from the ADMS-dispersion model runs for the Cartesian grid of receptors have been plotted on a map and used to select the worst-case receptors for the human health risk assessment (i.e. the human health risk assessment receptors were chosen to represent locations where the gridded concentrations and deposition fluxes were highest). The receptors used for the health risk assessment are described in Table 2 and shown in Figure 1.

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<sup>1</sup> This is usually accidental and associated with home-grown vegetables.

**Table 2: Receptors Used in the Health Risk Assessment**

Receptor	Description	Type
R1	Farmland north of the proposed development	Farm
R2	Farmland north of the proposed development	Farm
R3	Farmland south west of the proposed development	Farm
R4	Arable land north east of the proposed development	Farm
R5	Arable land north east of the proposed development	Farm
R6	Residential property in Great Houghton	Residential
R7	Allotments in Great Houghton	Farm
R8	Residential property near Little Houghton	Residential
R9	Residential property near Little Houghton	Residential
R10	Residential property south west of the proposed development	Residential
R11	Farmland north of the proposed development	Farm
R12	Pasture south east of the proposed development	Farm
R13	Arable land north south west of the proposed development	Farm
R14	Pasture north west of the proposed development	Farm
R15	Arable north east of the proposed development	Farm
R16	Arable north west of the proposed development	Farm
R17	Farmland north west of the proposed development	Farm
R18	Allotments in Great Houghton	Farm
R19	Allotments in Great Houghton	Farm
R20	Residential property in Great Houghton	Residential
R21	Residential property west of the proposed development	Residential



**Figure 1: Receptors for Health Risk Assessment**

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### *IRAP Model Inputs*

- 3.17 The outputs from the ADMS-5 dispersion model have been used as inputs to the IRAP model. From these, IRAP calculated the concentrations of the various congeners in the environmental media, foodstuffs, and the human population.
- 3.18 The IRAP model requires a wide range of input data to be defined as set out below. In many cases the default parameters have been used, as is common practice for such assessments.

### *Physical and Chemical Properties of the Pollutants*

- 3.19 These parameters determine how the pollutants behave in the environment and their presence and accumulation in various food sources. The HHRAP and IRAP default values have been used in this assessment.

### *Site-specific Information*

- 3.20 The IRAP model requires information about the location and its surroundings including:

- the fraction of animal feed grown on local soils and the amount of animal feed and soil consumed by various species;
- the interception fraction for above ground vegetation, forage and silage and lengths of vegetation exposure to deposition;
- data for assessing the risks with exposure to breast milk, such as infant bodyweight, fraction of mother's body weight that is fat etc.; and
- other physical parameters such as soil and air density etc.

The HHRAP and IRAP default parameters have been used for all of this information.

3.21 Other parameters need to be taken from site-specific data. These are set out in Table 3.

**Table 3: Site-specific Parameters Used**

Parameter	Value
Annual Mean Precipitation	58.1 cm/yr <sup>a</sup>
Annual Mean Wind Velocity	4.6 m/s <sup>b</sup>
Annual Mean Evapotranspiration	40.7 cm/yr <sup>c</sup>
Annual Mean Irrigation	0 cm/yr
Annual Mean Runoff	5.8 cm/yr <sup>d</sup>
Time period over which deposition occurs	30 yrs

<sup>a</sup> The average of three year's meteorological data.

<sup>b</sup> The average of five year's meteorological data.

<sup>c</sup> Assumed to be 70% of precipitation.

<sup>d</sup> Assumed to be 1-% of precipitation.

### Receptor Information

3.22 For each receptor type, IRAP requires information on receptor behaviour including absolute and relative food consumption rates, body weight, inhalation rates, and exposure frequency etc. The HHRAP and IRAP default values have been used in this assessment.

### IRAP Model Outputs

#### Cancer Risk

3.23 The HHRAP approach is to calculate the probability of affected receptors developing cancer over their lifetime as a result of emissions from the proposed Energy Centre. This risk is presented as an absolute number which represents a probability. For example, a value of  $1 \times 10^{-6}$  (or 0.000001) represents a one in one million chance of an effect over a lifetime's exposure.

### Hazard Risk

- 3.24 IRAP has also been used to calculate the 'Hazard Quotient' for each receptor. The 'Hazard Quotient' is a way of expressing the ratio of the predicted exposure level and a 'reference dose' which represents the level at which no adverse effects are expected. Hazard Quotients are pollutant and pathway specific and can then be summed to calculate a 'Hazard Index'. Of the congeners considered in this assessment, a reference dose has only been set for the most toxic congener (2,3,7,8-TCDD) via the ingestion pathway. Thus, for this assessment, the Hazard Quotient and the Hazard Index are the same. The Hazard Quotient is simply the exposure level divided by the reference dose and is thus unitless.

### Oral Intake of All Congeners

- 3.25 While the Hazard Quotient only takes account of intake of the most toxic congener (2,3,7,8-TCDD), the total oral intake of all modelled congeners has been derived from the IRAP model and compared against defined 'Tolerable Daily Intake Levels' (TDIs). The units for this assessment are toxic-equivalent-picogrammes<sup>2</sup> per kg of bodyweight per day (pg-TEQ/kg/d).

### Infant Exposure through Breast Milk

- 3.26 Dioxins and furans are extremely fat soluble and hence prone to accumulation in breast milk. The accumulated compounds can then be passed to the infant. Exposure through breast milk is measured by the Average Daily Dose (ADD) on the basis of an averaging time of one year. The units for this assessment are also pg-TEQ/kg/d.

### Concentrations in Soils

- 3.27 The final set of outputs derived from the IRAP model is the concentrations of dioxins and furans in soils. These are expressed as the sum of all congeners in µg per kg (µg/kg) of soil (dry weight).

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<sup>2</sup> One picogramme is equal to 0.000000000001 grammes.

## 4 Assessment Criteria

### Cancer Risk

- 4.1 One definition of 'acceptable risk' that has been widely used in the UK, is if exposure to a substance increases a person's chance of dying in any one year by one chance in a million (1:1,000,000 or  $1 \times 10^{-6}$ ) or less<sup>3</sup> (Hunter and Fewtrell, 2010). The one in one million figure used in the UK is an annual figure. Since risk is cumulative, assuming a 70 year lifetime, the equivalent lifetime risk is one in fourteen thousand (1:14,300 or  $7 \times 10^{-5}$ ).
- 4.2 HHRAP uses a value of one in one hundred thousand (1:100,000 or  $1 \times 10^{-5}$ ) for lifetime cancer risk. This is effectively more stringent than the 1 in 1 million annual risk figure and has thus been used for this study. The assessment criterion for cancer risk is thus  $1 \times 10^{-5}$ .

### Hazard Risk

- 4.3 As explained in Paragraph 3.24, the Hazard Quotient is the predicted exposure level divided by the 'reference dose'. The HHRAP reference dose relevant to this study is given in Table 4. If the Hazard Quotient is less than 1 (i.e. the predicted exposure is less than the reference dose), then no adverse health effects are expected. If the Hazard Quotient is greater than 1, then adverse health effects are possible. The Hazard Quotient is different from the cancer risk estimates; in that it cannot be translated to a probability that adverse health effects will occur and it is unlikely to be proportional to risk. It is important to note that a Hazard Quotient exceeding 1 does not necessarily mean that adverse effects will occur; it simply indicates the potential for an effect.

**Table 4: Reference Dose and Hazard Quotient**

Description	Value
Reference Dose (of 2,3,7,8-TCDD per kg body weight) (mg/kg/d)	$1 \times 10^{-9}$
Hazard Quotient	1

### Oral Intake of All Congeners

- 4.4 The World Health Organisation (WHO) has recommended a range of TDIs (Table 5). These represent a lifetime's exposure and short-term exceedences of the TDI are not of concern if the long-term average is not exceeded (WHO, 1998).
- 4.5 In the UK, the Health Protection Agency and the Department of Health are advised by the Committee on the Toxicity of Chemicals in Food, Consumer Products and the Environment (COT).

<sup>3</sup> By way of comparison, the likelihood of dying in a road traffic accident is approximately 1 in 17,500 per year <http://www.medicine.ox.ac.uk/bandolier/booth/Risk/transportpop.html>

The COT has also provided recommendations on TDIs, which are based on adverse effects on a developing foetus (since this represents the most sensitive exposure pathway) (COT, 2001). The TDIs used in this study are set out in Table 5.

**Table 5: Tolerable Daily Intake (TDI) Values**

Reference Source	TDI (pg-TEQ/kg/d)
(WHO, 1998)	1 – 4
(COT, 2001)	2

### Infant Exposure through Breast Milk

- 4.6 There is no official UK or USEPA assessment criterion for acceptable infant exposure. One approach that is often taken is to compare the ADD against average background exposure levels, while other studies have cited a threshold value of 50 pg-TEQ/kg/d of the congener 2,3,7,8-TCDD as being potentially harmful.
- 4.7 Two separate approaches have been taken here. The first is to compare the ADD for all congeners against an assumed nominal baseline dose of 100 pg-TEQ/kg/day<sup>4</sup>. The second is to compare the ADD for the congener 2,3,7,8-TCDD against the threshold value of 50 pg-TEQ/kg/day.

### Concentrations in Soils

- 4.8 The Environment Agency has developed Soil Guideline Values (SGVs) for dioxins, furans, and dioxin-like PCBs (Environment Agency, 2009). These are assessment criteria that can be used to evaluate the risk to human health from long-term exposure to chemicals in soil.
- 4.9 For residential and allotment land uses, the SGVs are based on estimates representative of exposure of young children because they are generally more likely to have higher exposures to soil contaminants. The toxic equivalence of the various congeners has been taken into account in the derivation of the SGVs. Thus, the mass sum of all congeners in the soil may be compared directly with the SGVs.
- 4.10 The SGVs used in this assessment are set out in Table 6. These are based on a generic profile of congeners which is representative of general diffuse pollution, but within the context of this assessment are considered to be sufficiently accurate.

<sup>4</sup> A compilation of European dioxin exposure data (DETR, 1999) found that, in 1993, the dioxin intake of firstborn infants, up to 2 months of age, might be around 106 pg-TEQ/kg/day in rural areas of the EU and 144 pg TEQ/kg/day in industrial areas. These intake levels fall rapidly after the first few months. These are well in excess of the TDIs, but, as explained in Paragraph 3.5, the TDIs refer to an average lifetime's exposure. Exposure is likely to have fallen since 1993 but these values nevertheless provide a basis for assessment.



**Table 6: Soil Guideline Values (SGVs) for Dioxins, Furans, and Dioxin-like PCBs <sup>a</sup>**

Land use	Sum of Congeners (µg/kg DW)
Residential	8
Allotment	8
Commercial	240

<sup>a</sup> Based on an assumed soil profile for urban soils and on a sandy loam soil.

### Generic Environment Agency Screening Criteria

- 4.11 The Environment Agency has considered potential impacts from industrial emissions in its H1 guidance (Environment Agency, 2016). This explains that regardless of what the baseline environmental conditions are, a process can be considered as insignificant if the long-term (annual mean) process contribution is <1% of the long-term environmental standard.
- 4.12 It should be recognised that this criterion determines when an impact can be screened out as insignificant. It does not imply that impacts will necessarily be significant above this level merely that above this level there is a potential for significant impacts.

## 5 Results

### Cancer Risk

- 5.1 The total lifetime cancer risks associated with emissions from the facility for each of the receptors are presented in Table 7.
- 5.2 The data in Table 7 show that the highest residential risk is predicted at receptor R6 (residential property in Great Houghton), where the predicted lifetime risk of developing cancer as a result of emissions from the proposed Energy Centre is  $2.9 \times 10^{-9}$  (1 in 345 million). The highest risks at any of the receptors that have been treated as farms are at receptors R2 and R4 (farmland north and north east of the proposed Energy Centre) where the risk is  $4.5 \times 10^{-6}$  (1 in 222 million). All of the results are well below the assessment criterion of  $1 \times 10^{-5}$  (1 in one hundred thousand). Such risks are conventionally considered to be acceptable in the UK.

**Table 7: Total Lifetime Cancer Risk for all Receptors <sup>a</sup>**

R	Description	Type <sup>b</sup>	Child	Adult
R1	Farmland north of the proposed development	F	$5.0 \times 10^{-7}$	$2.3 \times 10^{-6}$
R2	Farmland north of the proposed development	F	<b><math>9.7 \times 10^{-7}</math></b>	<b><math>4.5 \times 10^{-6}</math></b>
R3	Farmland south west of the proposed development	F	$1.1 \times 10^{-7}$	$5.2 \times 10^{-7}$
R4	Arable land north east of the proposed development	F	<b><math>9.7 \times 10^{-7}</math></b>	<b><math>4.5 \times 10^{-6}</math></b>
R5	Arable land north east of the proposed development	F	$9.2 \times 10^{-7}$	$4.3 \times 10^{-6}$
R6	Residential property in Great Houghton	R	<b><math>1.5 \times 10^{-9}</math></b>	<b><math>2.9 \times 10^{-9}</math></b>
R7	Allotments in Great Houghton	F	$1.3 \times 10^{-7}$	$6.2 \times 10^{-7}$
R8	Residential property near Little Houghton	R	$1.1 \times 10^{-9}$	$1.9 \times 10^{-9}$
R9	Residential property near Little Houghton	R	$1.3 \times 10^{-9}$	$2.5 \times 10^{-9}$
R10	Residential property south west of the proposed development	R	$1.4 \times 10^{-9}$	$2.6 \times 10^{-9}$
R11	Farmland north of the proposed development	F	$1.5 \times 10^{-7}$	$7.0 \times 10^{-7}$
R12	Pasture south east of the proposed development	F	$3.1 \times 10^{-7}$	$1.4 \times 10^{-6}$
R13	Arable land north south west of the proposed development	F	$2.7 \times 10^{-7}$	$1.3 \times 10^{-6}$
R14	Pasture north west of the proposed development	F	$4.0 \times 10^{-8}$	$1.9 \times 10^{-7}$
R15	Arable north east of the proposed development	F	$2.7 \times 10^{-7}$	$1.3 \times 10^{-6}$
R16	Arable north west of the proposed development	F	$2.1 \times 10^{-7}$	$9.7 \times 10^{-7}$
R17	Farmland north west of the proposed development	F	$1.5 \times 10^{-7}$	$6.8 \times 10^{-7}$
R18	Allotments in Great Houghton	F	$1.6 \times 10^{-7}$	$7.6 \times 10^{-7}$
R19	Allotments in Great Houghton	F	$1.6 \times 10^{-7}$	$7.4 \times 10^{-7}$
R20	Residential property in Great Houghton	R	$1.3 \times 10^{-9}$	$2.3 \times 10^{-9}$
R21	Residential property west of the proposed development	R	$9.2 \times 10^{-10}$	$1.7 \times 10^{-9}$
<b>Assessment Criterion</b>			<b><math>1 \times 10^{-5}</math></b>	

$1 \times 10^{-5}$  = 1 in one hundred thousand chance of an effect over a lifetime's exposure

$1 \times 10^{-6}$  = 1 in one million chance of an effect over a lifetime's exposure

$1 \times 10^{-8}$  = 1 in one hundred million chance of an effect over a lifetime's exposure

$1 \times 10^{-10}$  = 1 in one billion chance of an effect over a lifetime's exposure

<sup>a</sup> The highest relevant values are shown in bold.

<sup>b</sup> R = residential, F = farm.

5.3 Table 8 shows the pathways of exposure for receptors R2, R4 and R6. The most significant pathway for the residential receptors is eating home-grown vegetables, while the most significant pathway for farm receptors is drinking home-produced milk. As explained in Paragraph 3.14, by including receptors as farms, it is assumed that the location is an active farm at which only beef, pork, poultry, eggs, milk and vegetables produced at that farm are consumed. As there are unlikely to be any such locations in the vicinity of the proposed Energy Centre (i.e. all local residents who consume these foodstuffs are likely to purchase at least some of their food), the assessment is thus worst-case.

**Table 8: Total Lifetime Carcinogenic Risk by Pathway at Worst-case Receptors <sup>a</sup>**

Pathway	Receptor R2 (Farm)		Receptor R4 (Farm)		Receptor R6 (Residential)	
	Child	Adult	Child	Adult	Child	Adult
Eating above ground vegetables	$8.8 \times 10^{-9}$	$2.6 \times 10^{-8}$	$8.7 \times 10^{-9}$	$2.5 \times 10^{-8}$	<b><math>1.2 \times 10^{-9}</math></b>	<b><math>2.6 \times 10^{-9}</math></b>
Eating soil	$1.5 \times 10^{-9}$	$1.2 \times 10^{-9}$	$1.4 \times 10^{-9}$	$1.1 \times 10^{-9}$	$2.8 \times 10^{-10}$	$1.5 \times 10^{-10}$
Inhalation	$9.6 \times 10^{-11}$	$6.4 \times 10^{-10}$	$9.6 \times 10^{-11}$	$6.4 \times 10^{-10}$	$1.9 \times 10^{-11}$	$9.4 \times 10^{-11}$
Eating home-reared beef	$9.0 \times 10^{-8}$	$9.7 \times 10^{-7}$	$9.0 \times 10^{-8}$	$9.8 \times 10^{-7}$	0	0
Eating home-reared chicken	$2.1 \times 10^{-11}$	$2.3 \times 10^{-10}$	$2.0 \times 10^{-11}$	$2.2 \times 10^{-10}$	0	0
Eating home-produced eggs	$1.5 \times 10^{-11}$	$1.5 \times 10^{-10}$	$1.4 \times 10^{-11}$	$1.4 \times 10^{-10}$	0	0
Drinking home-produced milk	<b><math>8.6 \times 10^{-7}</math></b>	<b><math>3.5 \times 10^{-6}</math></b>	<b><math>8.7 \times 10^{-7}</math></b>	<b><math>3.5 \times 10^{-6}</math></b>	0	0
Eating home-reared pork	$4.7 \times 10^{-9}$	$4.1 \times 10^{-8}$	$4.7 \times 10^{-9}$	$4.1 \times 10^{-8}$	0	0
<b>Total Lifetime Risk</b>	$9.7 \times 10^{-7}$	$4.5 \times 10^{-6}$	$9.7 \times 10^{-7}$	$4.5 \times 10^{-6}$	$1.5 \times 10^{-9}$	$2.9 \times 10^{-9}$

$1 \times 10^{-5}$  = 1 in one hundred thousand chance of an effect over a lifetime's exposure

$1 \times 10^{-6}$  = 1 in one million chance of an effect over a lifetime's exposure

$1 \times 10^{-8}$  = 1 in one hundred million chance of an effect over a lifetime's exposure

$1 \times 10^{-10}$  = 1 in one billion chance of an effect over a lifetime's exposure

<sup>a</sup> Highest relevant values in each column are shown in bold.

## Hazard Risk

5.4 The Hazard Quotient for each of the receptors is set out in Table 9. All of the values are less than 1 and the risk of significant health effects is thus discounted. The Hazard Risk pathway breakdown for receptors R2, R4 and R6 is given in Table 10. Again, this shows that eating home-

grown vegetables is the dominant risk pathway for residents, while for farmers it is drinking home-produced milk.

**Table 9: Hazard Quotient for All Receptors <sup>a</sup>**

R	Description	Type <sup>b</sup>	Child	Adult
R1	Farmland north of the proposed development	F	$2.3 \times 10^{-3}$	$1.6 \times 10^{-3}$
R2	Farmland north of the proposed development	F	$4.6 \times 10^{-3}$	$3.2 \times 10^{-3}$
R3	Farmland south west of the proposed development	F	$4.6 \times 10^{-4}$	$3.2 \times 10^{-4}$
R4	Arable land north east of the proposed development	F	$4.6 \times 10^{-3}$	$3.2 \times 10^{-3}$
R5	Arable land north east of the proposed development	F	$4.4 \times 10^{-3}$	$3.1 \times 10^{-3}$
R6	Residential property in Great Houghton	R	$4.8 \times 10^{-6}$	$1.8 \times 10^{-6}$
R7	Allotments in Great Houghton	F	$6.3 \times 10^{-4}$	$4.4 \times 10^{-4}$
R8	Residential property near Little Houghton	R	$3.3 \times 10^{-6}$	$1.2 \times 10^{-6}$
R9	Residential property near Little Houghton	R	$4.1 \times 10^{-6}$	$1.5 \times 10^{-6}$
R10	Residential property south west of the proposed development	R	$4.4 \times 10^{-6}$	$1.6 \times 10^{-6}$
R11	Farmland north of the proposed development	F	$6.2 \times 10^{-4}$	$4.3 \times 10^{-4}$
R12	Pasture south east of the proposed development	F	$1.4 \times 10^{-3}$	$1.0 \times 10^{-3}$
R13	Arable land north south west of the proposed development	F	$1.3 \times 10^{-3}$	$8.9 \times 10^{-4}$
R14	Pasture north west of the proposed development	F	$1.9 \times 10^{-4}$	$1.3 \times 10^{-4}$
R15	Arable north east of the proposed development	F	$1.3 \times 10^{-3}$	$9.1 \times 10^{-4}$
R16	Arable north west of the proposed development	F	$9.8 \times 10^{-4}$	$6.8 \times 10^{-4}$
R17	Farmland north west of the proposed development	F	$6.8 \times 10^{-4}$	$4.8 \times 10^{-4}$
R18	Allotments in Great Houghton	F	$7.6 \times 10^{-4}$	$5.3 \times 10^{-4}$
R19	Allotments in Great Houghton	F	$7.5 \times 10^{-4}$	$5.2 \times 10^{-4}$
R20	Residential property in Great Houghton	R	$3.9 \times 10^{-6}$	$1.5 \times 10^{-6}$
R21	Residential property west of the proposed development	R	$2.8 \times 10^{-6}$	$1.1 \times 10^{-6}$
<b>Assessment Criterion</b>			<b>1</b>	

$$1 \times 10^{-3} = 0.001$$

$$1 \times 10^{-6} = 0.000001$$

<sup>a</sup> Highest relevant values are shown in bold.

<sup>b</sup> R = residential, F = farm.

**Table 10: Hazard Quotient by Pathway at Worst-case Receptors <sup>a</sup>**

Pathway	Receptor R2 (Farm)		Receptor R4 (Farm)		Receptor R6 (Residential)	
	Child	Adult	Child	Adult	Child	Adult
Eating above ground vegetables	$3.0 \times 10^{-5}$	$1.3 \times 10^{-5}$	$3.0 \times 10^{-5}$	$1.2 \times 10^{-5}$	<b><math>4.2 \times 10^{-6}</math></b>	<b><math>1.8 \times 10^{-6}</math></b>
Accidentally Eating soil	$3.3 \times 10^{-6}$	$3.6 \times 10^{-7}$	$3.0 \times 10^{-6}$	$3.3 \times 10^{-7}$	$6.1 \times 10^{-7}$	$6.6 \times 10^{-8}$
Eating home-reared beef	$4.2 \times 10^{-4}$	$6.9 \times 10^{-4}$	$4.3 \times 10^{-4}$	$6.9 \times 10^{-4}$	0	0
Eating home-reared chicken	$4.9 \times 10^{-8}$	$7.2 \times 10^{-8}$	$4.5 \times 10^{-8}$	$6.6 \times 10^{-8}$	0	0
Eating home-produced eggs	$3.4 \times 10^{-8}$	$4.7 \times 10^{-8}$	$3.1 \times 10^{-8}$	$4.3 \times 10^{-8}$	0	0
Drinking home-produced milk	<b><math>4.1 \times 10^{-3}</math></b>	<b><math>2.5 \times 10^{-3}</math></b>	<b><math>4.1 \times 10^{-3}</math></b>	<b><math>2.5 \times 10^{-3}</math></b>	0	0
Eating home-reared pork	$2.1 \times 10^{-5}$	$2.8 \times 10^{-5}$	$2.1 \times 10^{-5}$	$2.8 \times 10^{-5}$	0	0
<b>Total Hazard Quotient</b>	$4.6 \times 10^{-3}$	$3.2 \times 10^{-3}$	$4.6 \times 10^{-3}$	$3.2 \times 10^{-3}$	$4.8 \times 10^{-6}$	$1.8 \times 10^{-6}$

$$1 \times 10^{-3} = 0.001$$

$$1 \times 10^{-6} = 0.000001$$

$$1 \times 10^{-9} = 0.000000001$$

<sup>a</sup> Highest relevant values in each column shown in bold.

## Oral Intake of all Congeners

5.5 Table 11 sets out the predicted oral intake of all congeners for receptors R2, R4 and R6. The results are separately compared with the TDIs from both WHO and COT. The predicted intakes at receptor R6 are well below 1% of the TDIs, however the predicted intakes at receptors R2 and R4 exceed 1% of the TDIs.

5.6 The impacts at receptors R2 and R4, as shown in Table 11, are up to 6.6% of the lower-bound WHO assessment criterion and up to 3.3% of the COT assessment criterion. While it is not possible to immediately discount these changes as insignificant, they remain small. It must also be recognised that these changes are based on the assumption that the plant will emit continuously at the maximum emission rates allowed under the IED. Furthermore, as discussed in paragraph 3.14, when a receptor is included as a farmer, the assumption is made that the location is an active farm at which only beef, pork, poultry, eggs, milk and vegetables produced at that farm are consumed. It is highly unlikely that this is the case for receptors R2 and R4, which represent the

worst-case points within individual fields close to the proposed Energy Centre. Taking these factors into account, it is considered that the predicted oral intake presented in Table 11 represents an extreme worst case. The actual impacts are expected to be much lower and are therefore judged unlikely to pose an unacceptable risk.

**Table 11: Predicted Oral Intake of Dioxins and Furans at Worst-case Receptors (pg-TEQ/kg/d)**

Pathway	Receptor R2 (Farm)		Receptor R4 (Farm)		Receptor R6 (Residential)	
	Child	Adult	Child	Adult	Child	Adult
Eating above ground vegetables	$7.1 \times 10^{-4}$	$3.0 \times 10^{-4}$	$7.0 \times 10^{-4}$	$3.0 \times 10^{-4}$	$1.0 \times 10^{-4}$	$4.3 \times 10^{-5}$
Eating soil	$1.9 \times 10^{-4}$	$2.0 \times 10^{-5}$	$1.8 \times 10^{-4}$	$1.9 \times 10^{-5}$	$3.6 \times 10^{-5}$	$3.8 \times 10^{-6}$
Eating home-reared beef	$6.1 \times 10^{-3}$	$1.0 \times 10^{-2}$	$6.1 \times 10^{-3}$	$1.0 \times 10^{-2}$	0	0
Eating home-reared chicken	$2.6 \times 10^{-6}$	$3.9 \times 10^{-6}$	$2.5 \times 10^{-6}$	$3.7 \times 10^{-6}$	0	0
Eating home-produced eggs	$1.8 \times 10^{-6}$	$2.5 \times 10^{-6}$	$1.7 \times 10^{-6}$	$2.4 \times 10^{-6}$	0	0
Drinking home-produced milk	$5.9 \times 10^{-2}$	$3.5 \times 10^{-2}$	$5.9 \times 10^{-2}$	$3.5 \times 10^{-2}$	0	0
Eating home-reared pork	$3.5 \times 10^{-4}$	$4.5 \times 10^{-4}$	$3.4 \times 10^{-4}$	$4.5 \times 10^{-4}$	0	0
Total Intake	0.066	0.046	0.066	0.046	0.00014	0.00005
WHO Assessment Criteria (TDI)	1-4					
COT Assessment Criteria (TDI)	2					
Intake as % of 1 pg-TEQ/kg/d	6.6	4.6	6.6	4.6	0.014	0.005
Intake as % of 2 pg-TEQ/kg/d	3.3	2.3	3.3	2.3	0.007	0.002

$$1 \times 10^{-3} = 0.001$$

$$1 \times 10^{-6} = 0.000001$$

$$1 \times 10^{-9} = 0.000000001$$

### Infant Exposure through Breast Milk

- 5.7 Table 12 sets out the estimated ADDs for infant exposure through breast milk for receptors R2, R4 and R6. The predicted ADDs have been compared with the assessment criteria described in Paragraph 4.7. All of the ADDs are less than 1% of the respective criteria and the impacts can thus be discounted as insignificant.

**Table 12: Estimated Infant Average Daily Dose (ADD) of Dioxins and Furans (pg-TEQ/kg/d)**

Pathway	Receptor R2 (Farm)	Receptor R4 (Farm)	Receptor R6 (Residential)
<b>All Congeners</b>			
<b>ADD (pg TEQ/kg/day)</b>	0.69	0.69	0.0010
<b>Assessment Criterion (pg TEQ/kg/day)</b>	100		
<b>ADD as percentage of Criterion</b>	0.69	0.69	0.0010
<b>2,3,7,8-TCDD</b>			
<b>ADD (pg TEQ/kg/day)</b>	0.097	0.098	0.0001
<b>Assessment Criterion (pg TEQ/kg/day)</b>	50		
<b>ADD as percentage of Criterion</b>	0.19	0.20	0.0002

### Concentrations in Soils

- 5.8 Table 13 sets out the maximum process contributions to dioxin and furan concentrations in soils at receptors R2, R4 and R6. The predicted concentration has been compared with the residential SGV defined in Table 6. The predicted concentrations are well below 1% of the SGV. The impacts can thus be discounted as insignificant.

**Table 13: Maximum Process Contribution to Dioxin and Furan Concentrations in Soils**

Parameter	Receptor R2 (Farm)	Receptor R4 (Farm)	Receptor R6 (Residential)
<b>Process Contribution to Maximum Soil Concentration (µg/kg)</b>	0.000305	0.000291	0.00006
<b>Soil Guideline Value (SGV) (µg/kg)</b>	8		
<b>Process Contribution as % of Guideline Value</b>	0.0038	0.0036	0.001



## 6 Conclusions

6.1 The human health risk assessment has shown that:

- **cancer risk** - all of the predicted process contributions are less than the assessment criterion. They are at levels which are conventionally considered to be acceptable and are thus discounted as **insignificant**;
- **hazard risk** - all of the predicted process contributions are less than 1 and the risk of effects can be discounted as **insignificant**;
- **oral intake of all congeners** - all of the predicted process contributions at relevant locations are extremely small and are judged to be **insignificant**;
- **infant exposure through breast milk** - all of the predicted process contributions are less than 1% of the relevant assessment criteria and can thus be discounted as **insignificant**; and
- **concentrations in soils** - all of the predicted process contributions are less than 1% of the relevant assessment criterion and can thus be discounted as **insignificant**.

6.2 These conclusions are on the basis that the proposed Energy Centre will emit dioxins and furans constantly at the maximum level permitted by the European Directive (2010/75/EU, 2010). In practice, emissions are expected to be a small fraction of those assessed; meaning that the impacts will have been grossly over-stated.

6.3 This assessment has found no requirement for specific mitigation measures.

## 7 References

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## 8 Glossary

<b>Congener</b>	An individual dioxin or furan compound
<b>TEQ</b>	International toxic equivalence units
<b>IED</b>	Industrial Emissions Directive
<b>ES</b>	Environmental Statement
<b>ADMS</b>	Atmospheric Dispersion Modelling System
<b>IRAP</b>	Industrial Risk Assessment Program-Human Health
<b>HHRAP</b>	Human Health Risk Assessment Protocol
<b>USEPA</b>	United States Environmental Protection Agency
<b>UK</b>	United Kingdom
<b>Dioxins</b>	polychlorinated dibenzo-para-dioxins
<b>Furans</b>	polychlorinated dibenzofurans
<b>HMIP</b>	Her Majesty's Inspectorate of Pollution
<b>Hazard Quotient</b>	The ratio of the predicted exposure level and a 'reference dose' which represents the level at which no adverse effects are expected
<b>2,3,7,8-TCDD</b>	A highly toxic congener
<b>TDI</b>	Tolerable Daily Intake
<b>WHO</b>	World Health Organisation
<b>COT</b>	Committee on the Toxicity of Chemicals in Food, Consumer Products and the Environment
<b>SGV</b>	Soil Guideline Value
<b>PCB</b>	Polychlorinated Biphenyl

### Units of Mass

<b>kg</b>	Kilogramme = 1,000 grammes
<b>g</b>	Gramme
<b>µg</b>	Microgramme = 0.000001 grammes
<b>ng</b>	Nanogramme = 0.000000001 grammes
<b>pg</b>	Picogramme = 0.000000000001 grammes

## Other units

<b>m<sup>3</sup></b>	Cubic metre
<b>Nm<sup>3</sup></b>	Normalised cubic metre
<b>s</b>	Second
<b>µm</b>	Micrometer= 0.000001 metres

## 9 Appendices

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## A1 Professional Experience

### **Prof. Duncan Laxen, BSc (Hons) MSc PhD MEnvSc FIAQM**

Prof Laxen is an Associate of Air Quality Consultants, a company which he founded in 1993. He has over forty years' experience in environmental sciences and has been a member of Defra's Air Quality Expert Group and the Department of Health's Committee on the Medical Effects of Air Pollution. He has been involved in major studies of air quality, including nitrogen dioxide, lead, dust, acid rain, PM<sub>10</sub>, PM<sub>2.5</sub> and ozone and was responsible for setting up the UK's urban air quality monitoring network. Prof Laxen has been responsible for appraisals of all local authorities' air quality Review & Assessment reports and for providing guidance and support to local authorities carrying out their local air quality management duties. He has carried out air quality assessments for power stations; road schemes; ports; airports; railways; mineral and landfill sites; and residential/commercial developments. He has also been involved in numerous investigations into industrial emissions; ambient air quality; indoor air quality; nuisance dust and transport emissions. Prof Laxen has prepared specialist reviews on air quality topics and contributed to the development of air quality management in the UK. He has been an expert witness at numerous Public Inquiries, published over 70 scientific papers and given numerous presentations at conferences. He is a Fellow of the Institute of Air Quality Management.

### **Dr Imogen Heard, BSc (Hons) MSc PhD MInstPhys**

Dr Heard is a Senior Consultant with AQC, having joined the company in 2013. Prior to joining she worked as a scientist in the Atmospheric Dispersion and Air Quality area at the UK Met Office for four years, modelling the dispersion of a range of pollutants over varying spatial and temporal scales. She now works in the field of air quality assessment and has been involved in numerous development projects including road schemes, energy from waste facilities, urban extensions and energy centres. These have included the use of ADMS-5 and ADMS-Roads dispersion models to study the impacts of a variety of pollutants, including nitrogen dioxide, PM<sub>10</sub> and PM<sub>2.5</sub>, and the preparation of air quality assessment reports and air quality chapters for Environmental Statements. She also has experience in undertaking construction dust risk assessments and Air Quality Neutral assessments, as well as in preparing local authority reports.

Full CVs are available at [www.aqconsultants.co.uk](http://www.aqconsultants.co.uk).