Proposed Aire Valley Clean Energy Facility

Environmental Permit Application – Air Quality Impact Assessment

Report for Endless Energy Ltd

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Executive summary

The proposed Aire Valley Clean Energy Facility will treat approximately 148,000 tonnes of commercial and industrial waste per annum, based on the estimated throughput at design point, generating both heat and electricity. The air quality impact assessment for the proposed facility was carried out as follows:

(a) Assessment of baseline air quality

(b) Identification of potentially sensitive locations

(c) Dispersion modelling study of emissions to forecast air concentrations and deposition rates at potentially sensitive locations

(d) Evaluation of forecast levels of released substances against relevant standards, guidelines, critical levels and critical loads

(e) Assessment of plume visibility

(f) Assessment of abnormal operating conditions/accidental releases

(g) Mitigation measures

(h) Conclusions

The main focus of the air quality assessment was the evaluation of modelled levels against relevant standards and guidelines. Levels of relevant substances were forecast at sensitive receptors to enable an assessment of the effects on air quality with regard to human health risks to be evaluated. Levels of relevant released substances were also forecast at designated habitat sites in the local area to enable an assessment of the potential effects on habitat sites due to emissions to air from the proposed facility to be carried out.

The study used a wide range of information on baseline air quality to characterise baseline conditions in the vicinity of the proposed facility. A state-of-the-art computer model was used to forecast the levels of substances emitted from the proposed facility that would result in the local area. The forecast levels of released substances combined with baseline levels were assessed against relevant air quality standards and guidelines.

In all cases, modelled levels of released substances when combined with background levels were forecast to comply with standards and guidelines for air quality at all locations in the vicinity of the proposed facility.

The proposed development is forecast to have no significant effects on air quality during abnormal operating conditions, and no significant cumulative effects are forecast to occur. No amenity issues such as odours or dusts would be expected to arise outside the site boundary, and emissions to air from the proposed facility are forecast to have no significant effects at designated habitat sites.

A screening assessment of the potential impacts on air quality at European habitat sites located near the proposed facility indicates that a more detailed assessment is not required.

The impact of the proposed facility on local ambient nitrogen dioxide and particulate matter (PM_{10}) levels was evaluated using a set of independent Environmental Protection UK criteria. This analysis was carried out using a very conservative approach, combining the highest forecast concentration changes in the vicinity of the proposed development with the highest baseline values recorded in recent years. On this basis, the maximum impact in relation to annual mean nitrogen dioxide can be described as “slight” and the maximum impact in relation to annual mean PM_{10} levels can be described as “negligible”. The maximum impacts at individual receptor sites will be less than the impacts described above, and are considered not to be significant.

The study was carried out using a highly conservative approach to ensure that any air quality effects are more likely to be overestimated than underestimated. On the basis of this assessment, it was concluded that the proposed facility will have no significant adverse effects on air quality. Consequently, it was concluded that no further mitigation is necessary, other than the extensive mitigation and control measures already built into the proposed facility.

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1 Introduction

The assessment and control of emissions to air from the proposed Aire Valley Clean Energy Facility is a key aspect of the environmental permit application for the proposed facility. This report provides an assessment of the air quality impacts of the proposed facility.

The proposed facility will include the following components:

- An energy-from-waste (EfW) power station. This facility will use moving grate technology for combustion of approximately 148,000 tonnes per annum commercial and industrial (C&I) waste, based on the estimated throughput at design point. Process water is heated to produce steam to drive a steam turbine which powers an electricity generator.
- A waste plastic melting plant. This plant will process approximately 30,000 tonnes per annum of plastic materials. This facility is not included in the permit application.
- Offices and visitor centre.

As well as being an important issue in its own right, the air quality assessment also informed the assessments of ecological and health issues. The air quality impact assessment for the proposed Clean Energy Facility was carried out as follows:

(a) Assessment of baseline air quality

(b) Identification of potentially sensitive locations

(c) Dispersion modelling study of emissions to forecast air concentrations and deposition rates at potentially sensitive locations

(d) Evaluation of forecast levels of released substances against relevant standards, guidelines, critical levels and critical loads

(e) Assessment of plume visibility

(f) Assessment of abnormal operating conditions/accidental releases

(g) Mitigation measures

(h) Conclusions

The main focus of the air quality assessment was the evaluation of modelled levels against relevant standards and guidelines.

Levels of relevant substances were forecast at sensitive receptors to enable an assessment of the effects on air quality with regard to human health risks to be evaluated.

Levels of relevant released substances were forecast at relevant designated habitat sites in the local area. This information was used to carry out a screening assessment in relation to the potential effects on habitat sites due to emissions to air from the proposed facility, with more detailed assessment in any situations where this was warranted. Information on designated habitat sites was obtained from the Defra MAGIC resource (www.magic.gov.uk) and the Conservation Agencies' APIS resource (www.apis.ac.uk).

2 Baseline air quality

A wide range of information sources was considered to enable baseline air quality in the local area to be characterised.

Reports produced by Bradford City Council for the purposes of local air quality management were reviewed to identify any information on baseline air quality which was relevant to the assessment of the proposed facility. This information was also evaluated to identify any concerns expressed by the local authority in respect of air quality at or in the vicinity of the proposed development. Bradford City Council has declared four air quality management areas (AQMAs) within the borough, but these are all located within the Bradford urban area, and do not extend near to the proposed development site.[1]

Bradford City Council currently operates seven continuous air monitoring stations across the city. The most representative site for the proposed development is the site at Keighley, 1.9 km from the proposed facility. Levels of nitrogen dioxide and particulate matter (PM_{10}, $PM_{2.5}$) are measured at this location. Levels of nitrogen dioxide are also measured using a diffusion tube technique at two locations in the vicinity of the site: 12 Prospect Street, Keighley (3.3 km west of the proposed facility), and Aireworth Road, Keighley (0.7 km west of the proposed facility).

Relevant measurements and data available from national resources were considered. These resources included the UK national air quality archive[2], and the www.apis.ac.uk resource operated by the nature conservation agencies. The information used included data from the following databases:

- Toxic Organic Micropollutants (TOMPs) network
- Trace elements monitoring network
- Ammonia and acid gases monitoring network
- Deposition monitoring network
- National background air quality maps, produced by Defra
- Estimated background nitrogen and acid deposition values at European sites from www.apis.ac.uk.

Although the information was not all local to the proposed development, it provided a useful dataset to enable a complete picture of baseline air quality to be gained. Having reviewed the available information, a representative baseline air quality level was identified. This was designed to provide a realistic worst-case estimate of baseline air quality levels in the study area, based on the best quality and most representative available data. A detailed evaluation of baseline air quality data was carried out, and representative baseline air quality levels for each substance of potential concern were summarised, as set out in Table 1 below.

Table 1: Baseline air quality in the study area

Substance	Long-term baseline level	Basis
Particulate matter (PM_{10})	17 µg/m^3	Highest level measured at Keighley Centre monitoring station between 2009 and 2015. This level is higher than the interpolated map values.
Particulate matter ($PM_{2.5}$)	17 µg/m^3	Assumed to be the same as the measured PM_{10} level as a conservative approach. This level is higher than the value measured at Keighley Centre in 2015 and higher than the interpolated map values.
Benzene	0.71 µg/m^3	Highest level measured at Leeds Centre monitoring station between 2012 and 2016. The use of data from Leeds Centre is likely to be an overestimate for the vicinity of the proposed facility.

[1] City of Bradford MDC, "2016 Air Quality Annual Status Report (ASR)," January 2017
[2] UK air quality archive, http://uk-air.defra.gov.uk/data/, accessed June 2017

Substance	Long-term baseline level	Basis
Hydrogen chloride	1.01 µg/m^3	Highest level measured at Ladybower monitoring station between 2010 and 2015.
Hydrogen fluoride	2.46 µg/m^3	Short-term peak level suggested by EPAQS[3].
Carbon monoxide	519 µg/m^3	Highest level measured at Leeds Centre monitoring station between 2012 and 2016. The use of data from Leeds Centre is likely to be an overestimate for the vicinity of the proposed facility.
Sulphur dioxide (annual mean)	2.53 µg/m^3	Highest level measured at Leeds Centre monitoring station between 2012 and 2016. The use of data from Leeds Centre is likely to be an overestimate for the vicinity of the proposed facility.
Sulphur dioxide (99.9th percentile of 15 minute mean concentrations)	87 µg/m^3	
Sulphur dioxide (99.7th percentile of 1 hour mean concentration)	34 µg/m^3	
Nitrogen dioxide	29 µg/m^3	Highest level recorded at Keighley Centre monitoring station between 2009 and 2015. This level is equivalent to the highest level recorded at diffusion tube locations in Keighley from 2010 to 2015, and is higher than the interpolated map values. Consequently, this level is likely to be conservative for assessment of the vicinity of the proposed development site.
Ammonia	1.16 µg/m^3	Highest level measured at the Ladybower survey site between 2010 and 2015. Levels on the edge of a town such as the proposed development location are if anything likely to be lower than those in a rural area because of the influence of agricultural sources. Consequently, this level is likely to be conservative for assessment of the vicinity of the proposed development site.
Dioxins and furans ITEQ	55 fgTEQ/m^3	Highest level measured at urban and rural locations in the UK between 2010 and 2012 (level recorded at Manchester, 2010).
PAHs (benz(a)pyrene)	0.143 ng/m^3	Highest level measured at any rural background location in the UK between 2012 and 2016 (level recorded at Stoke Ferry, 2012).
Metals		
Cadmium	0.12 ng/m^3	Levels measured at Manchester Wythenshawe as part of national survey in 2013. Likely to constitute an overestimate of baseline air quality levels in the study area.
Mercury	2.11 ng/m^3	
Arsenic	0.73 ng/m^3	
Lead	6.17 ng/m^3	
Chromium	4.51 ng/m^3	
Copper	42.8 ng/m^3	
Manganese	11.26 ng/m^3	
Nickel	1.44 ng/m^3	
Vanadium	1.16 ng/m^3	
Cobalt	0.16 ng/m^3	

[3] Expert Panel on Air Quality Standards, "*Guidelines for Halogens and Hydrogen Halides in Ambient Air for Protecting Human Health against Acute Irritancy Effects*," 2006

Substance	Long-term baseline level	Basis
Chromium VI	0.90 ng/m^3	Derived from total chromium measurement, on the basis of Environment Agency guidance that 20% of total chromium is in the form of chromium VI.[4]
Antimony	0.84 ng/m^3	Highest level recorded at the three closest monitoring stations between 2010 and 2013 (level recorded at Heigham Holmes, 2012).
Thallium		No national measurement. Baseline measurements used in relation to other developments[5] confirms that baseline levels are not significant in relation to the air quality standards and guidelines.

[4] Environment Agency, Environmental Risk Assessment Framework – H1 Annex F – Air Emissions, December 2011, https://consult.environment-agency.gov.uk/psc/ta6-6lq-mole-valley-feed-solutions-ltd/supporting_documents/Supporting%20Documents%20%20H1%20Annex%20F%20%20Air%20Emissions.pdf

[5] Veolia ES Staffordshire Limited, Project W2R: Energy Recovery Facility, Appendix 6.1: Air Quality Technical Report, December 2010, available via https://apps2.staffordshire.gov.uk/SCC/TrimDocProvider/?ID=003/07/06/04/10426 [accessed June 2017]

3 Methodology

3.1 Air quality modelling study

The air quality study was carried out in accordance with Environment Agency and Defra guidance on air quality modelling studies[6,7], and established good practice for air quality modelling and assessment. The study considered emissions from the EfW power station of substances controlled under the Industrial Emissions Directive (2010/75/EU), together with ammonia and polycyclic aromatic hydrocarbons, which may potentially also be significant.

The facility will also include an emergency diesel generator (5.3 MWth), with a 10 m stack. This unit will operate <500 hours per year, and will comply with the emission limit values set by the Medium Combustion Plant Directive (Annex II, Part 2, Table 2). Therefore, as there are no sensitive receptors within 150 m[8], this facility has not been included in the assessment, as per Environment Agency guidance[9].

In summary, the substances to be assessed are set out in Table 2.

Table 2: Substances to be assessed in the air quality modelling study

Substance	EfW Facility	3 x Silo filter outlets
Particulate matter (PM_{10} and $PM_{2.5}$)	✓	✓
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	✓	
Polycyclic aromatic hydrocarbons (PAHs)	✓	
Ammonia	✓	

The Atmospheric Dispersion Modeling System (ADMS) 5.2 dispersion model[10] was used to evaluate the levels of released substances in the vicinity of the proposed Clean Energy Facility. Levels of released substances were evaluated at the identified sensitive locations, and the highest forecast levels at any point in the vicinity of the site were identified. The model was also used to provide contour plots of levels of the key substances emitted from the proposed facility.

Five years meteorological data was obtained from a nearby, representative meteorological station. The closest weather station to the proposed EfW Facility is at Bingley, approximately 6 km south of the proposed facility. Measurements at this station are representative of the weather conditions likely to be experienced at the proposed development site. The meteorological data covered the years 2012 to 2016.

Meteorological data was sourced from the NOAA surface observations archive and processed into an hourly sequential format suitable for use in the dispersion model. Data filling was carried out where

[6] Department for Environment, Food & Rural Affairs, "Risk assessments for specific activities: environmental permits" available via https://www.gov.uk/government/collections/risk-assessments-for-specific-activities-environmental-permits [accessed June 2017]
[7] Environment Agency and Department for Environment, Food & Rural Affairs, "Environmental permitting: air dispersion modelling reports" available via https://www.gov.uk/guidance/environmental-permitting-air-dispersion-modelling-reports [accessed June 2017]
[8] Two receptors, S17 and S18, have been excluded as they represent the closest boundary of the King George V Playing Field, not a physical receptor. See Section 3.4 for further information about receptors.
[9] Environment Agency – Air Quality Modelling and Assessment Unit – Diesel Generator NO2 Short term Impact Assessment via https://consult.defra.gov.uk/airquality/medium-combustion-plant-and-controls-on-generators/supporting_documents/Generator%20EA%20air%20dispersion%20modelling%20report.pdf
[10] More information about ADMS 5.2 available from http://www.cerc.co.uk/environmental-software/ADMS-model.html [accessed June 2017]

necessary according to the methodology provided by the USEPA in their “Meteorological Monitoring Guidance for Regulatory Modelling Applications” guidance document[11]. The recommended filling procedure is based on the persistence method, where a missing value is replaced by the use of data from the previous hour(s). In addition data from the nearby Leeds Bradford meteorological station was used to gap fill missing cloud cover values where appropriate. Missing cloud cover data is quite common in meteorological data sets, though on this occasion after gap-filling the data capture is good, i.e. ≥90% for all meteorological parameters. The data capture for wind direction and wind speed at the Bingley meteorological station was found to be good.

The proposed development site is located in a hilly area. Terrain gradients in the vicinity of the site exceed 1 in 10 over significant distances in some areas, and the effects of terrain on dispersion could potentially be significant. Consequently, the effects of terrain on dispersion of emissions from the proposed facility were taken into account. Local terrain data was incorporated into the modelling study at the highest appropriate resolution.

Local land use patterns can affect the structure of the atmosphere. For example, the presence of high-rise buildings in an industrial or city centre area results in increased turbulence in the atmosphere. Conversely, areas with low vegetation or open water have less influence on the atmosphere, and tend to result in a more stable atmosphere. This is represented in the dispersion model using a parameter known as the “surface roughness length”. The surface roughness length used in this study was 0.5 metres, representative of parkland and open suburbia. The influence of temperature inversions on the dispersion of pollutants is considered by the dispersion model. This factors in both the changes in air temperature and the influence of local terrain.[12]

3.2 Deposition

The air quality model was used to model deposition to land of the substances identified in relevant Environment Agency guidance.[6] The substances of potential concern are listed in Table B8 of this guidance, and comprise:

- Arsenic
- Cadmium
- Chromium
- Copper
- Lead
- Mercury
- Nickel

Deposition of these substances was modelled following the screening approach set out in the Environment Agency guidance. This procedure assumes a dry deposition velocity of 0.01 m/s, which is multiplied by 3 in order to account for both wet deposition and dry deposition processes. The highest modelled deposition rates at any location in the study area were assessed against the benchmarks set out by the Environment Agency.

Additionally, deposition of nitrogen and acids at designated habitat sites was also investigated to ensure that the proposed development would have no significant effects at these protected sites. This focused on European and nationally-designated sites within 10 km of the proposed development site, and locally designated sites within 2 km of the proposed facility, following Environment Agency guidance.[6] A number of European sites, Sites of Special Scientific Interest (SSSIs) and locally designated sites were identified in this zone (see Section 3.4).

In contrast to the screening approach adopted for assessment of metal deposition, the assessment of deposition of nitrogen and acids at designated habitat sites was carried out in accordance with the

[11] United States Environmental Protection Agency, “Meteorological Monitoring Guidance for Regulatory Modelling Applications” available via https://www3.epa.gov/scram001/guidance/met/mmgrma.pdf [accessed June 2017]
[12] CERC “Note 110: Temperature inversions within ADMS via http://cerc.co.uk/environmentalsoftware/assets/data/doc_newsletters/CERC_note_110_Temperature_inversions.pdf

relevant Environment Agency guidance.[13] In accordance with this guidance, the following deposition velocities were assumed for the study:

Table 3: Deposition velocities

Substance	Deposition velocities (m/s)	
	Grassland	Woodland
Ammonia	0.02	0.03
Nitric oxide	0	0
Nitrogen dioxide	0.0015	0.003
Sulphur dioxide	0.012	0.024

Critical load information for the SSSIs and Local Wildlife Sites under consideration was taken from the APIS website (www.apis.ac.uk). Modelled deposition rates were assessed against the relevant critical loads identified for each designated habitat site.

3.3 Process design and emissions

Data on the process design and emissions was obtained from published data sources and agreed with the project team. This information comprised the following aspects for each emission source:

(a) Emissions concentration and/or release rate data.

(b) Emission temperature and volumetric flow/velocity data.

(c) Emission oxygen and moisture content for combustion sources.

(d) Location, height and diameter of the release points.

Based on advice from the design organisation, emissions from the EfW power station were assumed to be at the limits set in Chapter IV of the Industrial Emissions Directive (IED) (2010/75/EU). For the following parameters, emissions from the EfW installation were assumed to be at lower levels than the maximum values permitted by the IED, on the basis of advice from the design organisation on achievable releases for the proposed technology:

- NOx emissions (long-term): 150 mg/Nm^3 (below IED limit of 200 mg/Nm^3)
- Sulphur dioxide emissions (long-term): 18 mg/Nm^3 (below IED limit of 50 mg/Nm^3)
- Ammonia emissions: 5 mg/Nm^3 (below benchmark in BREF note of 10 mg/Nm^3)

Emissions of PAHs were assumed to be at the level identified in a planning and permit application for a similar facility in England.[14]

Source and emissions data used in the study are set out in Table 4 and Table 5.

Table 4: Source information

Parameter	Units	Value for			
		EfW Facility	PAC silo filter outlet	Lime silo filter outlet	Residue silo filter outlet
Stack location • **Easting:** • **Northing:**	**Metres**	407987 441455	407979 441447	407976 441443	407977 441417
Stack height	**Metres**	60 m	35.5 m*	35.5 m*	35.5 m*

[13] Environment Agency, "AQTAG 06: Technical Guidance on detailed modelling approach for an appropriate assessment for emissions to air." 20 April 2010 Version 10; Environment Agency, "*Habitats Directive – Environment Agency policy," Appendix 7 "Stage 1 and 2 Assessment of new PIR permissions under the Habitats Regulations*," issued 30 January 2009. Environment Agency, "*Habitats Directive: taking a new permission, plan or project through the regulations*," issued 10 August 2010

[14] Resource Recovery Solutions (Derbyshire) Limited, "*Sinfin Waste Treatment Facility Environmental Permit Application (EA/EPR/WP3133KP/A001), Impact Assessment Report,*" Produced by Scott Wilson, June 2009; United Utilities, "Human Health Risk Assessment: Energy from Waste Facility," Final Report produced by RPS Ltd, Version 1, March 2009

Parameter	Units	Value for			
		EfW Facility	PAC silo filter outlet	Lime silo filter outlet	Residue silo filter outlet
Stack internal (flue) diameter	**Metres**	1.47 m	0.3 m	0.3 m	0.3 m
Volume flux	**Cubic metres per second (m^3/s)**	39.41	0.14	0.14	0.7
Velocity	**Metres per second (m/s)**	23.2	1.98	1.98	10
Operating pattern		Continuous	Continuous	Continuous	Continuous
Discharge temperature	**Degrees C**	140	Ambient (15)	Ambient (15)	80
Discharge oxygen level	**% v/v**	6.4	-	-	-
Discharge moisture level	**% v/v**	19.32	-	-	-

* The silo outlets were estimated to be 0.5m above the height of the roofline.

Table 5: Concentrations of released substances

Substance	EfW Facility	
	Emission concentration for averaging periods >= 24 hours	Emission concentration for averaging periods < 24 hours
Particulate matter	10 mg/Nm^3	n/a
Volatile organic compounds	10 mg/Nm^3	20 mg/Nm^3
Hydrogen chloride	10 mg/Nm^3	60 mg/Nm^3
Hydrogen fluoride	1 mg/Nm^3	4 mg/Nm^3
Carbon monoxide	n/a	150 mg/Nm^3
Sulphur dioxide	18 mg/Nm^3	200 mg/Nm^3
Oxides of nitrogen	150 mg/Nm^3	400 mg/Nm^3
Metals group 1: Cadmium and Thallium	0.05 mg/Nm^3	
Metals group 2: Mercury	0.05 mg/Nm^3	
Metals group 3: Antimony, Arsenic, Lead, Chromium, Cobalt, Copper, Manganese, Nickel, Vanadium	0.5 mg/Nm^3	
Dioxins and furans	0.1 ng/Nm^3	
Polycyclic aromatic hydrocarbons as benz(a)pyrene	0.001 mg/Nm^3	
Ammonia	5 mg/Nm^3	

Note: "n/a" – not applicable (no short-term air quality standard with averaging period <24 hours for particulate matter and no short-term air quality standard with averaging period >=24 hours for carbon monoxide)

Where a short-term (typically half-hour) and a long-term limit (typically 24 hour) is set for emissions to air from the EfW Facility, the long-term limit was used to model concentrations for assessment against air quality standards and guidelines with an averaging period of 24 hours or more. The short-term limit was used to model concentrations for assessment against air quality standards and guidelines with an averaging period of less than 24 hours.

The air quality model was run for a range of stack heights, in order to identify the stack design which gives the optimum balance between the chimney size and the consequent air quality impact. On the basis of the model results, an appropriate stack height was identified. Model results are presented for the proposed stack height in Section 4.1.

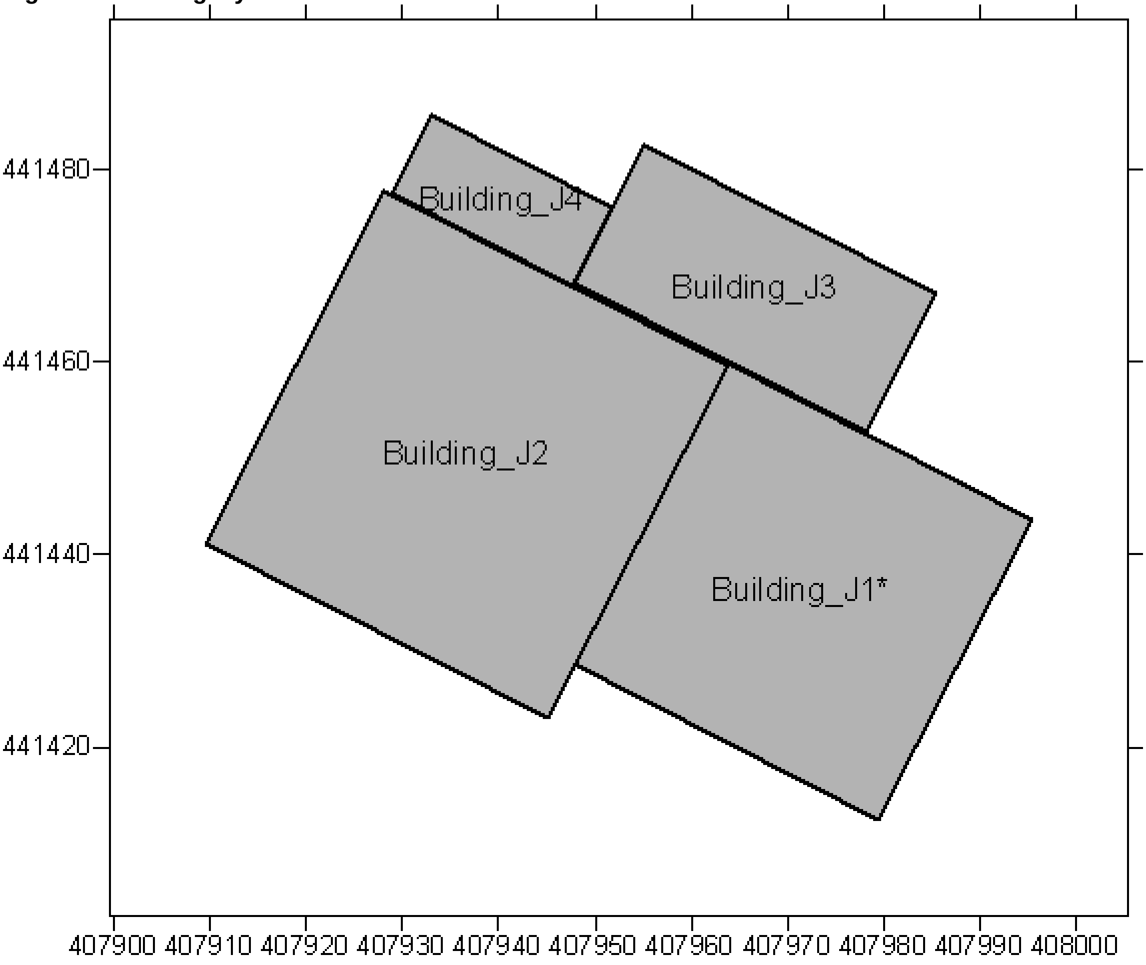
It was assumed that 70% of oxides of nitrogen are present as nitrogen dioxide for assessing long-term mean concentrations, and 35% present as nitrogen dioxide for assessing short-term mean concentrations, following Environment Agency guidance.[15]

The presence of buildings adjacent to the release point can affect the dispersion of emissions. Buildings do not have any significant effect on dispersion if they are less than 40% of the stack height. The effect of the proposed adjacent process buildings with a height greater than ~24 metres was taken into account in the present study using the appropriate modules of the ADMS dispersion model. The parameters used to represent these buildings were as set out in Table 6, and illustrated in Figure 1.

Table 6: Model parameters for site buildings

Parameter	Building J1	Building J2	Building J3	Building J4
Centre easting (m)	407971	407937	407967	407940
Centre northing (m)	441436	441450	441468	441477
Length (m)	36	40	34	21
Width (m)	35	41	16	9
Height (m)	35	28	24	30.5
Angle	297°			

Figure 1: Building layout



[15] Environment Agency, "*Conversion ratios for NO_x and NO_2*," undated, available from http://webarchive.nationalarchives.gov.uk/20140328084622/http:/www.environment-agency.gov.uk/static/documents/Conversion_ratios_for__NOx_and_NO2_.pdf

3.4 Receiving environment

Baseline air quality in the local receiving environment is described in Section 2. The proposed facility does not lie in or near an Air Quality Management Area. This is reflected in the relatively low baseline levels of PM_{10} and nitrogen dioxide described in Section 2.

Potentially sensitive locations in the vicinity of the facility were identified from Ordnance Survey mapping and from site visits. A notional radius of 3 km was used for this assessment. These sensitive locations included residential properties, schools, medical centres, leisure facilities, allotments, and farms.

The identified potentially sensitive locations in the vicinity of the proposed facility are listed in Table 7. These locations are shown in Figure 3 and Figure 4.

Table 7: Potentially sensitive locations in the vicinity of the proposed facility

Location		Easting	Northing	Approx. distance from stack (km)
S1	The Croft 1 Residential/Farm	407828	441370	0.18
S2	The Croft 2 Residential/Farm	407773	441334	0.25
S3	Thwaites Brow Road Commercial 1	407731	441375	0.27
S4	Thwaites Brow Road Commercial 2	407588	441386	0.40
S5	The Orchard Residential	407568	441281	0.45
S6	Rose Street Residential	407519	441270	0.50
S7	Primrose Street (south) Residential	407517	441163	0.55
S8	Clay Hall Farm Residential/Farm	407724	441016	0.51
S9	Thwaites Brow Road Residential	407637	441067	0.52
S10	Airedale Road Commercial	407727	441539	0.27
S11	Gasworks Road Commercial	407773	441482	0.22
S12	Middle Way Residential	407194	441412	0.79
S13	Thwaites Lane Commercial	407473	441427	0.51
S14	Garforth Road Residential	407391	441813	0.69
S15	Aireworth Road Residential	407298	441716	0.74
S16	King George V Playing Field 1 Recreational	407863	441613	0.20
S17	King George V Playing Field 2 Recreational	407984	441560	0.11
S18	King George V Playing Field 3 Recreational	408050	441509	0.08
S19	King George V Playing Field 4 Recreational	408031	441613	0.16
S20	King George V Playing Field 5 Recreational	408121	441534	0.16
S21	Aire Valley Road Commercial	408177	441372	0.21
S22	Marley Cottages Residential	408428	441210	0.50
S23	Airedale Cricket Club Recreational	408235	441819	0.44
S24	Bradford Road Riddlesden Residential	408481	441871	0.65
S25	East Riddlesden Hall Residential	407896	442054	0.61
S26	Westlea Avenue Riddlesden Residential	407809	442100	0.67
S27	Kinara Close Residential	407548	442015	0.71
S28	Airedale Road Commercial 2	407402	441565	0.59
S29	Haworth Allotments 1	403174	437234	6.40
S30	Haworth Allotments 2	402877	437285	6.60

Location		Easting	Northing	Approx. distance from stack (km)
S31	**Silsden Allotments**	403747	446032	6.24

Additionally levels of released substances were assessed at a grid of points extending 3 km in each direction from the centre of the site. The grid size was 101 × 101 points, resulting in a grid resolution of 60 m. The size of the grid was reviewed to confirm that the point of maximum concentration was identified.

Designated habitat sites (European sites, Ramsar Sites and SSSIs) within 10 km of the proposed facility were considered, following Environment Agency guidance.[6] European sites include Special Areas of Conservation (SAC) sites and Special Protection Areas (SPA) sites. Distances were measured from the closest point on the designated habitat site to the centre of the proposed facility. Receptor sites were also included for woodland features within the South Pennine Moors. Although emissions from the proposed facility could potentially affect designated sites further away from the proposed facility, any impacts would be less significant than those forecast at sites within the 10 km zone. No further assessment was carried out in relation to SSSIs designated on the basis of their geological interest alone. The designated sites identified within 10 km of the proposed facility are set out in Table 8.

Additionally, discussions were held with local wildlife organisations to identify any locally designated sites within 2 km of the proposed development. These sites are listed in Table 8, and are classified as follows:

1. SEGI - Sites of Ecological or Geological Importance

   Sites of Ecological or Geological Importance' (SEGI) are areas identified by the relevant local authority as being important for their flora, fauna, geological or physiological features. They are of county-wide importance.

2. LWS - Local Wildlife Sites

   West Yorkshire is currently going through a process of merging 2nd and 3rd tier local sites into a single Local Wildlife Site (LWS) designation. The intent is that sites should be given the same protection as SEGIs, as set out in Unitary Development Plans (UDPs) and Local Development Frameworks (LDFs).

3. BWA - Bradford Wildlife Areas

   Bradford Wildlife Areas (BWA) are third tier sites, designated by the local authority on the basis of their amenity value. Many of these sites have recently been resurveyed and are being assessed against new Local Wildlife Sites (LWS) criteria.

Table 8: Designated habitat sites in the vicinity of the proposed facility

Site		Designation	X(m)	Y(m)	Approx. distance from stack (km)
H1	**South Pennine Moors SSSI, South Pennine Moors SAC, and South Pennine Moors Phase 2 SPA: Ilkley Moor section**	SSSI / SAC / SPA	407930	443851	2.40
H2			408434	443875	2.46
H3			409010	444045	2.78
H4			410168	443857	3.24
H5			410265	443754	3.24
H6			410350	443584	3.18
H7			410478	443499	3.22
H8			410775	442893	3.14
H9			410920	442189	3.02
H10			411727	442250	3.82
H11			411109	446499	5.93
H12			411935	446400	6.33
H13			412440	446637	6.83
H14			412684	446758	7.08

H15	South Pennine Moors SSSI, South Pennine Moors SAC, and South Pennine Moors Phase 2 SPA: Keighley Moor section	SSSI / SAC / SPA	399548	442268	8.48
H16			399869	441922	8.13
H17			400070	441201	7.92
H18			400355	440273	7.72
H19			400634	439605	7.58
H20			400725	439363	7.56
H21			400355	438501	8.18
H22			401628	436524	8.05
H23			401847	436088	8.15
H24			402817	433819	9.22
H25			403357	433328	9.35
H26			404776	433407	8.66
H27			405540	432661	9.13
H28			405995	432121	9.54
H29			406511	431848	9.72
H30			398767	436860	10.3
H31	Bingley South Bog	SSSI	411442	438744	4.39
H32	Trench Meadows	SSSI	413031	438859	5.67
H33	Beechcliffe Ings	SEGI	406100	442500	2.16
H34	Coppice Bog and Pond	SEGI	408700	439000	2.56
H35	Leeds-Liverpool Canal (part Leeds)	SEGI	408000	442400	0.95
H36	Sunnydale, East Morton	SEGI	410200	442800	2.59
H37	Hainworth Wood	LWS	405900	439700	2.73
H38	Harden Moor and Deepcliffe Wood	LWS	408100	439400	2.06
H39	How Beck Wood Riddlesden	LWS	408500	442200	0.90
H40	Beechcliffe Ox-Bow Lake	BWA	406200	442700	2.18
H41	Castlefields Marsh	BWA	409400	441100	1.46
H42	Deepcliffe Wood, Harden	BWA	407700	439100	2.37
H43	East Morton Sewage Works	BWA	408600	441800	0.70
H44	Elam Wood, Keighley	BWA	406000	442800	2.40
H45	Hollin Plantation, Bingley	BWA	408006	440400	1.06
H46	Low Wood, Keighley	BWA	405800	443600	3.06
H47	North Beck, Keighley	BWA	405500	440900	2.55
H48	Park Wood, Keighley	BWA	407600	441200	0.46
H49	Rivock Edge Plantation	BWA	407300	444100	2.73
H50	Spring Bank, Keighley	BWA	405800	439700	2.80
H51	St Ives Estate	BWA	408100	439800	1.66
H52	Stockbridge Nature Reserve	BWA	407400	442200	0.95

3.5 Standards and guidelines

Levels of released substances were assessed against the relevant standards and guidelines for air quality. These standards and guidelines derive from a range of references, including:

- European environmental quality standards

- Air quality regulations for England
- Expert group recommendations
- World Health Organisation recommendations
- Environmental assessment levels (EALs) derived from occupational exposure standards

The standards and guidelines used in the assessment were specified at a level such that no significant adverse effects on air quality would be expected to arise provided air quality complies with the relevant standards and guidelines.

The key reference point to identify air quality standards and guidelines was the Environment Agency's guidance on "Air emissions risk assessment for your environmental permit"[16]. The principles, standards and guidelines set out in this guidance were adopted for this assessment. The relevant standards and guidelines are set out in Table 9.

Table 9: Air quality standards and guidelines

Substance	Averaging time	Standard value (µg/m^3)
Particulate matter (PM_{10})	Annual mean	40
Particulate matter (PM_{10})	90.4th percentile of 24 hour means	50
Particulate matter ($PM_{2.5}$) (target)	Annual mean	20
Volatile organic compounds (assessed against standard for benzene)	Annual mean	3.25
Hydrogen chloride	Maximum hourly mean	750
Hydrogen fluoride	Annual mean	16
Hydrogen fluoride	Maximum hourly mean	160
Hydrogen fluoride (vegetation)	Maximum 24 hour mean	5
Carbon monoxide	Maximum 8 hour mean	10,000
Sulphur dioxide	99.9th percentile of 15 minute means	266
Sulphur dioxide	99.7th percentile of hourly means	350
Sulphur dioxide	99.2nd percentile of 24 hour means	125
Sulphur dioxide (vegetation)	Annual mean	20
Sulphur dioxide (vegetation)	Winter mean	20
Nitrogen dioxide	Annual mean	40
Nitrogen dioxide	99.79th percentile of hourly means	200
Oxides of nitrogen (vegetation)	Annual mean	30
Oxides of nitrogen (vegetation)	Maximum 24 hour mean	75
Ammonia	Annual mean	180
Ammonia	Maximum hourly mean	2,500
Ammonia (vegetation)	Annual mean	1 or 3
Cadmium	Annual mean	0.005
Thallium	Annual mean	No standard
Thallium	Maximum hourly mean	No standard
Mercury	Annual mean	0.25
Mercury	Maximum hourly mean	7.5
Antimony	Annual mean	5
Antimony	Maximum hourly mean	150

[16] Environment Agency, Department for Environment, Food & Rural Affairs, "Guidance – Air emissions risk assessment for your environmental permit" available via https://www.gov.uk/guidance/air-emissions-risk-assessment-for-your-environmental-permit

Substance	Averaging time	Standard value ($\mu g/m^3$)
Arsenic	Annual mean	0.003
Lead	Annual mean	0.25
Chromium	Annual mean	5
Chromium	Maximum hourly mean	150
Chromium VI	Annual mean	0.0002
Cobalt	Annual mean	No standard
Cobalt	Maximum hourly mean	No standard
Copper	Annual mean	10
Copper	Maximum hourly mean	200
Manganese	Annual mean	150
Manganese	Maximum hourly mean	1,500
Nickel	Annual mean	0.02
Vanadium	Annual mean	5
Vanadium	Maximum 24 hour mean	1
Dioxins and furans ITEQ	Annual mean	No standard
PAHs as benzo(a)pyrene	Annual mean	0.00025

Following Environment Agency guidance,[6] modelled 15 minute mean levels of sulphur dioxide were increased by a factor of 1.34 to account for the shorter averaging period compared to the one hour averaging period of the meteorological data.

Standards and guidelines specified for the protection of human health should in principle be applied at locations where people are likely to be present over the relevant averaging period. In practice, the study was carried out by assessing air quality across the grid of points covering the vicinity of the proposed facility. The study was carried out to ensure compliance with air quality standards and guidelines at all locations in the study area for substances released from elevated locations.

3.6 Assessment of metals

The Environment Agency has published guidance on the assessment of the group of nine metals,[17] which was used for this study. This guidance sets out a staged procedure for the assessment of these metals:

(a) **Step 1:** Carry out the impact assessment assuming each metal contributes 100% of the group concentration limit. Screen out any metals which meet the following criteria:

- If the long-term process contribution (PC) is less than 1% of the air quality standard/guideline, or the short-term PC is less than 10% of the air quality standard/guideline, screen out this metal. Otherwise:
- If the long-term or short-term combined process contribution (PC) plus background is less than 100% of the air quality standard/guideline, screen out this metal.

(b) **Step 2:** For any metals not screened out at Step 1, undertake case-specific screening using maximum emission concentrations for each metal provided by the Environment Agency. Screen out any metals which meet the same criteria as used at Step 1:

- If the long-term process contribution (PC) is less than 1% of the air quality standard/guideline, or the short-term PC is less than 10% of the air quality standard/guideline, screen out this metal. Otherwise:
- If the long-term or short-term combined process contribution (PC) plus background is less than 100% of the air quality standard/guideline, screen out this metal.

[17] Environment Agency, "*Guidance to Applicants on Impact Assessment for Group 3 Metals Stack Releases*", Version 4, 28 June 2016

If it is not possible to screen out metals under Step 1 and 2, applicants must justify the use of any data lower than the maximum emission concentrations provided by the Environment Agency.

3.7 Assessment of deposition

The Environment Agency guidance[18] Table B8 sets benchmarks for maximum deposition rates of a subset of the substances released from the proposed facility. These are set out in Table 10.

Table 10: Maximum deposition rate benchmarks for released substances

Substance	Maximum deposition rate (mg/m^2-day)
Arsenic	0.02
Cadmium	0.009
Chromium	1.5
Copper	0.25
Lead	1.1
Mercury	0.004
Nickel	0.11

3.8 Critical levels and loads at designated habitat sites

Forecast levels of released substances were assessed against the critical levels in Table 10, and against critical loads specified for the protection of natural ecosystems at designated habitat sites within 10 km of the proposed facility. Critical load values were taken or derived using professional judgment from the Air Pollution Information System resource, operated by the conservation agencies.[19]

This assessment considered the contribution to nitrogen deposition and acid deposition. The critical load for nitrogen is expressed as the rate of nitrogen deposition per unit area per year which can be tolerated by the habitat site.

If specified for a particular site, the acid critical load is made up of a contribution from nitrogen-derived acid and sulphur-derived acid. The assessment of emissions from the proposed facility with regard to acid deposition was carried out using the "Critical Load Function Tool" and supporting guidance provided on the APIS website.[20] Specifically, the "detailed explanation" provided for this tool sets out the basis for calculating process contribution as a percentage of the critical load. The guidance sets out the calculation to be used if the combined background and process contribution is below the minimum critical load point referred to as "*CLminN*". However, this condition did not apply at any designated habitat site in the study area.

The guidance goes on to set out the calculation to be used in the majority of cases, where the combined background and process contribution is above the *CLminN* value. In this case, the calculation is as follows:

*PC as %CL function = ((PC of S+N deposition)/CLmaxN)*100*

A contribution of less than 1% of the relevant long-term critical level/critical load was considered to represent an insignificant contribution, following the approach broadly set out in Environment Agency guidance.[6,13] A contribution of less than 10% of the relevant short-term critical level was considered to represent an insignificant contribution, again following Environment Agency guidance.

[18] Environment Agency, Environmental Risk Assessment Framework – H1 Annex F – Air Emissions, December 2011, https://consult.environment-agency.gov.uk/psc/ta6-6lq-mole-valley-feed-solutions-ltd/supporting_documents/Supporting%20Documents%20%20H1%20Annex%20F%20%20Air%20Emissions.pdf
[19] Environment Agency, Natural England and others, www.apis.ac.uk [accessed June 2017]
[20] Environment Agency, Natural England and others, www.apis.ac.uk/critical-load-function-tool [accessed June 2017]

If any modelled air concentrations and deposition rates were identified to be above 1% of the relevant critical level/critical load values at locations where background deposition rates are close to or above the relevant standards, further evaluation was carried out.

3.9 Plume visibility

The proposed Clean Energy Facility may from time to time give rise to a visible plume of white water vapour. The likely extent of visible plumes emitted from the proposed EfW Facility was assessed using the appropriate module of the ADMS model.

Information on the assumed moisture content of the plume is given in Table 4. The value of 19.32 % moisture in the EfW flue gases by volume is equivalent to 13.02 % by mass. The ADMS model was used to forecast the plume length for every hour of meteorological data recorded between 07:00 and 19:00. The forecast plume lengths were assessed against the criteria set out in a previous version of the key Environment Agency guidance.[21] This guidance indicates that a plume can be considered as having an insignificant or low impact if it crosses the site boundary less than 5% of daylight hours per year.

3.10 Cumulative impacts

The potential for cumulative effects with existing sources of emissions to air was taken into account by the use of appropriate background air quality data.

The potential for cumulative effects with proposed sources of emissions to air was evaluated by identifying whether there are any other relevant proposed developments in the vicinity of the proposed Clean Energy facility. It is understood that no potentially relevant cumulative developments have been highlighted by the Local Planning Authority, or the Client team.

3.11 Abnormal operating scenarios

Articles 46 and 47 of the Industrial Emissions Directive provide operators of incineration plants with some operational flexibility to resolve plant problems without initiating a complete shutdown of the proposed EfW Facility. These scenarios are termed 'abnormal operations' and include incidents such as technically unavoidable stoppages, disturbances or failures of the pollution control equipment or monitoring equipment. The IED requires that such abnormal operations must not exceed a maximum of four hours at any one time and the cumulative duration of these periods must not exceed 60 hours in a year. If the failure cannot be rectified after four hours, then the EfW Facility must shut down.

It is important to ensure that any environmental impacts associated with foreseeable abnormal operating scenarios are properly considered. Potential increases in emissions associated with abnormal operating conditions were considered in outline, as a sensitivity analysis in relation to the forecast maximum emissions under normal operating conditions.

3.12 Other air quality issues

Localised site-specific issues such as the control of odours, dust and bioaerosols during operation were considered in outline. The controls built into the design of the scheme were highlighted, and any key issues for design and operation of the proposed facility were identified.

3.13 Results interpretation

Modelled levels of released substances were assessed against the air quality standards and guidelines set out above.

There are no air quality standards for dioxins and furans, because the majority of exposure takes place via indirect exposure pathways. Consequently, modelled levels of dioxins and furans were assessed using an exposure modelling system, as described in the Health Impact Assessment of this Environmental Statement.

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[21] Environment Agency, SEPA and NI Environment and Heritage Service, "*Integrated Pollution Prevention and Control (IPPC): Environmental Assessment and Appraisal of BAT*," Version 6 2003

Modelled acid and nutrient nitrogen deposition rates at designated habitat sites were assessed against site-specific benchmarks, as described in Section 3.8 above.

Modelled levels of nitrogen dioxide and PM_{10} were also evaluated using the approach developed by Environmental Protection UK.[22] This enables the scale of potential impacts on air quality to be described on a consistent and independent basis (see Table 11).

Table 11: Impact descriptors for individual receptors

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

After completing this comprehensive range of evaluations, conclusions were drawn with regard to the potential effects on air quality of the proposed facility during the operational phase. Recommendations were made for any appropriate monitoring or mitigation measures.

3.14 Conservative approach

This study was carried out on a conservative basis, to ensure that modelled concentrations and impacts are more likely to be overestimated than underestimated. The conservative assumptions adopted in this study are listed below:

- It was assumed that the facility will operate continuously, whereas in practice there will be some process down-time.
- It was assumed that emissions of most substances from the EfW Facility will be at the maximum limits permitted under the Industrial Emissions Directive. In practice, emissions will be substantially lower than these limits.
- It was assumed that all particulate matter emitted from the proposed facility is likely to be in the PM_{10} and $PM_{2.5}$ size fractions. In practice, some emitted particulate matter will be in larger size fractions, although current information indicates that the majority of particulate matter will be in the smaller size fraction.
- It was assumed that 35% of oxides of nitrogen were present as nitrogen dioxide for the purposes of modelling short-term mean concentrations, and 70% for long-term mean concentrations. In practice, the proportion present as nitrogen dioxide will be significantly lower, particularly in the areas close to the facility at which the highest modelled concentrations of released substances are forecast to occur.
- The highest modelled concentrations for any of the five years of meteorological data was used in the study.
- Volatile organic compounds were assessed against the demanding air quality standard for benzene, although benzene is no more than a minor component of VOC emissions from combustion processes such as the proposed facility.
- Baseline air quality levels were selected on the basis of the highest levels likely to be applicable to the study area.

[22] Institute of Air Quality Management, "Land-Use Planning & Development Control: Planning For Air Quality" available via http://www.iaqm.co.uk/text/guidance/air-quality-planning-guidance.pdf [accessed June 2017]

4 Results

4.1 Identification of appropriate stack height

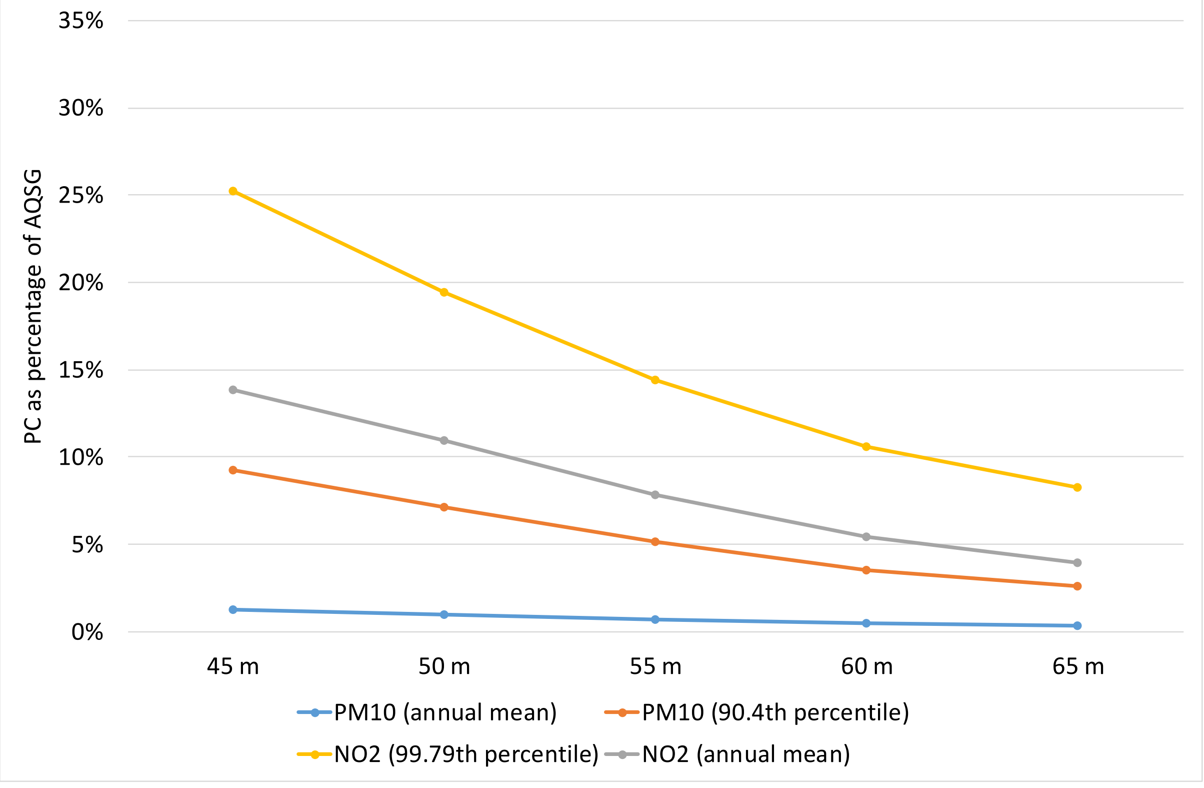
In identifying an appropriate stack height, there are two key aspects to consider from the perspective of control of air quality impacts:

(a) Identifying a point at which increases in stack height no longer provide a significant benefit in reducing environmental concentrations of released substances; and

(b) Ensuring that the modelled environmental concentrations of released substances for this stack height are at acceptable levels.

In the case of the proposed Clean Energy Facility, a further constraint was placed on potential stack heights by planning constraints. It was considered that a stack height of 60 m would be the maximum acceptable height in planning terms. Consequently, while lower stack heights were investigated, the approach adopted was to ensure that the modelled impact using a stack height of 60 m was acceptable, and that forecast levels of released substances complied with all relevant air quality standards and guidelines. The following plot provides the results of the stack height assessment for the proposed facility, illustrating the maximum long and short-term concentrations of NO_2 and PM_{10}, as a percentage of the respective air quality standard or guideline (AQSG), for stacks between 45 m and 65 m.

Figure 2: Stack height assessment results



The results illustrate a clear reduction in maximum pollutant concentrations between 45 m and 60 m, whereas above 60 m the reductions become less distinct. On this basis, a stack height of 60 metres was adopted for the proposed facility. Model results set out in the remainder of this document are on the basis of a stack height of 60 metres for the EfW Facility.

4.2 Air quality model results

4.2.1 Model results

As set out above, the ADMS version 5.2 model was used to identify the highest levels of released substances which are forecast to occur in the local area. These model results are set out in Table 12.

Table 12: Maximum modelled air concentrations of released substances

Substance	Averaging time	AQ Standard/ Guideline (µg/m³)	Baseline (µg/m³)	Process contribution (µg/m³)	PC/ AQSG	Combined process + baseline (µg/m³)	Combined/ AQSG
Particulate matter (PM_{10})	**Annual mean**	40	17	0.27	0.67%	17	43%
Particulate matter (PM_{10})	**90.4th percentile of 24 hour means**	50	34	0.70	1.40%	35	69%
Particulate matter ($PM_{2.5}$)	**Annual mean**	25	17	0.27	1.08%	17	69%
VOCs (assessed as benzene)	**Annual mean**	3.25	0.71	0.21	6.39%	0.92	28%
Hydrogen chloride	**Maximum hourly mean**	750	2.02	27	3.66%	29	3.93%
Hydrogen fluoride	**Annual mean**	16	2.46	0.021	0.13%	2.48	16%
Hydrogen fluoride	**Maximum hourly mean**	160	4.92	1.83	1.14%	6.75	4.22%
Carbon monoxide	**Maximum 8 hour mean**	10000	519	27	0.27%	546	5.46%
Sulphur dioxide	**99.9th percentile of 15 minute means**	266	87	43	16%	130	49%
Sulphur dioxide	**99.7th percentile of hourly means**	350	34	30	9%	64	18%
Sulphur dioxide	**99.2nd percentile of 24 hour means**	125	14	1.93	1.54%	16	12%
Nitrogen dioxide	**Annual mean**	40	29	2.18	5.45%	31	78%
Nitrogen dioxide	**99.79th percentile of hourly means**	200	58	21	11%	79	40%
Ammonia	**Annual mean**	180	1.16	0.10	0.06%	1.26	0.70%
Ammonia	**Maximum hourly mean**	2500	2.32	9.15	0.37%	11	0.46%
Cadmium	**Annual mean**	0.005	0.00012	0.0010	21%	0.0012	23%
Thallium	**Annual mean**	No AQSG	No data	0.0010	n/a	n/a	n/a
Thallium	**Maximum hourly mean**	No AQSG	No data	0.023	n/a	n/a	n/a

Substance	Averaging time	AQ Standard/ Guideline (µg/m³)	Baseline (µg/m³)	Process contribution (µg/m³)	PC/ AQSG	Combined process + baseline (µg/m³)	Combined/ AQSG
Mercury	**Annual mean**	0.25	0.0021	0.0010	0.42%	0.0031	1.26%
Mercury	**Maximum hourly mean**	7.5	0.0042	0.023	0.30%	0.027	0.36%
Antimony	**Annual mean**	5	0.00084	0.0012	0.023%	n/a	n/a
Antimony	**Maximum hourly mean**	150	0.0017	0.025	0.017%	n/a	n/a
Arsenic	**Annual mean**	0.003	0.00073	0.0012	38%	0.0019	63%
Lead	**Annual mean**	0.25	0.0062	0.0012	0.46%	0.0073	2.93%
Chromium	**Annual mean**	5	0.0045	0.0012	0.023%	0.0057	0.11%
Chromium	**Maximum hourly mean**	150	0.00902	0.025	0.017%	0.034	0.023%
Chromium VI	**Annual mean**	0.0002	0.00090	0.00023 (see Section 4.3)	115%	0.0011	566% (See Section 4.3)
Cobalt	**Annual mean**	No AQSG	0.00016	0.0012	n/a	n/a	n/a
Cobalt	**Maximum hourly mean**	No AQSG	0.00032	0.025	n/a	n/a	n/a
Copper	**Annual mean**	10	0.043	0.0012	0.012%	0.044	0.44%
Copper	**Maximum hourly mean**	200	0.086	0.025	0.013%	0.11	0.056%
Manganese	**Annual mean**	150	0.011	0.0012	0.00077%	0.012	0.0083%
Manganese	**Maximum hourly mean**	1500	0.023	0.025	0.0017%	0.048	0.0032%
Nickel	**Annual mean**	0.02	0.0014	0.0012	5.77%	0.0026	13%
Vanadium	**Annual mean**	5	0.0012	0.0012	0.023%	0.0023	0.046%
Vanadium	**Maximum 24 hour mean**	1	0.0023	0.0071	0.71%	0.009	0.94%
Dioxins and furans ITEQ	**Annual mean**	No AQSG	5.50E-08	2.08×10^{-9}	n/a	5.71×10^{-8}	n/a
PAHs as benzo(a)pyrene	**Annual mean**	0.00025	0.00014	0.000021	8%	0.00016	66%

Notes. PC: process contribution; AQSG: air quality standard or guideline
The data for the group of nine metals in Table 12 are on the basis that each metal accounts for 11% of the emissions limit for the group as a whole. The data for chromium VI is on the basis that chromium VI accounts for 20% of the total chromium concentration. Environment Agency research confirms that this is a conservative approach. See Section 4.3 for further details on the assessment of metals.

4.2.2 Model results summary

The results in Table 12 confirm that:

- All modelled process contributions due to emissions from the proposed facility comply with the relevant air quality standards and guidelines, with the exception of chromium VI. The chromium VI assessment is a screening process, which is discussed in more detail in Section 4.3 below.
- The substances with the highest process contribution due to emissions from the proposed facility relative to the air quality standard or guideline (maximum PC/AQSG >3%) are:
    - Volatile organic compounds (VOCs – assessed against the air quality standard for benzene): Annual mean
    - Hydrogen chloride: Maximum hourly mean
    - Sulphur dioxide: 99.9th percentile of 15 minute means
    - Sulphur dioxide: 99.7th percentile of 1 hour means
    - Nitrogen dioxide: Annual mean
    - Nitrogen dioxide: 99.79th percentile of 1 hour means
    - Cadmium: Annual mean
    - Arsenic: Annual mean
    - Nickel: Annual mean
    - Chromium VI: Annual mean
    - Polycyclic Aromatic Hydrocarbons (PAHs): Annual mean

Modelled levels of these substances, with the exception of chromium VI, are shown in Figure 3 to Figure 12. Other than the screening calculations for metals discussed further in Section 4.3 below, the highest modelled process contribution is 16% of the air quality standard, for the 99.9th percentile of 15 minute mean sulphur dioxide levels.

- All combined concentrations due to emissions from the proposed facility added to background levels comply with the relevant air quality standards and guidelines, with the exception of chromium VI. The chromium VI assessment is a screening process, which is discussed in more detail in Section 4.3 below.
- Other than the screening calculations for metals, the substances with the highest combined concentration due to emissions from the proposed facility added to background levels relative to the air quality standard or guideline (maximum Combined/AQSG >50%) are:
    - PM_{10}: 90.4th percentile of 24 hour means - Combined/AQSG: 69 %
    - $PM_{2.5}$: Annual mean – Combined / AQSG: 69 %
    - Nitrogen dioxide: Annual mean – Combined / AQSG: 78 %
    - PAHs as Benzo(a)pyrene: Annual mean – Combined / AQSG: 66 %

  These relatively high combined concentrations are due almost completely to the estimated baseline levels of these substances.

There are no air quality standards or guidelines for dioxins and furans. This is because exposure to dioxins and furans takes place primarily via indirect pathways such as consumption of meat and dairy products. The potential exposure of local residents and others to dioxins and furans is evaluated in the Health Impact Assessment of this Environmental Statement.

Modelled levels of released substances at individual receptor locations are lower than the maximum values set out in Table 12. Modelled concentrations of key substances at specific receptor locations are set out in Appendix 2.

4.3 Assessment of metals

The forecast levels of the group of nine metals were assessed in accordance with the staged process set out in Environment Agency guidance.[17]

4.3.1 Staged assessment

Step 1: Worst case screening

In the worst case screening step each metal is assumed to contribute 100% of the group concentration limit and chromium VI is assumed to account for 20% of the total chromium concentration. This assessment is set out in Table 13. The assessment shows that all metals can be screened out from requiring further assessment with the exception of arsenic and chromium VI.

Table 13: Screening assessment of metals: Step 1

Substance	Averaging time	Standard/ guideline (µg/m³)	PC (µg/m³)	PC/ AQSG	Screen based on PC	Base-line (µg/m³)	PEC (µg/m³)	PEC/ AQSG	Screen based on PEC
Antimony	**Annual mean**	5	0.010	0.21%	Screen out				
Antimony	**Max hourly mean**	150	0.23	0.15%	Screen out				
Arsenic	**Annual mean**	0.003	0.010	346%	Consider PEC	0.00073	0.011	371%	Further assessment
Lead	**Annual mean**	0.25	0.010	4.16%	Consider PEC	0.0062	0.017	6.62%	Screen out
Chromium	**Annual mean**	5	0.010	0.21%	Screen out				
Chromium	**Max hourly mean**	150	0.23	0.15%	Screen out				
Chromium VI	**Annual mean**	0.0002	0.0021	1039%	Consider PEC	0.00090	0.0030	1490%	Further assessment
Cobalt	**Annual mean**	No AQSG	0.010	n/a	No AQSG				
Cobalt	**Max hourly mean**	No AQSG	0.23	n/a	No AQSG				
Copper	**Annual mean**	10	0.010	0.10%	Screen out				
Copper	**Max hourly mean**	200	0.23	0.11%	Screen out				
Manganese	**Annual mean**	150	0.010	0.0069%	Screen out				
Manganese	**Max hourly mean**	1500	0.23	0.015%	Screen out				

Substance	Averaging time	Standard/ guideline (µg/m³)	PC (µg/m³)	PC/ AQSG	Screen based on PC	Base-line (µg/m³)	PEC (µg/m³)	PEC/ AQSG	Screen based on PEC
Nickel	**Annual mean**	0.02	0.010	52%	Consider PEC	0.0014	0.012	59%	Screen out
Vanadium	**Annual mean**	5	0.010	0.21%	Screen out				
Vanadium	**Max 24 hour mean**	1	0.064	6.41%	Screen out				

Step 2: Case specific screening

The Environment Agency guidance[17] contains a summary of "*monitoring data from Municipal Waste Incinerators and Waste Wood Co-Incinerators between 2007 and 2015.*" The proposed facility is designed to result in minimal emissions of metals to the atmosphere, due to the use of a sophisticated flue gas treatment system. In view of this, it is anticipated that emissions of metals from the proposed facility will be at least as good as emissions from established waste treatment facilities in England and Wales. Notwithstanding the sophisticated design of the proposed facility, in order to ensure a conservative assessment, emissions for arsenic and chromium VI were re-evaluated on the basis of the mean effective concentrations of 0.0010 mg/Nm³ and 0.000035 mg/Nm³, respectively, taken from Appendix A of the Environment Agency guidance note. This assessment is set out in Table 14. It confirms that arsenic and chromium VI can be screened out from requiring further assessment.

Table 14: Screening assessment of metals: Step 2

Substance	Averaging time	Standard/ guideline (µg/m3)	PC (µg/m3)	PC/ AQSG	Screen based on PC	Base-line (µg/m3)	PEC (µg/m3)	PEC/ AQSG	Screen based on PEC
Arsenic	**Annual mean**	0.003	2.1×10^{-5}	0.69%	Screen out				
Chromium VI	**Annual mean**	0.0002	7.3×10^{-7}	0.36%	Screen out				

4.3.2 Conclusions of assessment of metals

This structured process confirms that emissions to air of metals from the process are forecast to comply with relevant air quality standards and guidelines, and have no significant effects on air quality.

4.4 Deposition

The maximum modelled deposition rates of released substances were assessed against Environment Agency benchmarks.[18]

Table 15: Deposition model results

Substance	Maximum deposition rate benchmark (mg/m^2-day)	Maximum modelled deposition rate (mg/m^2-day)	Maximum modelled rate as percentage of benchmark
Arsenic	0.02	0.0030	15%
Cadmium	0.009	0.0027	30%
Chromium	1.5	0.0030	0.20%
Copper	0.25	0.0030	1.2%
Lead	1.1	0.0030	0.27%
Mercury	0.004	0.0027	68%
Nickel	0.11	0.0030	2.7%

The highest modelled deposition rate as a percentage of the benchmark was for mercury. In this case, the modelled deposition rate was 68% of the applicable benchmark. For all other substances, and in all other locations away from the point of maximum modelled impact, the contribution was a smaller proportion of the benchmark.

4.5 Ultrafine particulate matter

Modern EfW combustion facilities make only a slight contribution to levels of airborne particles. It may be the very smallest particles ("ultrafine" or "nano" particles – that is, particles with a diameter of 0.1 microns or less) which are of concern with regard to their effects on health. It is also plausible that the risks to health associated with particulate matter are more closely linked to the number of particles, rather than the mass of particles.

As with other sources of emissions to air, there is limited data on emissions of nanoparticles from EfW combustion facilities. Recently published research describes measurements of particulate matter emitted from a waste to energy incinerator in Piacenza, Italy.[23] The study found that no particles with aerodynamic diameters greater than 2.5 µm were measured, confirming the effectiveness of the emissions control technology in removing larger particles. 65% of the measured $PM_{2.5}$ mass was from sub-micrometre particles (PM_1) and the contribution of $PM_{0.1}$ to the mass of particulates was negligible. Most of the mass was from particles that were between 0.1 and 1 microns in aerodynamic diameter. The numbers of particles were distributed approximately equally between particles greater than and less than 0.1 micron. Similar particle mass distributions were recorded at the SELCHP waste incinerator in south-east London.

A subsequent environmental monitoring survey investigated ultrafine particles in the environment in the vicinity of the Piacenza facility.[24] Levels of particulate matter were found to be low in the Italian context. An analysis of the elemental composition of particulates indicated that sources other than the waste to energy facility accounted for all the elements present, and the contribution from the waste to energy facility was not detectable. In a separate study of fine and ultrafine particles on the surface of foodstuffs in Italy,[25] the authors concluded that "little evidence is found for particles whose origin could be attributed to industrial combustion processes, such as waste incineration". Similarly,

[23] Buonanno, G., Ficco, G., and Stabile, L. (2009) *Size distribution and number concentration of particles at the stack of a municipal waste incinerator*. Waste Management. 29. 749-755.
[24] Buonanno G, Stabile L, Avino P, Belluso E, "Chemical, dimensional and morphological ultrafine particle characterization from a waste-to-energy plant," Waste Management 31 (2011) 2253–2262
[25] Giordano C, Bardi U, Garbini D, Suman M, "Analysis of particulate pollution on foodstuff and other items by environmental scanning electron microscopy," Microsc Res Tech. 2011 Oct;74(10):931-5.

Morishita et al. found that waste incineration facilities made a minimal contribution to $PM_{2.5}$ levels in urban environments in the United States.[26]

These findings indicate that waste combustion facilities make a small contribution to levels of ultrafine particles, analogous to the findings in relation to larger particles. Other sources like road traffic and cooking are likely to be much more important sources, even in the immediate vicinity of a waste thermal treatment facility.

4.6 Designated habitat sites

4.6.1 Airborne concentrations

The ADMS model was used to forecast levels of released substances at European and nationally designated habitat sites within 10 km of the proposed facility, and at locally designated sites within 2 km of the proposed facility.

The modelled airborne concentrations were as follows:

Table 16: Modelled process contributions at designated habitat sites

Designated site	Airborne concentrations (µg/m³)				
	Annual mean NO_x	Annual mean SO_2	Annual mean NH_3	Max. 24 hour mean NO_x	Max. 24 hour mean HF
South Pennine Moors SSSI/SAC/ SPA: Ilkley Moor section	0.12	0.014	0.0040	1.44	0.0096
South Pennine Moors SSSI/SAC/ SPA: Keighley Moor section	0.026	0.0030	0.0010	0.70	0.0047
Bingley South Bog	0.093	0.011	0.0031	1.52	0.010
Trench Meadows	0.055	0.0065	0.0018	0.67	0.0045
Beechcliffe Ings	0.17	0.020	0.0055	2.35	0.016
Coppice Bog and Pond	0.028	0.0034	0.00095	0.72	0.0048
Leeds-Liverpool Canal (part Leeds)	0.27	0.032	0.0089	4.35	0.029
Sunnydale, East Morton	0.16	0.019	0.0052	1.21	0.0081
Hainworth Wood	0.060	0.0072	0.0020	1.08	0.0072
Harden Moor and Deepcliffe Wood	0.035	0.0042	0.0012	1.12	0.0075
How Beck Wood Riddlesden	0.58	0.069	0.019	4.05	0.027
Beechcliffe Ox-Bow Lake	0.16	0.020	0.0054	2.04	0.014
Castlefields Marsh	0.57	0.068	0.019	3.17	0.021
Deepcliffe Wood, Harden	0.039	0.0047	0.0013	1.34	0.0089
East Morton Sewage Works	1.16	0.14	0.039	6.87	0.046
Elam Wood, Keighley	0.15	0.018	0.0050	1.89	0.013
Hollin Plantation, Bingley	0.082	0.010	0.0027	2.81	0.019
Low Wood, Keighley	0.071	0.0085	0.0024	1.14	0.0076
North Beck, Keighley	0.10	0.012	0.0033	1.62	0.011
Park Wood, Keighley	0.47	0.057	0.016	8.78	0.059
Rivock Edge Plantation	0.033	0.0039	0.0011	1.02	0.0068
Spring Bank, Keighley	0.058	0.0070	0.0019	1.06	0.0070
St Ives Estate	0.044	0.0053	0.0015	1.43	0.010
Stockbridge Nature Reserve	0.23	0.028	0.0078	4.56	0.030

[26] Morishita M, Keeler GJ, Kamal AS, Wagner JG, Harkema JR, Rohr AC , "Identification of ambient PM2.5 sources and analysis of pollution episodes in Detroit, Michigan using highly time-resolved measurements," Atmospheric Environment 45 (2011) 1627-1637
Morishita M, Keeler GJ, Kamal AS, Wagner JG, Harkema JR, Rohr AC , "Source identification of ambient PM2.5 for inhalation exposure studies in Steubenville, Ohio using highly time-resolved measurements," Atmospheric Environment 45 (2011b) 7688-7697

These modelled concentrations were assessed against the applicable air quality standards and guidelines for the protection of vegetation (referred to as “critical levels”), as follows:

Table 17: Assessment of modelled process contributions at designated habitat sites against critical levels

Designated site	Annual mean NO_x	Annual mean SO_2	Annual mean NH_3	Max. 24 hour mean NO_x	Max. 24 hour mean HF
Critical level (μg/m³)	**30**	**20**	**1**	**75**	**5**
Modelled concentration as % of air quality standard/guideline					
South Pennine Moors SSSI/SAC/ SPA: Ilkley Moor section	0.40%	0.072%	0.40%	1.92%	0.19%
South Pennine Moors SSSI/SAC/ SPA: Keighley Moor section	0.085%	0.015%	0.085%	0.93%	0.093%
Bingley South Bog	0.31%	0.056%	0.31%	2.02%	0.20%
Trench Meadows	0.18%	0.033%	0.18%	0.89%	0.089%
Beechcliffe Ings	0.55%	0.10%	0.55%	3.14%	0.31%
Coppice Bog and Pond	0.095%	0.017%	0.095%	0.96%	0.10%
Leeds-Liverpool Canal (part Leeds)	0.89%	0.16%	0.89%	5.80%	0.58%
Sunnydale, East Morton	0.52%	0.093%	0.52%	1.62%	0.16%
Hainworth Wood	0.20%	0.036%	0.20%	1.44%	0.14%
Harden Moor and Deepcliffe Wood	0.12%	0.021%	0.12%	1.50%	0.15%
How Beck Wood Riddlesden	1.92%	0.35%	1.92%	5.40%	0.54%
Beechcliffe Ox-Bow Lake	0.54%	0.10%	0.54%	2.72%	0.27%
Castlefields Marsh	1.90%	0.34%	1.90%	4.23%	0.42%
Deepcliffe Wood, Harden	0.13%	0.023%	0.13%	1.78%	0.18%
East Morton Sewage Works	3.88%	0.70%	3.88%	9.15%	0.92%
Elam Wood, Keighley	0.50%	0.090%	0.50%	2.52%	0.25%
Hollin Plantation, Bingley	0.27%	0.049%	0.27%	3.74%	0.37%
Low Wood, Keighley	0.24%	0.042%	0.24%	1.52%	0.15%
North Beck, Keighley	0.33%	0.060%	0.33%	2.16%	0.22%
Park Wood, Keighley	1.57%	0.28%	1.57%	11.71%	1.17%
Rivock Edge Plantation	0.109%	0.020%	0.11%	1.36%	0.14%
Spring Bank, Keighley	0.19%	0.035%	0.19%	1.41%	0.14%
St Ives Estate	0.15%	0.027%	0.15%	1.91%	0.19%
Stockbridge Nature Reserve	0.78%	0.14%	0.78%	6.08%	0.61%

All modelled process contributions were less than 1% of the long-term mean critical levels, and less than 10% of the short-term mean critical levels, with the following exceptions:

- Annual mean NO_x:
    - How Beck Wood Riddlesden LWS
    - Castlefields Marsh BWA
    - East Morton Sewage Works BWA
    - Park Wood, Keighley BWA
- Annual mean NH_3:
    - How Beck Wood Riddlesden LWS
    - Castlefields Marsh BWA
    - East Morton Sewage Works BWA
    - Park Wood, Keighley BWA

- Maximum 24 hour mean NO_x:
    - Park Wood, Keighley BWA

In order to further investigate levels of NO_x and NH_3 at these specific locations, background levels of NO_x and gaseous ammonia were sourced from Defra's data selector tool[27]. The results of this assessment are provided in Table 18. Background levels of oxides of nitrogen have been taken from Defra's background maps for 2014 at locations relevant to each habitat site. The figure for background gaseous ammonia is an average of the 2014 concentration recorded at two monitoring stations in Yorkshire; Tadcaster (1.08 µg/m³) and Easingwold (0.62 µg/m³).

Table 18: Further assessment of modelled process contributions at locally designated habitat sites

Designated sites	Site coordinates		Defra background map coordinates (2014)		Airborne conc. (µg/m³)	Background conc. (µg/m³)	Combined airborne conc. and background conc. as % of critical level
	Easting	Northing	Easting	Northing			
NOx							
How Beck Wood Riddlesden	408 500	442 200	408 500	442 200	0.58	17	59%
Castlefields Marsh	409 400	441 100	409 500	441 500	0.57	17	59%
East Morton Sewage Works	408 600	441 800	408 500	441 500	1.17	18	64%
Park Wood, Keighley	407 600	441 200	407 500	441 500	0.48	23	78%
NH3							
How Beck Wood Riddlesden	408 500	442 200	n/a	n/a	0.019	0.85	87%
Castlefields Marsh	409 400	441 100	n/a	n/a	0.019		87%
East Morton Sewage Works	408 600	441 800	n/a	n/a	0.039		89%
Park Wood, Keighley	407 600	441 200	n/a	n/a	0.016		87%

On this basis, the combined process contribution and background levels of NO_x and NH_3 are forecast to comply with the critical levels at all designated sites where the process contribution is above 1% of the critical level.

It is therefore concluded that no significant impacts are forecast to occur at designated sites within 10 km of the proposed development due to airborne concentrations of relevant substances.

4.6.2 Deposition

Modelled deposition rates due to emissions from the proposed facility were calculated from the modelled airborne concentrations by multiplying by the appropriate deposition velocity. Nutrient nitrogen deposition rates were calculated by multiplying the deposition rates of nitrogen dioxide and ammonia by the mass fraction of nitrogen in each substance (nitrogen dioxide: 14/46; ammonia: 14/17). Acid deposition rates (kEq/ha/year) were calculated by multiplying the modelled deposition rate by the maximum number of hydrogen ions produced per molecule of each substance, and dividing by the molecular weight (nitrogen dioxide: 1/46; ammonia: 1/14; sulphur dioxide: 2/64; hydrogen chloride: 1/36.5).

The modelled deposition rates were assessed on the assumption of 70% conversion of NO_x to NO_2.

The modelled deposition rates are set out in the following table.

[27] Defra data selector tool via http://uk-air.defra.gov.uk/data/data_selector

Table 19: Modelled deposition rates at designated habitat sites

Designated site	Modelled substance deposition rate (kg/ha/year)			Modelled nitrogen/acid deposition rate		
	NO_x	SO_2	NH_3	Nutrient nitrogen* (kgN/ha/year)	Nitrogen-derived acid* (kEq/ha/year)	Sulphur-derived acid (kEq/ha/year)
South Pennine Moors SSSI/SAC/ SPA: Ilkley Moor section (Using deposition velocities for grassland)	0.057	0.054	0.025	0.033	0.0027	0.0019
South Pennine Moors SSSI/SAC/ SPA: Ilkley Moor section (Using deposition velocities for woodland*)	0.043	0.041	0.014	0.021	0.0017	0.0014
South Pennine Moors SSSI/SAC/ SPA: Keighley Moor section (Using deposition velocities for grassland)	0.012	0.012	0.0054	0.0070	0.00057	0.00040
South Pennine Moors SSSI/SAC/ SPA: Keighley Moor section (Using deposition velocities for woodland*)	0.016	0.015	0.0053	0.0077	0.00062	0.00052
Bingley South Bog	0.044	0.042	0.020	0.026	0.0021	0.0015
Trench Meadows	0.026	0.025	0.011	0.015	0.0012	0.00088
Beechcliffe Ings	0.078	0.075	0.035	0.045	0.0037	0.0027
Coppice Bog and Pond	0.013	0.013	0.0060	0.0078	0.00063	0.00045
Leeds-Liverpool Canal (part Leeds)	0.13	0.12	0.056	0.073	0.0059	0.0042
Sunnydale, East Morton	0.073	0.070	0.033	0.042	0.0034	0.0024
Hainworth Wood	0.057	0.055	0.019	0.028	0.0022	0.0019
Harden Moor and Deepcliffe Wood	0.033	0.032	0.011	0.016	0.0013	0.0011
How Beck Wood Riddlesden	0.55	0.52	0.18	0.27	0.021	0.018
Beechcliffe Ox-Bow Lake	0.077	0.074	0.034	0.045	0.0036	0.0026
Castlefields Marsh	0.27	0.26	0.12	0.16	0.013	0.0090
Deepcliffe Wood, Harden	0.037	0.035	0.012	0.018	0.0014	0.0012
East Morton Sewage Works	0.55	0.53	0.24	0.32	0.026	0.018
Elam Wood, Keighley	0.14	0.14	0.047	0.069	0.0055	0.0047
Hollin Plantation, Bingley	0.077	0.074	0.026	0.038	0.0030	0.0026
Low Wood, Keighley	0.067	0.064	0.022	0.033	0.0026	0.0022
North Beck, Keighley	0.047	0.046	0.021	0.027	0.0022	0.0016
Park Wood, Keighley	0.45	0.43	0.15	0.22	0.017	0.015
Rivock Edge Plantation	0.031	0.030	0.010	0.015	0.0012	0.0010
Spring Bank, Keighley	0.028	0.027	0.012	0.016	0.0013	0.00094
St Ives Estate	0.021	0.020	0.0093	0.012	0.0010	0.00071
Stockbridge Nature Reserve	0.11	0.11	0.049	0.064	0.0052	0.0037

* The South Pennine Moors consists of approximately 99 % inland water bodies, bogs, marshes, fens, heath, scrub and grassland, with the remaining consisting of mixed and broad-leaved deciduous woodland [28]. Deposition velocities for woodland were applied at areas of woodland identified within the South Pennine Moors SPA/SAC, using Defra's Magic Map application[29] (Ref. H11, H12, H13, H14 & H30).

Modelled deposition rates were assessed against the relevant critical loads, obtained from the APIS website. The "Site-relevant critical loads" feature of the website was used to obtain critical loads for European sites and SSSIs. The "Search by location" feature was used to obtain critical loads for locally designated sites. Following guidance provided via the APIS website, the process contribution to acid deposition was calculated as the combined process contribution to sulphur- and nitrogen-derived acid, as a percentage of the CLMaxN critical load value.

Table 20: Critical levels for designated sites in the vicinity of the proposed facility

Designated site	Habitat type	Minimum critical load for nitrogen deposition (kgN/ha/year)	Minimum critical load for acid deposition (MinCLMaxN) (kEqH$^+$/ha/year)
South Pennine Moors SSSI/SAC/ SPA: Ilkley Moor section (Using deposition velocities for grassland)	Blanket bogs/Transition mires and quaking bogs	5	0.569
South Pennine Moors SSSI/SAC/ SPA: Ilkley Moor section (Using deposition velocities for woodland)	Old Sessile Oak Woods	10	0.713
South Pennine Moors SSSI/SAC/ SPA: Keighley Moor section (Using deposition velocities for grassland)	Blanket bogs/Transition mires and quaking bogs	5	0.569
South Pennine Moors SSSI/SAC/ SPA: Keighley Moor section (Using deposition velocities for woodland)	Old Sessile Oak Woods	10	0.713
Bingley South Bog	Variety of fenland habitats	15	2.38
Trench Meadows	Variety of fenland habitats	20	2.38
Beechcliffe Ings	Variety of fenland habitats	10	2.038
Coppice Bog and Pond	Variety of fenland habitats	10	2.038
Leeds-Liverpool Canal (part Leeds)	Variety of fenland habitats	10	2.038
Sunnydale, East Morton	Bogs	10	0.62
Hainworth Wood	Woodland	10	3.24
Harden Moor and Deepcliffe Wood	Woodland	10	3.24
How Beck Wood Riddlesden	Woodland	10	3.24
Beechcliffe Ox-Bow Lake	Variety of fenland habitats	10	2.038
Castlefields Marsh	Marshland	10	Not sensitive
Deepcliffe Wood, Harden	Woodland	10	3.24
East Morton Sewage Works	Ornithological interest, grey heron	N/A	Not sensitive
Elam Wood, Keighley	Woodland	10	3.24
Hollin Plantation, Bingley	Woodland	10	3.24
Low Wood, Keighley	Woodland	10	3.24
North Beck, Keighley	Ornithological interest; watercourse	N/A	Not sensitive

[28] Joint Nature Conservation Committee, South Pennine Moors, available via http://jncc.defra.gov.uk/protectedsites/sacselection/sac.asp?EUCode=UK0030280 [accessed June 2017]
[29] Defra – Magic Map via http://magic.defra.gov.uk/home.htm [accessed June 2017]

Park Wood, Keighley	Woodland	10	3.24
Rivock Edge Plantation	No information available	No information	No CL
Spring Bank, Keighley	Semi-improved grassland	No comparable habitat	Not sensitive
St Ives Estate	Bogs	10	0.62
Stockbridge Nature Reserve	Ornithological interest; watercourse	N/A	Not sensitive

The modelled deposition rates shown in Table 19 were assessed against the critical loads as set out in Table 20. The results of this assessment are set out in Table 21.

Table 21: Assessment of modelled process contributions to acid and nitrogen deposition at designated habitat sites against critical loads

Designated site	Process contribution to nitrogen deposition as % of critical load	Process contribution to acid deposition as % of critical load
South Pennine Moors SSSI/SAC/ SPA: Ilkley Moor section (Using deposition velocities for grassland)	0.53%	0.80%
South Pennine Moors SSSI/SAC/ SPA: Ilkley Moor section (Using deposition velocities for woodland)	0.17%	0.43%
South Pennine Moors SSSI/SAC/ SPA: Keighley Moor section (Using deposition velocities for grassland)	0.11%	0.17%
South Pennine Moors SSSI/SAC/ SPA: Keighley Moor section (Using deposition velocities for woodland)	0.06%	0.16%
Bingley South Bog	0.14%	0.15%
Trench Meadows	0.061%	0.088%
Beechcliffe Ings	0.37%	0.31%
Coppice Bog and Pond	0.063%	0.053%
Leeds-Liverpool Canal (part Leeds)	0.59%	0.50%
Sunnydale, East Morton	0.34%	0.95%
Hainworth Wood	0.23%	0.13%
Harden Moor and Deepcliffe Wood	0.13%	0.07%
How Beck Wood Riddlesden	2.21%	1.22%
Beechcliffe Ox-Bow Lake	0.36%	0.31%
Castlefields Marsh	1.26%	Not sensitive
Deepcliffe Wood, Harden	0.15%	0.082%
East Morton Sewage Works	N/A	Not sensitive
Elam Wood, Keighley	0.57%	0.32%
Hollin Plantation, Bingley	0.31%	0.17%
Low Wood, Keighley	0.27%	0.15%
North Beck, Keighley	N/A	Not sensitive
Park Wood, Keighley	1.81%	1.00%
Rivock Edge Plantation	No information	No CL
Spring Bank, Keighley	No comparable habitat	Not sensitive
St Ives Estate	0.10%	0.27%
Stockbridge Nature Reserve	N/A	Not sensitive

All modelled process contributions to acid and nutrient nitrogen deposition were below 1% of the critical load values, with the exception of marginal exceedances of the 1% threshold for nitrogen deposition at How Beck Wood Riddlesden LWS, Castlefields Marsh and Park Wood, and marginal exceedances of the 1% threshold for acid deposition at How Beck Wood Riddlesden LWS. Note that this threshold is designed to apply for screening at European sites, and a forecast process contribution marginally above this level at three locally designated sites does not constitute a significant adverse impact. Any impact from the proposed development would not be detectable by any practicable means, and would be minimal compared to the impact of other sources of emissions to air such as road traffic emissions. The minimal forecast impact from the proposed development should also be viewed in the context of the importance of site management measures in improving biodiversity at locally designated sites, and in the context of generally declining background airborne concentrations and deposition of substances contributing to nitrogen deposition.

It is therefore concluded that no significant impacts are forecast to occur at designated sites within 10 km of the proposed development due to acid or nutrient nitrogen deposition.

4.6.3 European sites

The highest modelled deposition rate at any European site or Ramsar site (i.e., the two sections of the South Pennine Moors, H1 to H30) is 0.80% of the relevant critical load. The highest modelled airborne concentrations were 0.40% of the relevant long-term critical level and 1.92% of the relevant short-term critical level. Hence, all long-term mean modelled air concentrations and deposition rates are below 1% of the relevant critical loads/levels, and all short-term mean modelled concentrations are below 10% of the relevant critical levels.

Guidance from the Environment Agency used by Natural England indicates that a likely significant effect is identified when the long-term Process Contribution (PC) is greater than 1%, and the Predicted Environmental Concentration (PEC) is greater than 70% of the relevant critical load/level, or when the short-term process contribution is greater than 10% of the relevant critical level. The information set out in Sections 4.6.1 and 4.6.2 above indicates that the process contributions would be less than 1% of the long-term critical levels and critical loads, and less than 10% of the short-term critical levels.

In view of these results, and in the context of generally declining baseline levels of the relevant substances, there is no likelihood of a significant effect on the designated interest features of the European sites, having regard to the conservation objectives of those sites. Following the Environment Agency guidance, it is concluded that an Appropriate Assessment is not required.

4.7 Plume visibility

The modelled lengths of visible white water vapour plumes from the 60 m stack are set out in Table 22. The design organisation indicated that the moisture content of emissions at load maximum continuous rating will be 19.32 %. This moisture content was modelled to determine the potential for visible white water plume from the stack.

Table 22: Forecast visible plume frequencies (% of daylight hours)

Parameter	Model results					
	2012	2013	2014	2015	2016	Average
Occurrence of no visible plume	88%	82%	90%	89%	88%	87%
Occurrence of a visible plume of any length	12%	18%	10%	11%	12%	13%
Proportion of time plume length longer than 50 m	3%	6%	3%	3%	4%	4%

This assessment shows that with a moisture content of 19.32 %, the plume would be visible only infrequently and would cross the boundary of the site (estimated to be ~50 m at its closest point) on average during 4% of daylight hours (between 7am and 6pm). Following Section 3.8.2 of the relevant Environment Agency guidance (previous version of the Environment Agency H1 guidance, as no specific guidance is given in current version),[21] a plume crossing the site boundary for less than 5 % of the time would be classified as “Low” impact. As the distance between the stack and site boundary varies considerably, and because the plume will not cross the boundary at its closest point for the majority of wind directions, a moisture content of 19.32 % by volume can be considered to result in a “Low” impact due to plume visibility.

The longer plume lengths typically occur under conditions of high relative humidity, because of the low capacity of the atmosphere to hold further water without it condensing to a visible white water vapour plume. These conditions are typically cloudy, for much the same reason. Hence, the longer plumes are typically viewed against a background of white or grey cloudy skies, rather than against a background of blue skies. This tends to reduce the visual impact of plumes associated with facilities of this nature.

4.8 Other air quality issues

It will be important for the proposed facility not to give rise to excessive dust, odour or bioaerosols during operation. Under normal operating conditions, no odour, bioaerosols or dust issues would be expected to arise outside the site boundary. This is because air will be drawn into the EfW building through the reception area, and used in the combustion of fuel. This is well established practice for waste combustion facilities of this nature, and will be effective in preventing any significant escape of odour, bioaerosols or dust from the building. Further control on the potential for odours and bioaerosols can be achieved by ensuring good mixing of waste in the bunkers and minimising residence time of waste materials at the facility.

In the event of boiler down-time, there will be no boiler air demand to draw potentially odorous air from the waste reception hall through the combustion process. The risk of odours will be minimised by avoiding having putrescible waste materials present at the site during planned down-time, and by minimising the duration of unplanned shut-downs. In the unlikely event of extended boiler down-time, waste will be removed from the building. If necessary, odour control can be maintained by keeping the main doors closed, and providing air extraction and treatment using a temporary plant. Full details on the practices to be adopted to minimise and control odorous emissions from the site are provided in the Odour Management Plan.

4.9 Abnormal operating conditions

Foreseeable abnormal operating scenarios which could potentially affect emissions to air are set out below.

4.9.1 Scenario 1: Failure of NOx control

Description of event: Emissions of oxides of nitrogen are controlled by careful control of the combustion and use of flue gas recirculation. A failure of the NO_x emissions control system could theoretically result in a short-term increase in emissions of oxides of nitrogen. The Industrial Emissions Directive provide for an increase in NO_x emissions from 200 mg/Nm^3 to 400 mg/Nm^3 over short periods of up to 60 hours per year. This was the scenario modelled. The plant is constantly monitored by the Continuous Emission Monitoring System (CEMS) and Supervisory Control and Data Acquisition (SCADA) system, which will alarm should emissions approach the permitted limits for normal operation. If this cannot be resolved quickly, waste feed to the plant will be halted to prevent further emissions.

Evaluation: The potential effects of a short-term increase in NO_x emissions on hourly mean concentrations of NO_x has already been taken into account in the modelling study results set out in Section 4.2 above. The potential effects of a short-term increase in emissions of oxides of nitrogen on long-term mean concentrations are shown in Table 23.

Table 23: Assessment of Abnormal Operating Scenario 1 (annual mean)

Substance	AQ Standard/ Guideline (µg/m^3)	Baseline (µg/m^3)	Process contribution (µg/m^3)	PC/ AQSG	Combined process + baseline (µg/m^3)	Combined/ AQSG
Nitrogen dioxide	40	29	2.18	5.45%	31.2	78%
Nitrogen dioxide Scenario 1	40	29	2.21	5.52%	31.2	78%

In view of the margin between the modelled short-term nitrogen dioxide concentration and the air quality standard, this event is considered highly unlikely to result in an exceedance of the short-term air quality standard for nitrogen dioxide.

The short duration of any such incident means that it would have no more than a minimal effect on long-term mean concentrations resulting from emissions to air from the facility, as shown in Table 23.

4.9.2 Scenario 2: Failure of particulate abatement

Description of event: In the event of a failure of a bag filter, the process line would be halted to enable a repair to be carried out without resulting in an exceedance of the emission limit. However, in the unlikely event that this cannot be achieved, the Industrial Emissions Directive specifies that particulate matter could be emitted during abnormal operations at up to 150 mg/m³ for a period of up to four hours. These conditions could take place for a maximum of 60 hours per year. This was the case modelled. Again, the CEMS and SCADA system will constantly monitor the plant and detect any increase in emissions. Where possible adjustments will be made to ensure emissions are kept within limits. However if necessary a controlled shut down of a line will be undertaken to prevent emissions.

Evaluation: The short-term potential effects of these conditions on emissions to air were assessed on the basis that emissions of particulate matter could theoretically be increased to 150 mg/Nm³ for 4 hours in any 24 hour period, every day of the year. Since the Industrial Emissions Directive specifies that particulate matter can be emitted at this higher concentration for a maximum of 60 hours per year, this approach results in a very conservative assessment of the 90.4th percentile of 24 hour PM_{10} means.

Long-term mean concentrations of particulate matter and associated substances (metals, PAHs and dioxins/furans) were also assessed on the basis that emissions of particulate matter could theoretically be increased to 150 mg/Nm³ for 60 hours in a year.

The results of this assessment are summarized in Table 24 below.

Table 24: Assessment of Abnormal Operating Scenario 2 (annual mean except where stated)

Substance	AQ Standard/ Guideline	Baseline	Process contribution	PC/ AQSG	Combined process + baseline (µg/m³)	Combined/ AQSG
PM_{10}	40	17	0.21	0.52%	17.2	43%
PM_{10} Scenario 2	40	17	0.23	0.57%	17.2	43%
PM_{10} 90.4th percentile of 24 hour means	50	34	0.59	1.18%	34.6	69%
PM_{10} 90.4th percentile of 24 hour means Scenario 2	50	34	8.87	18%	42.9	86%
$PM_{2.5}$	25	17	0.21	0.83%	17.2	69%
$PM_{2.5}$ Scenario 2	25	17	0.23	0.91%	17.2	69%
Cadmium	0.005	0.00012	0.0010	21%	0.0012	23%
Cadmium Scenario 2	0.005	0.00012	0.0011	23%	0.0013	25%
Mercury	0.25	0.0021	0.0010	0.42%	0.0031	1.26%
Mercury Scenario 2	0.25	0.0021	0.0011	0.46%	0.0032	1.30%
Antimony	5	0.00084	0.0012	0.023%	0.0020	0.040%
Antimony Scenario 2	5	0.00084	0.0013	0.025%	0.0021	0.042%
Arsenic	0.003	0.00073	0.0012	38%	0.0019	63%
Arsenic Scenario 2	0.003	0.00073	0.0013	42%	0.0020	67%
Lead	0.25	0.0062	0.0012	0.46%	0.0073	2.93%
Lead Scenario 2	0.25	0.0062	0.0013	0.51%	0.0074	2.97%
Chromium	5	0.0045	0.0012	0.023%	0.0057	0.11%
Chromium Scenario 2	5	0.0045	0.0013	0.025%	0.0058	0.12%
Chromium VI	0.0002	0.00090	0.00023	115% (see Section 4.3)	0.0011	566% (see Section 4.3)
Chromium VI Scenario 2 (screening assessment)	0.0002	0.00090	7.97×10^{-7}	0.40% (see Section 4.3)	0.00090	451% (see Section 4.3)

Substance	AQ Standard/ Guideline	Baseline	Process contribution	PC/ AQSG	Combined process + baseline (µg/m³)	Combined/ AQSG
Copper	10	0.043	0.0012	0.012%	0.044	0.44%
Copper Scenario 2	10	0.043	0.0013	0.013%	0.044	0.44%
Manganese	150	0.011	0.0012	0.00077%	0.012	0.0083%
Manganese Scenario 2	150	0.011	0.0013	0.00084%	0.013	0.0084%
Nickel	0.02	0.0014	0.0012	5.77%	0.0026	13%
Nickel Scenario 2	0.02	0.0014	0.0013	6.33%	0.0027	14%
Vanadium	5	0.0012	0.0012	0.023%	0.0023	0.046%
Vanadium Scenario 2	5	0.0012	0.0013	0.025%	0.0024	0.049%
Dioxins and furans ITEQ	No AQSG	5.50×10^{-8}	2.08×10^{-9}	n/a	5.71×10^{-8}	n/a
Dioxins and furans ITEQ Scenario 2	No AQSG	5.50×10^{-8}	2.28×10^{-9}	n/a	5.73×10^{-8}	n/a
PAHs (benz(a)pyrene)	0.00025	0.00014	0.000021	8.3%	0.00016	66%
PAHs (benz(a)pyrene) Scenario 2	0.00025	0.00014	0.000023	9.1%	0.00017	66%

These results indicate that Scenario 2 process contributions due to emissions from the proposed facility comply with the relevant air quality standards and guidelines. The assessment of the process contribution to chromium VI is based on a staged screening assessment, which was discussed in more detail in Section 4.3. Specifically, emissions for chromium Vi were evaluated on the basis of a mean effective concentration of 0.000035 mg/Nm³ during normal operation (8700 hours of the year), and a mean effective concentration of 15 times 0.000035 mg/Nm³ during abnormal operation (60 hours of the year).

The Scenario 2 combined concentrations due to emissions from the proposed facility added to baseline air quality levels also comply with the relevant air quality standards and guidelines, with the exception of chromium VI. The exceedance of combined concentration for chromium VI is due almost entirely to the estimated baseline concentration of chromium VI, which is several times the relevant air quality standards and guidelines. The baseline levels for chromium VI were estimated using concentrations measured at the Manchester Wythenshawe monitoring site. This site is likely to represent an overestimate of baseline levels in the study area, and therefore this represents a conservative overestimate of the expected combined concentration of chromium VI in the event of a bag filter failure.

In general, the annual mean concentrations associated with Scenario 2 are very similar to the annual mean concentrations under normal operating conditions. The failure of a bag filter would result in a temporary increase to the 24 hour PM_{10} concentration, but this increased concentration is not expected to exceed the relevant air quality standards and guidelines.

4.9.3 Scenario 3: Failure of acid gas abatement

Description of event: Failure of the acid gas abatement system could potentially result in increased emissions of acid gases for a short period. The short-term unabated discharge concentrations of acid gases were assumed to be 2x the limits set in the IED, as follows:

Hydrogen chloride: 120 mg/Nm³

Hydrogen fluoride: 8 mg/Nm³

Sulphur dioxide: 400 mg/Nm³

Again, the occurrence of these conditions is limited to four hours before processing must cease, and to a maximum of 60 hours in a year.

Evaluation: The potential effects of these conditions on short-term (≤24 hour) peak emissions to air were assessed on the basis that emissions of acid gases could theoretically be increased to the above levels for 4 hours in any 24 hour period, every day of the year. Since the Industrial Emissions Directive specifies that particulate matter can be emitted at this higher concentration for a maximum of 60 hours per year, this approach again results in a very conservative assessment of short-term means.

Long-term (annual) mean concentrations of hydrogen fluoride were also assessed on the basis that emissions of hydrogen fluoride could theoretically be increased to 8 mg/Nm^3 for 60 hours in a year.

Hydrogen chloride and sulphur dioxide will be monitored continuously so any increase in emissions will be detected and appropriate preventative action can be taken. Hydrogen fluoride will be monitored periodically, as permitted by the IED. However, these levels will be in compliance where hydrogen chloride levels are within limits.

Table 25: Assessment of Abnormal Operating Scenario 3

Substance	AQ Standard/ Guideline	Baseline	Process contribution	PC/ AQSG	Combined process + baseline	Combined/ AQSG
Hydrogen chloride maximum 1 hour mean	750	2.02	27	3.66%	29	3.9%
Hydrogen chloride maximum 1 hour mean Scenario 3	750	2.02	55	7.3%	57	7.6%
Hydrogen fluoride annual mean	16	2.46	0.021	0.13%	2.48	15.5%
Hydrogen fluoride annual mean	16	2.46	0.022	0.14%	2.48	15.5%
Hydrogen fluoride maximum 1 hour mean	160	4.92	1.83	1.14%	6.75	4.2%
Hydrogen fluoride maximum 1 hour mean Scenario 3	160	4.92	3.66	2.3%	9	5.4%
Sulphur dioxide 99.9th %ile of 15 minute means	266	87	43	16%	130	48.9%
Sulphur dioxide 99.9th %ile of 15 minute means Scenario 3	266	87	86	32.3%	173	65.0%
Sulphur dioxide 99.7th %ile of 1 hour means	350	34	30	8.5%	64	18.2%
Sulphur dioxide 99.7th %ile of 1 hour means Scenario 3	350	34	60	17.0%	93	26.7%
Sulphur dioxide 99.2nd %ile of 24 hour means	125	14	1.93	1.54%	16	12.5%
Sulphur dioxide 99.2nd %ile of 24 hour means Scenario 3	125	14	42.8	34.3%	56	45.2%

These results indicate that all Scenario 3 process contributions due to emissions from the proposed facility comply with the relevant air quality standards and guidelines. All Scenario 3 combined concentrations due to emissions from the proposed facility added to baseline air quality levels also comply with the relevant air quality standards and guidelines.

Again, the margins of safety built in to the design of the proposed facility means that any short-term failure would not be expected to result in exceedances of the air quality standards and guidelines.

4.9.4 Scenario 4: Failure of activated carbon injection

This could potentially result in a short-term increase in emissions of particle-bound pollutants such as metals and dioxins and furans. Activated carbon injection systems are reported to be up to 98.7%

efficient in the removal of dioxins and furans.[30] On this basis, it was assumed that in the event of a failure of the activated carbon system, emissions of substances associated with particulate matter could theoretically increase by a factor of the order of 100 times for a period of up to 60 hours in a calendar year. This is considered to be a conservative assessment as particulate bound pollutants will continue to be be captured by the bag filters. The SCADA system will monitor carbon usage and will detect and highlight any issues so that appropriate remedial measures can be put in place.

The margins of safety built in to the design of the proposed facility means that any short-term failure would not be expected to result in the exceedances of short-term air quality standards and guidelines. The potential effect of this increase on long-term mean concentrations is set out in Table 26.

Table 26: Assessment of Abnormal Operating Scenario 4 (annual means)

Substance	AQ Standard/ Guideline	Baseline	Process contribution	PC/ AQSG	Combined process + baseline	Combined / AQSG
Cadmium	0.005	0.00012	0.0010	21%	0.0012	23%
Cadmium Scenario 4	0.005	0.00012	0.0017	35%	0.0019	37%
Mercury	0.25	0.0021	0.0010	0.42%	0.0031	1.3%
Mercury Scenario 4	0.25	0.0021	0.0017	0.70%	0.0039	1.5%
Antimony	5	0.00084	0.0012	0.023%	n/a	n/a
Antimony Scenario 4	5	0.00084	0.0019	0.039%	n/a	n/a
Arsenic	0.003	0.00073	0.0012	38%	0.0019	63%
Arsenic Scenario 4	0.003	0.00073	0.0019	65%	0.0027	89%
Lead	0.25	0.0062	0.0012	0.46%	0.0073	2.9%
Lead Scenario 4	0.25	0.0062	0.0019	0.77%	0.0081	3.2%
Chromium	5	0.0045	0.0012	0.023%	0.0057	0.11%
Chromium Scenario 4	5	0.0045	0.0013	0.026%	0.0058	0.12%
Chromium VI	0.0002	0.00090	0.00023 (see Section 4.3)	115%	0.0011 (see Section 4.3)	566%
Chromium VI Scenario 4 (screening assessment)	0.0002	0.00090	0.0000012 (see Section 4.3)	0.61%	0.00090 (see Section 4.3)	452%
Copper	10	0.043	0.0012	0.012%	0.044	0.44%
Copper Scenario 4	10	0.043	0.0019	0.019%	0.045	0.45%
Manganese	150	0.011	0.0012	0.00077%	0.012	0.0083%
Manganese Scenario 4	150	0.011	0.0019	0.0013%	0.013	0.0088%
Nickel	0.02	0.0014	0.0012	5.8%	0.0026	13%
Nickel Scenario 4	0.02	0.0014	0.0019	10%	0.0034	17%
Vanadium	5	0.0012	0.0012	0.023%	0.0023	0.046%
Vanadium Scenario 4	5	0.0012	0.0019	0.039%	0.0031	0.062%
Dioxins and furans ITEQ	No AQSG	5.5×10^{-8}	2.08×10^{-9}	n/a	5.71×10^{-8}	n/a
Dioxins and furans ITEQ Scenario 4	No AQSG	5.50×10^{-8}	3.49×10^{-9}	n/a	5.85×10^{-8}	n/a

[30] Moo Been Chang, Jung Jeng Lin "*Memory effect on the dioxin emissions from municipal waste incinerator in Taiwan,*" Chemosphere Volume 45, Issue 8, December 2001, Pages 1151–1157. Quoted in Environmental Statement for proposed Willows Power and Recycling Centre, Cory Wheelabrator, 2011.

PAHs (benz(a)pyrene)	0.00025	0.00014	0.000021	8.3%	0.00016	66%
PAHs (benz(a)pyrene) Scenario 4	0.00025	0.00014	0.000035	14%	0.00018	71%

These results indicate that Scenario 4 process contributions due to emissions from the proposed facility comply with the relevant air quality standards and guidelines. The assessment of the process contribution to chromium VI is based on a staged screening assessment, which was discussed in more detail in Section 4.3. Specifically, emissions for chromium VI were evaluated on the basis of a mean effective concentration of 0.000035 mg/Nm^3 during normal operation (8700 hours of the year), and a mean effective concentration of 100 times 0.000035 mg/Nm^3 during abnormal operation (60 hours of the year).

The Scenario 4 combined concentrations due to emissions from the proposed facility added to baseline air quality levels also comply with the relevant air quality standards and guidelines, with the exception of chromium VI. The exceedance of combined concentration for chromium VI is due almost entirely to the estimated baseline concentration of chromium VI, which is several times the relevant air quality standards and guidelines. As discussed in Section 4.9.2 above, the baseline levels for chromium VI were estimated using concentrations measured at the Manchester Wythenshawe monitoring site. This site was selected as being likely to represent an overestimate of baseline levels in the study area, and therefore this represents a conservative overestimate of the expected combined concentration of chromium VI in the event of a bag filter failure.

In general, the annual mean concentrations associated with Scenario 4 are very similar to the annual mean concentrations under normal operating conditions. Again, the margins of safety built in to the design of the proposed facility means that any short-term failure would not be expected to result in exceedances of the air quality standards and guidelines.

4.9.5 Conclusions

It is concluded that foreseeable abnormal operating conditions would not result in a significant increase in emissions of airborne pollutants, and would not pose a significant risk of exceedance of the relevant air quality standards and guidelines.

4.10 Assessment of cumulative impacts

The potential for cumulative impacts due to process emissions was considered during the planning process by reviewing the planning portal on the Bradford City Council website[31].

It is understood that no planning permission has been granted, or valid applications made, for developments in the vicinity of the proposed facility which could be considered as having a potential cumulative impact with the proposed facility.

[31] https://www.bradford.gov.uk/planning-and-building-control/planning-applications/view-planning-applications/

5 Conclusions

5.1 Summary

This study describes an assessment of potential effects on air quality of substances emitted from the proposed Clean Energy facility, Aire Valley Road, Keighley.

Modelled levels of all released substances when combined with background levels are forecast to comply with standards and guidelines for air quality.

The proposed development is forecast to have no significant effects on air quality during abnormal operating conditions or due to road traffic emissions, and no significant cumulative effects are forecast to occur. No odour, bioaerosol or dust issues would be expected to arise outside the site boundary.

Emissions to air from the proposed facility are forecast to have no significant effects at nearby European, national or locally designated habitat sites. Specifically with regard to European sites, guidance from the Environment Agency indicates that a likely significant effect is identified when the long-term Process Contribution (PC) is greater than 1%, and the Predicted Environmental Concentration (PEC) is greater than 70% of the relevant critical load/level, or when the short-term process contribution is greater than 10% of the relevant critical level. The information set out in Section 4.6 indicates that the process contributions would be less than 1% of the long-term critical levels and critical loads, and less than 10% of the short-term critical levels. In view of these results, and in the context of generally declining baseline levels of the relevant substances, there is no likelihood of a significant effect on the designated interest features of the European sites, having regard to the conservation objectives of those sites. Following the Environment Agency guidance, it is concluded that an Appropriate Assessment is not required.

The study was carried out using a conservative approach to ensure that any air quality effects are more likely to be overestimated than underestimated.

On the basis of this assessment, it is concluded that the proposed facility will have no significant adverse effects on air quality.

5.2 EPUK criteria

The EPUK criteria set out in Section 3.13 provide standard descriptors to be used in describing the forecast air quality effects of the proposed development. While these are designed primarily for use in relation to traffic emissions, they can also be applied to describing the impact of emissions to air from the proposed facility. The assessment for annual mean nitrogen dioxide and PM_{10} levels is as follows:

- Nitrogen dioxide
  AQ Standard/Guideline (annual mean): 40 µg/m^3
  Maximum forecast change: 2.18 µg/m^3 (5.45% of AQSG)
  Combined concentration (process + baseline): 31.2 µg/m^3 (78% of AQSG)
  Impact descriptor: **Slight**
- PM_{10}
  AQ Standard/Guideline (annual mean): 40 µg/m^3
  Maximum forecast change: 0.21 µg/m^3 (0.52% of AQSG)
  Combined concentration (process + baseline): 17.2 µg/m^3 (43% of AQSG)
  Impact descriptor: **Negligible**

The above analysis reflects a conservative approach, using the highest forecast concentration changes in the vicinity of the proposed development coupled with the highest baseline values recorded in recent years. On this basis, the maximum impact in relation to annual mean nitrogen dioxide can be described as “slight” and the maximum impact in relation to annual mean PM_{10} levels can be described as “negligible”. The maximum impacts at individual receptor sites will be less than the impacts described above.

5.3 Mitigation and monitoring

In view of the finding that the proposed Clean Energy Facility will have no significant adverse effects on air quality, it is concluded that no further mitigation is necessary, other than the extensive mitigation and control measures already built into the proposed facility.

Emissions from the proposed facility will be measured continuously, and as part of a programme of periodic monitoring. Operation of the facility including emission monitoring will be managed under the terms of the permit for the proposed facility under the Environmental Permitting Regulations (England and Wales) 2016. The permit will also set conditions to assure application of Best Available Techniques in the operation of the facility.

In view of the low forecast levels of released substances, and conservative assumptions built in to the modelling study, it is most unlikely that an environmental monitoring programme would be effective in identifying a detectable change in air quality which could be linked to emissions from the proposed facility. However, if required, an ambient air quality monitoring programme could be designed as a cross-check on the conclusions of the study.

6 Figures

Figure 3: Potentially sensitive locations (all identified locations)

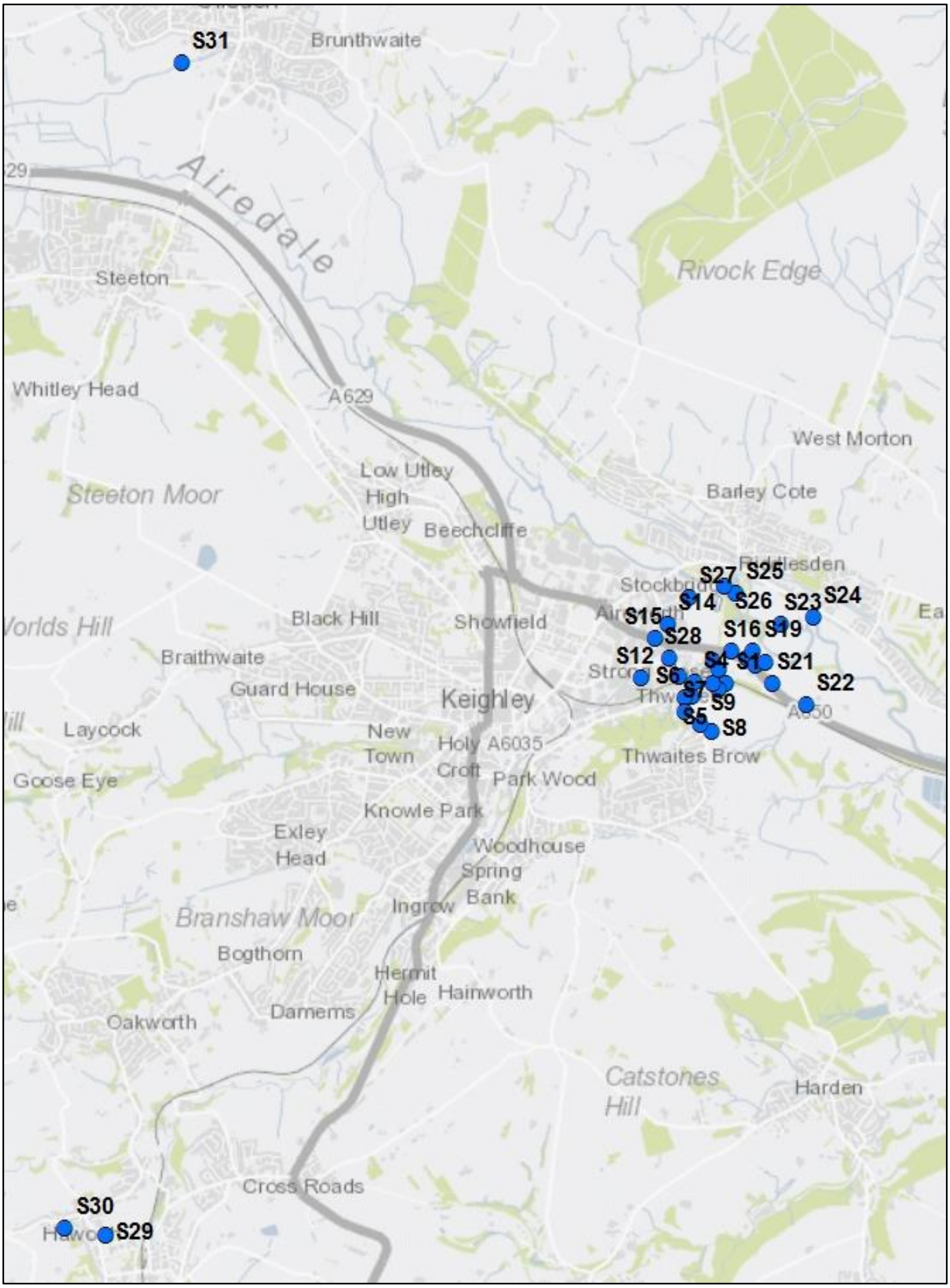


Figure 4: Potentially sensitive locations (near vicinity of proposed facility)

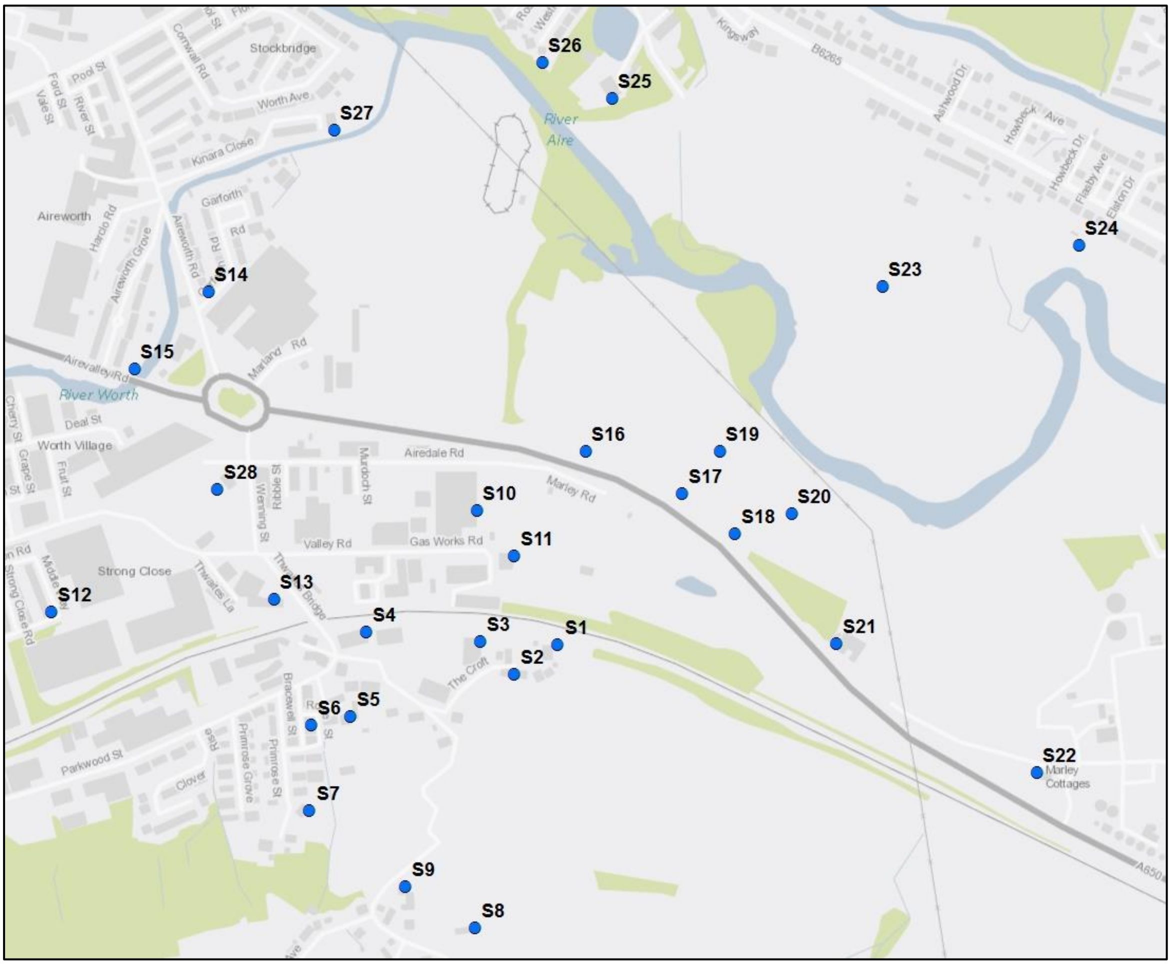


Figure 5: Designated habitat sites

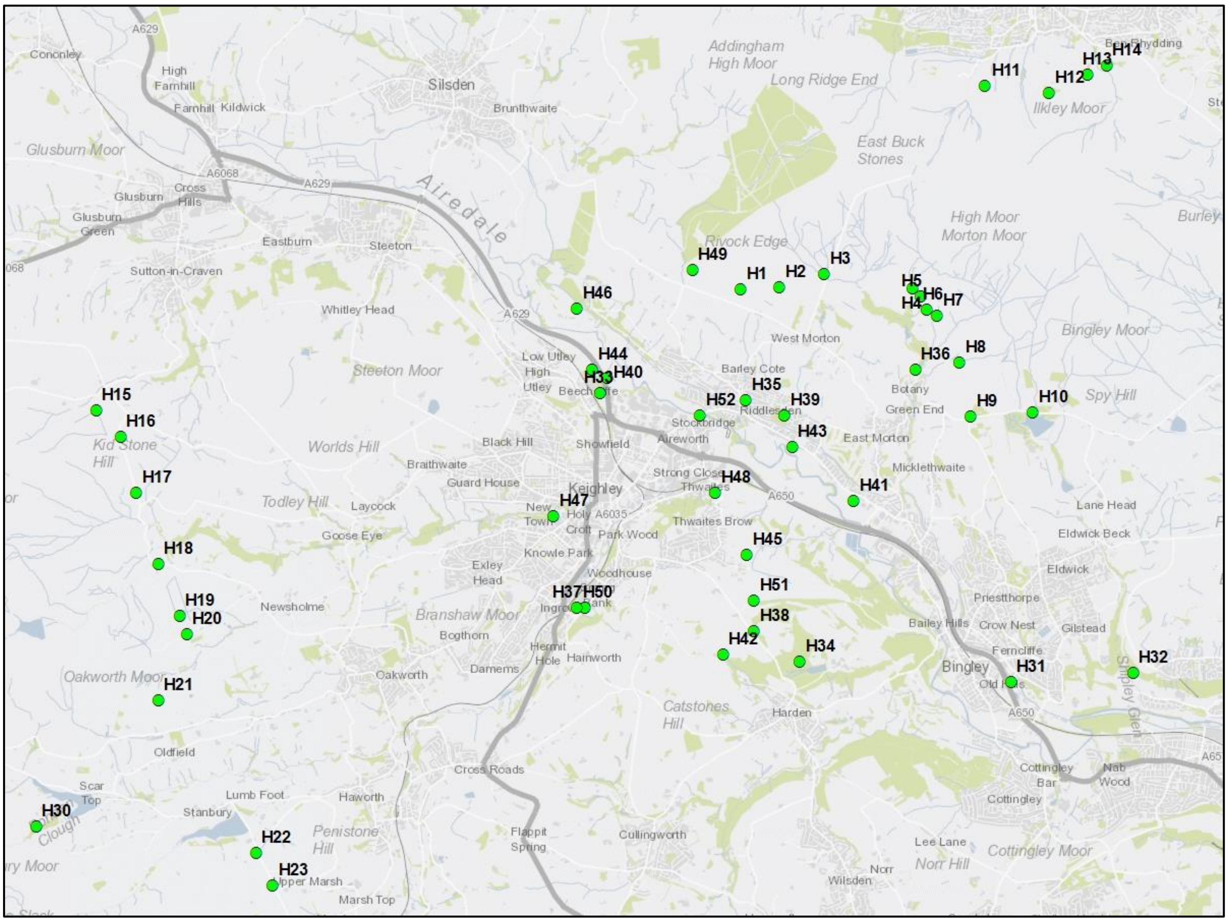


Figure 6: Annual mean VOC concentrations (assessed as benzene) due to emissions from the proposed facility (µg/m³)

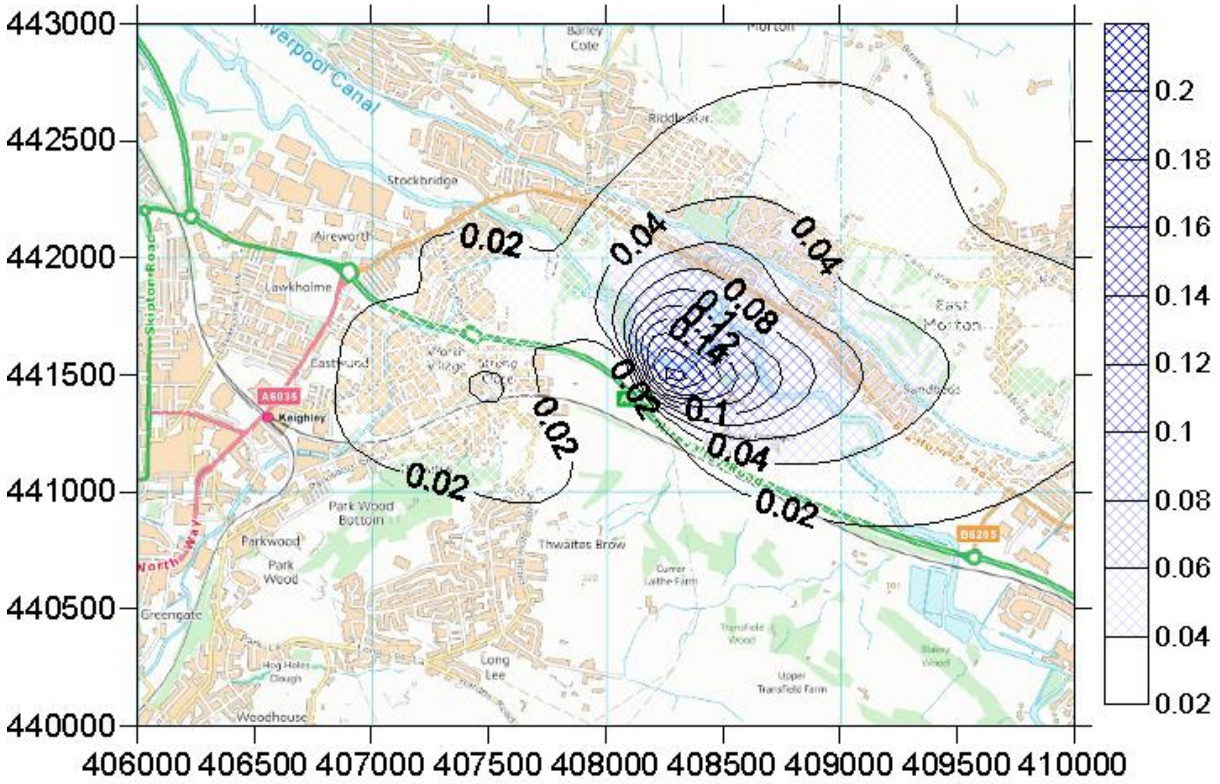


Figure 7: Maximum hourly mean hydrogen chloride concentrations due to emissions from the proposed facility (µg/m³)

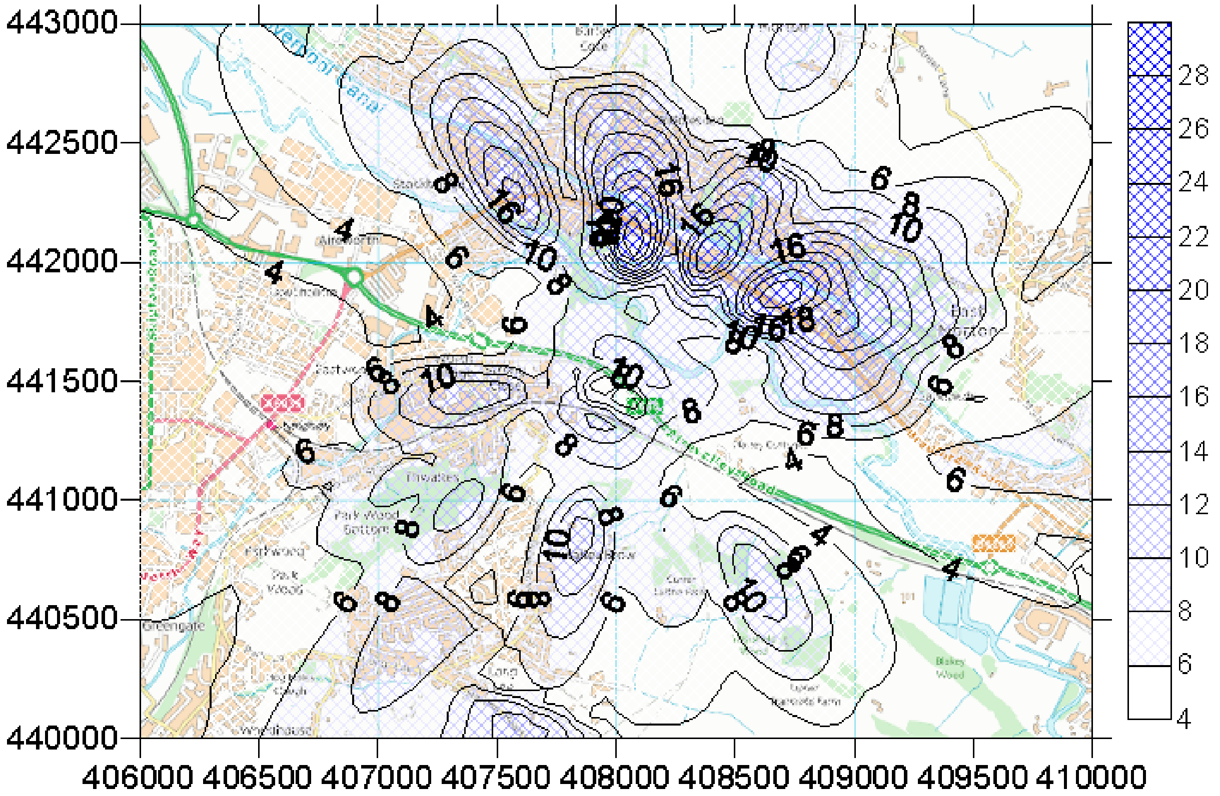


Figure 8: 99.9th percentile of 15-minute mean sulphur dioxide concentrations due to emissions from the proposed facility (µg/m³)

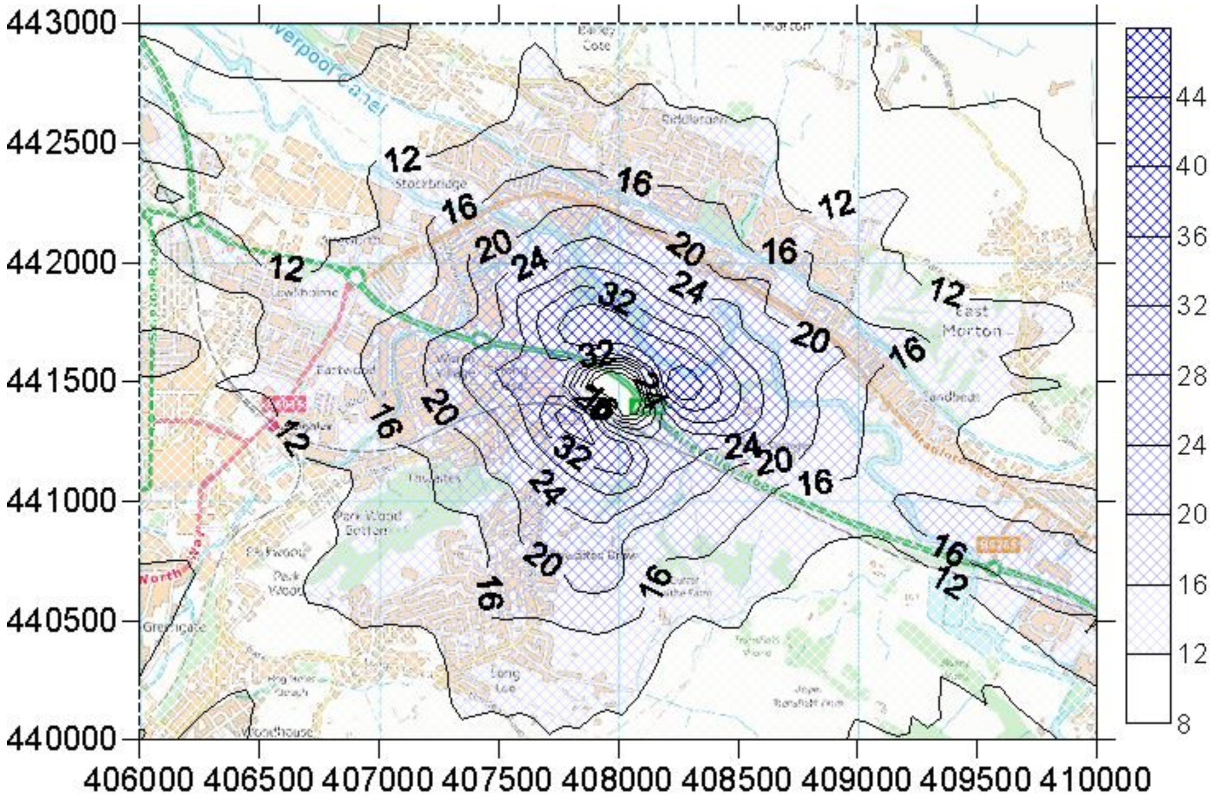


Figure 9: 99.7th percentile of hourly mean sulphur dioxide concentrations due to emissions from the proposed facility (µg/m³)

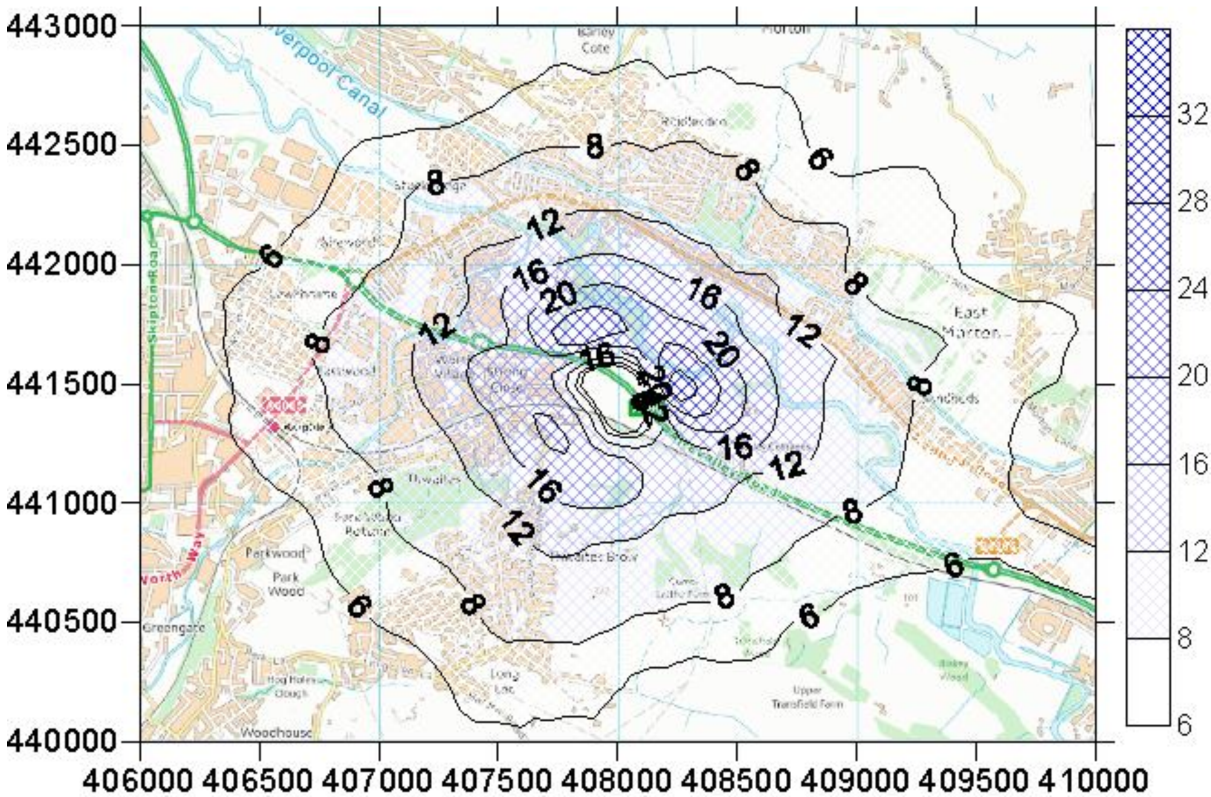


Figure 10: Annual mean nitrogen dioxide concentrations due to emissions from the proposed facility (µg/m³)

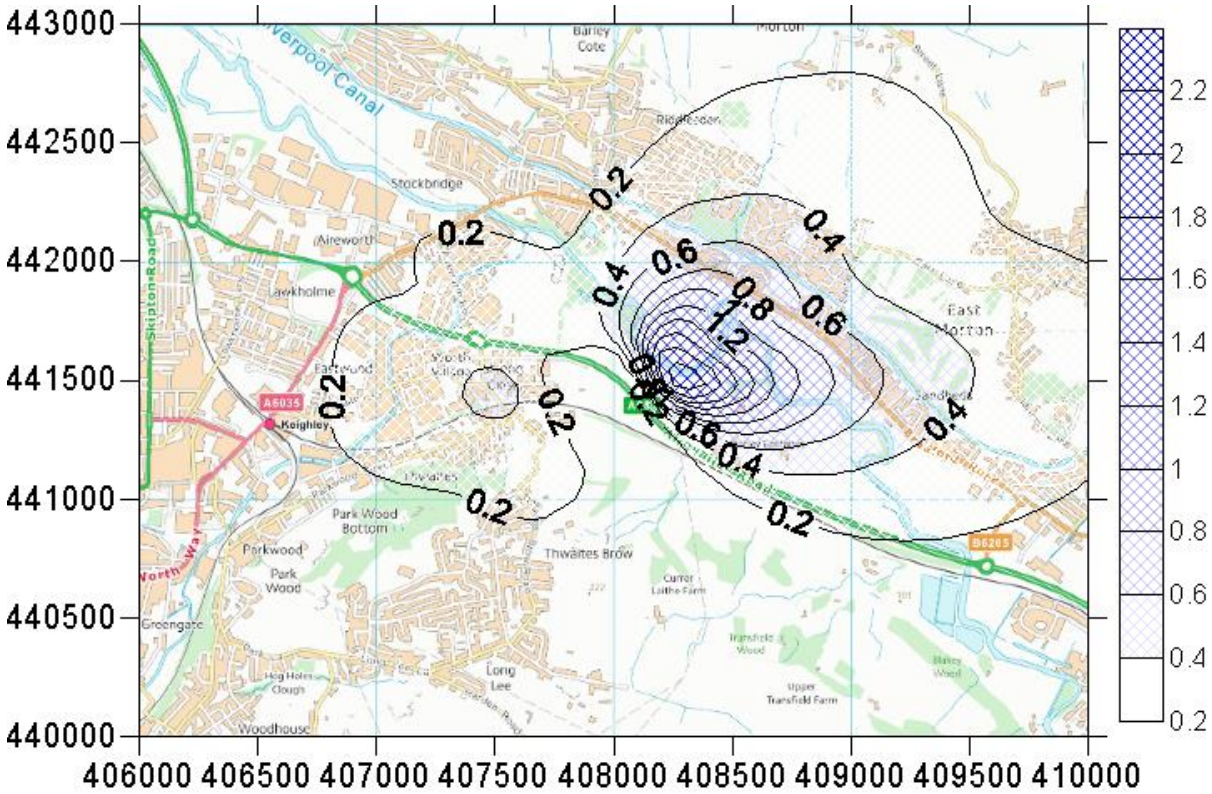


Figure 11: 99.79th percentile of 1 hour mean nitrogen dioxide concentrations due to emissions from the proposed facility (µg/m³)

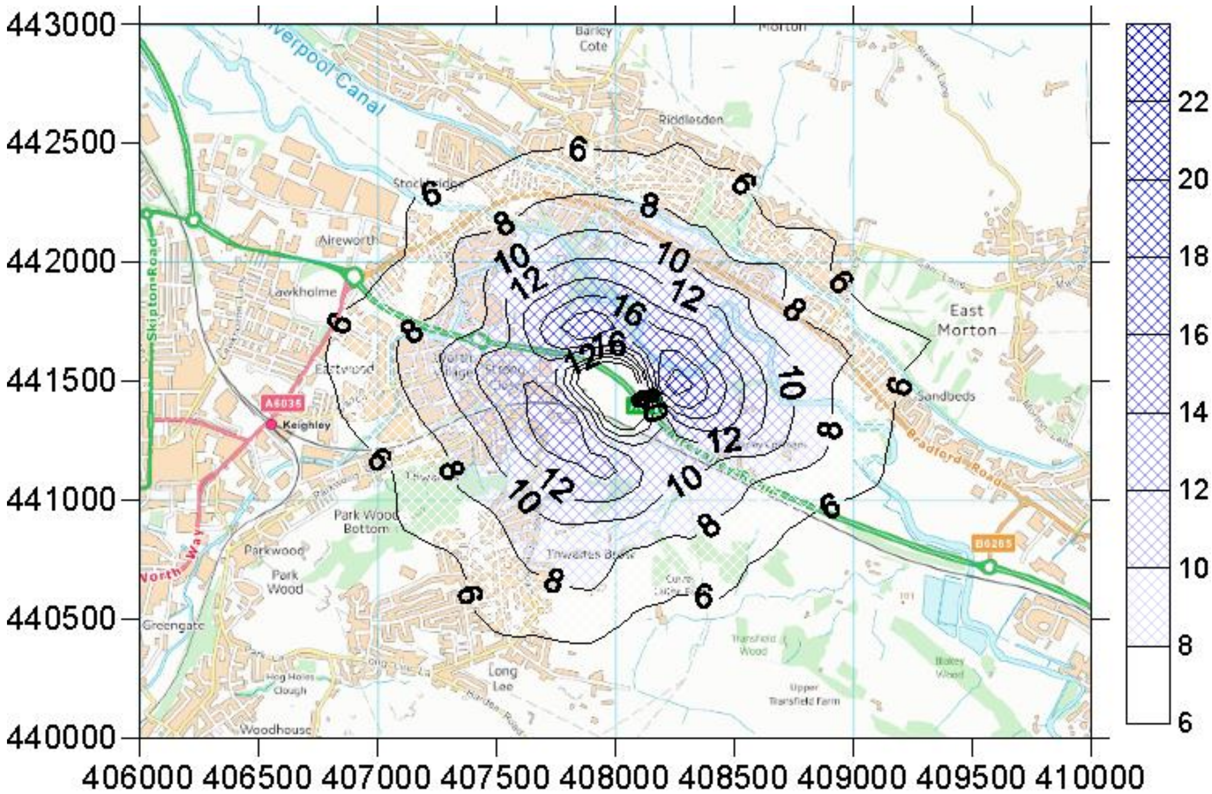


Figure 12: Annual mean cadmium concentrations due to emissions from the proposed facility (µg/m³)

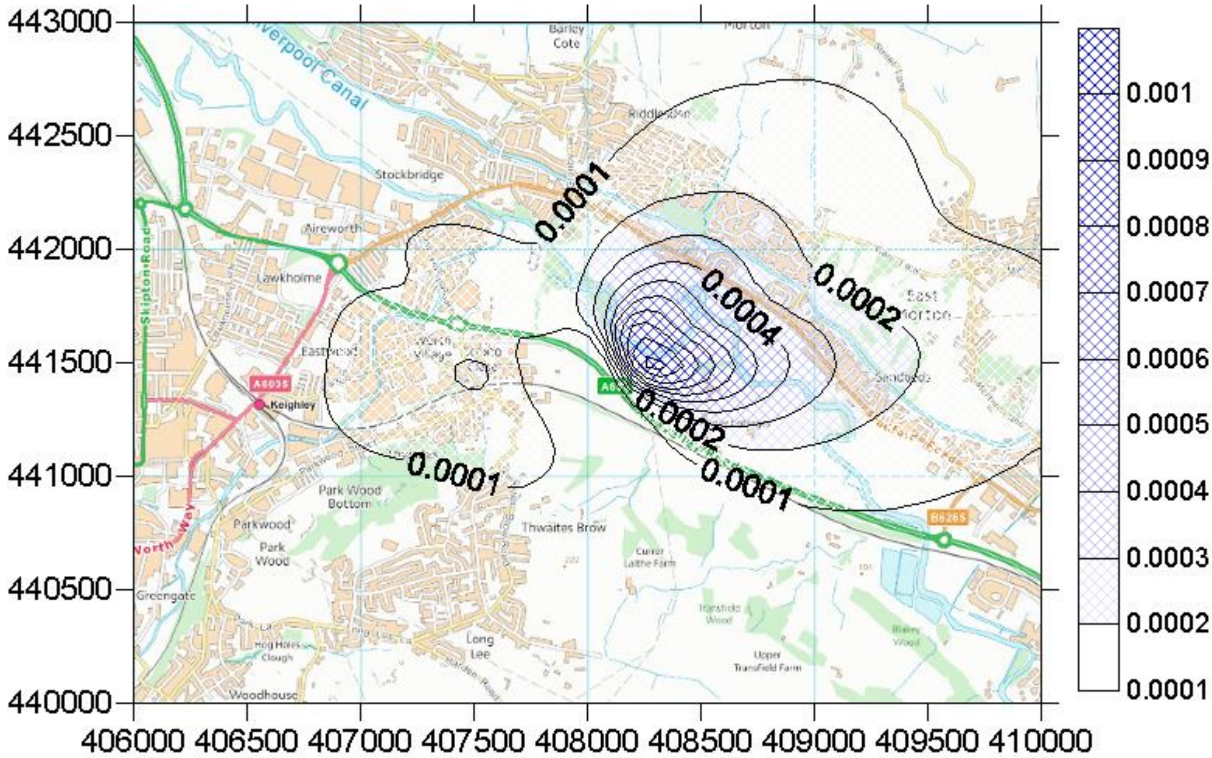


Figure 13: Annual mean arsenic concentrations due to emissions from the proposed facility (µg/m³)

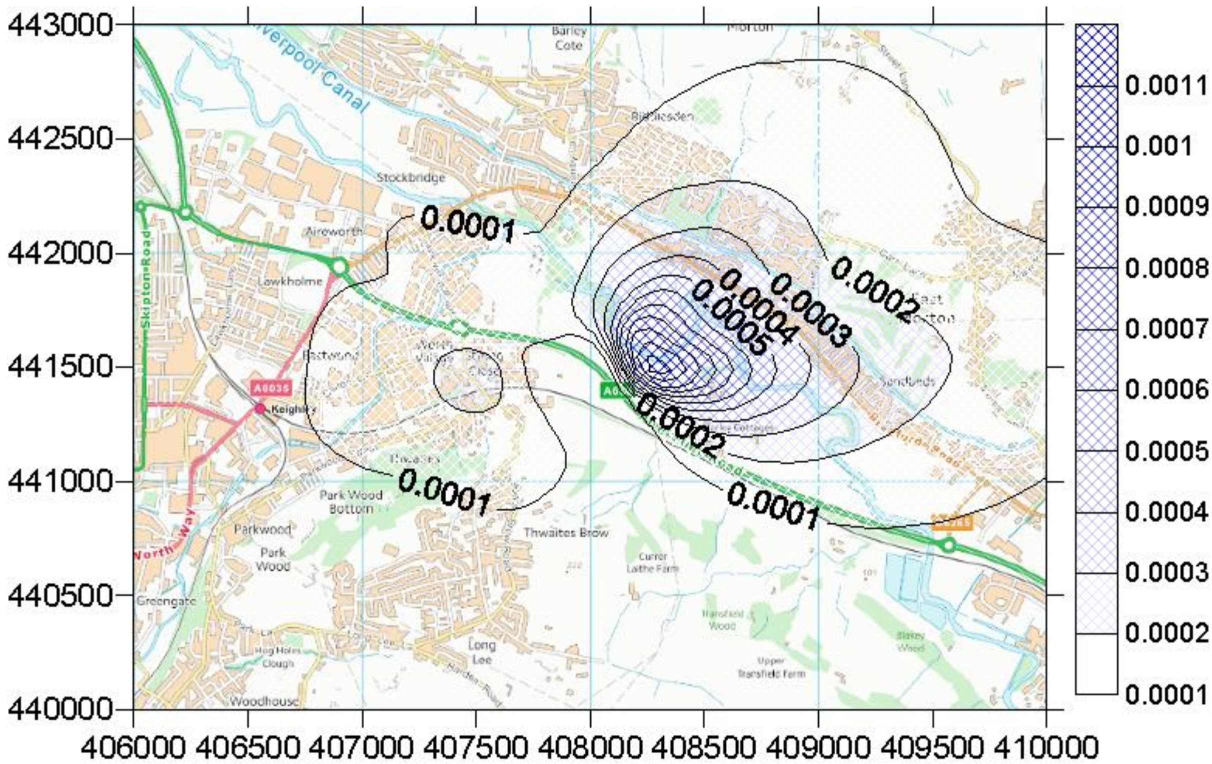


Figure 14: Annual mean nickel concentrations due to emissions from the proposed facility (µg/m³)

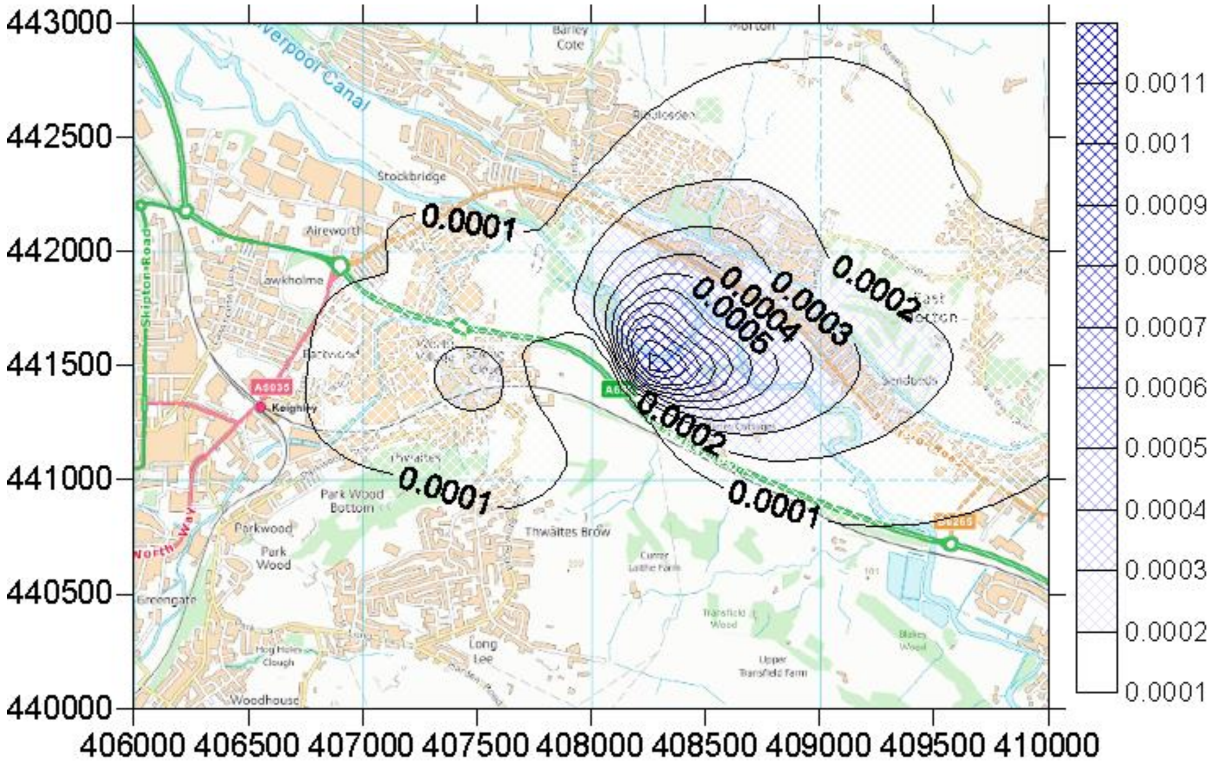
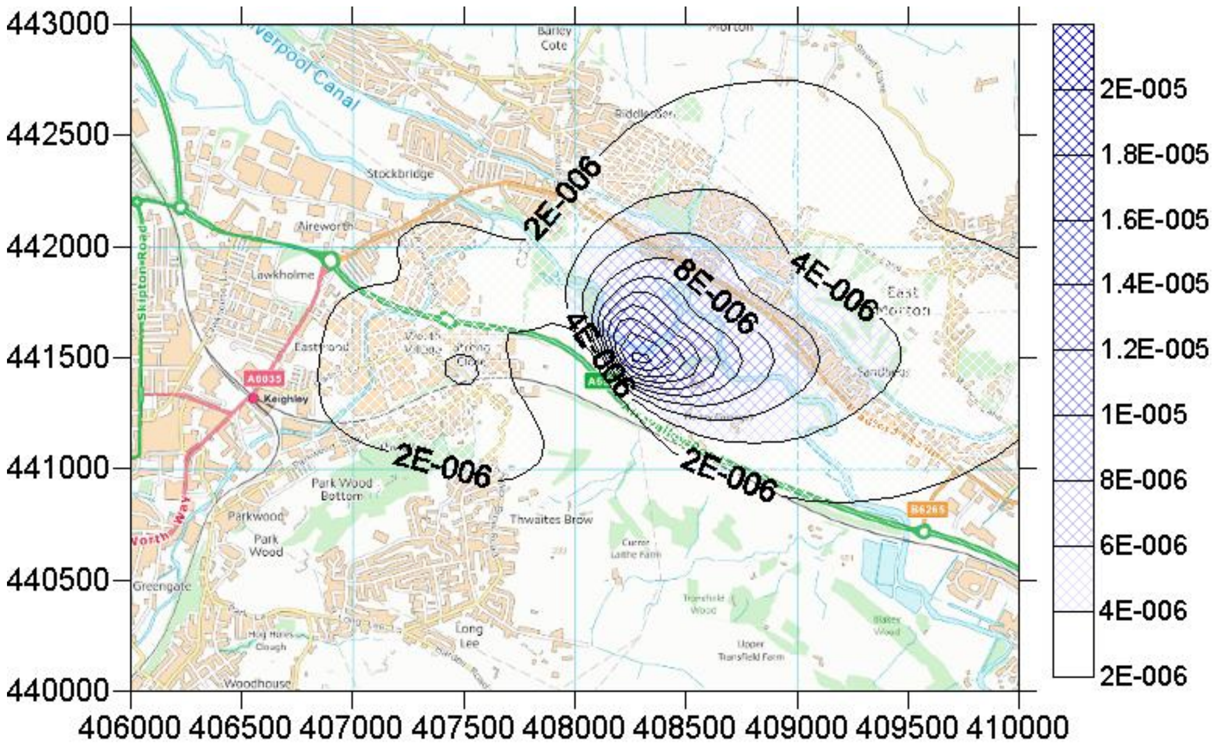


Figure 15: Annual mean Polycyclic Aromatic Hydrocarbon concentrations due to emissions from the proposed facility (µg/m³)



Appendices

Appendix 1: Baseline air quality data
Appendix 2: Modelled levels at individual receptor locations

Appendix 1: Baseline air quality data

A1.1 Bradford City Council: continuous air quality monitoring

Bradford City Council carries out continuous measurements of a range of airborne pollutants.[32] The most representative monitoring station for levels of oxides of nitrogen, PM_{10} and $PM_{2.5}$ is the Keighley Air Quality Station, located in Keighley town centre at North Street, 1.9 km west of the site.

Table A1.1: Continuous monitoring data: Keighley

Substance	Annual mean measured level (µg/m³) at Keighley Air Quality Station						
	2009	2010	2011	2012	2013	2014	2015
PM_{10}	15	17	13	17	17	12	14
$PM_{2.5}$	n/a	n/a	n/a	n/a	n/a	n/a	10
Nitrogen dioxide	22	26	29	29	27	27	28

A1.2 Bradford City Council: other air quality surveys

Bradford City Council carries out measurements of nitrogen dioxide at 34 locations across the borough.[32] The two closest locations to the proposed development are at 12 Prospect St Keighley Kerbside (3.3 km west of the proposed development) and Aireworth Road Kerbside (0.7 km west of the proposed development). The annual mean measured levels of nitrogen dioxide at these locations during from 2010 to 2015 were as follows.[32]

Table A1.2: Levels of nitrogen dioxide measured by Bradford City Council

Location		Annual mean measured level of nitrogen dioxide (µg/m³) in					
		2010	2011	2012	2013	2014	2015
12 Prospect St Keighley Kerbside	**3.3 km west of site**	19	13	24	29	21	17
Aireworth Road Kerbside	**0.7 km west of site**	n/a	n/a	n/a	n/a	n/a	27

A1.3 Other continuous monitoring network data

The UK data archives contain measurements from continuous monitors across the UK.[33] The Leeds Centre monitoring station is designated as an urban background site and records levels of benzene, carbon monoxide and sulphur dioxide.

Table A1.3: Continuous monitoring data: Leeds Centre

Substance	Measured levels (µg/m³) at Leeds Centre				
	2012	2013	2014	2015	2016
Benzene (annual mean)	0.62	0.67	0.71[34]	0.66	0.60
Carbon monoxide (annual mean)	519	206	253	254	267
Sulphur dioxide (99.9th percentile of 15 minute mean concentrations)	80	87	32	21	14
Sulphur dioxide (99.7th percentile of 1 hour mean concentrations)	17	34	27	15	9
Sulphur dioxide (annual mean)	2.06	2.22	2.53	1.63	1.44

[32] City of Bradford MDC, "2016 Air Quality Annual Status Report (ASR)," January 2017
[33] Defra, "UK-Air: Air information resource," http://uk-air.defra.gov.uk/ accessed March 2017
[34] 2014 annual measured benzene concentration updated to reflect full 2014 calendar year, from UK-Air website, accessed June 2017.

A1.4 Metals monitoring network data

Metals are measured at 24 locations across the UK.[35] The majority of these measurements are carried out in industrial areas close to metals processing factories. These measurements are not representative of the study area. The Manchester Wythenshawe site was selected as being likely to represent an overestimate of baseline levels in the study area. Baseline levels of metals measured at this location in 2013 were as follows[33]:

- Vanadium 1.16 ng/m^3
- Nickel 1.44 ng/m^3
- Mercury 2.11 ng/m^3
- Manganese 11.26 ng/m^3
- Lead 6.17 ng/m^3
- Copper 42.8 ng/m^3
- Cobalt 0.16 ng/m^3
- Chromium 4.51 ng/m^3
- Cadmium 0.12 ng/m^3
- Arsenic 0.73 ng/m^3

Antimony is measured at 11 locations across the UK.[36] Annual measurements for the three sites closest to the proposed development between 2010 and 2013 were as follows:

Table A1.4: Antimony monitoring data from metals monitoring network

Site	Annual mean measured levels (ng/m^3) in			
	2010	2011	2012	2013
Auchencorth Moss	0.46	0.33	0.26	0.24
Cockley Beck	0.75	0.35	0.26	0.23
Heigham Holmes	0.83	0.79	0.84	0.66

A1.5 Ammonia and acid gases monitoring network data

Ammonia and acid gases have been measured at 95 locations across the UK, although a number of these monitoring stations have been discontinued.[37] The most representative ammonia monitoring station for the proposed development site was identified as Ladybower. Measurements of airborne ammonia and hydrogen chloride made at Ladybower station are set out in Table A1.5.

Table A1.5: Measurements from UK ammonia and acid gases monitoring network

Substance	Measured annual mean concentration at Ladybower (µg/m^3)						
	2010	2011	2012	2013	2014	2015	2015
Ammonia	1.16	1.08	0.78	0.82	1.15	0.93	0.71
Hydrogen chloride	0.28	0.29	0.25	0.44	0.40	0.23	1.01

A1.6 Toxic Organic Micropollutants network data

Dioxins and furans were measured at six locations across the UK from 2010 to 2012.[33] Measured levels of dioxins and furans at these locations are set out in Table A1.6.

[35] Defra, "*Annual Report for 2010 on the UK Heavy Metals Monitoring Network*," Report Ref. AS 61 prepared by NPL
[36] Defra, https://uk-air.defra.gov.uk/data/data_selector?#mid, accessed June 2017.
[37] Defra, http://pollutantdeposition.defra.gov.uk/networks accessed July 2017

Table A1.6: Dioxin and furan measurements from UK national monitoring network

Site	Measured concentration (fg TEQ/m³)		
	2010[38]	2011	2012
Auchencorth Moss	19	0.8	0.1
Hazelrigg	19	2.0	8.8
High Muffles	17	1.0	4.3
London	48	3.7	16
Manchester	55	13	33
Weybourne	17	2.5	9.3

PAHs are measured by Digitel sampler at 33 locations across the UK.[33] Concentrations of benz(a)pyrene measured at rural background locations from 2012 to 2016 are set out in Table A1.7.

Table A1.7: Benz(a)pyrene measurements from UK national monitoring network

Site	Measured concentration (ng/m³)				
	2012	2013	2014	2015	2016
Auchencorth Moss	0.055	0.032	0.026	0.022	0.023
Harwell	0.082	0.084	0.055	0.055	n/a
Hazelrigg	0.082	0.021	0.057	0.063	0.051
High Muffles	0.074	0.065	0.071	0.067	0.051
Stoke Ferry	0.143	0.123	0.093	0.092	0.137

A1.7 Defra interpolated data

Defra has produced a set of interpolated maps to provide indicative background levels of airborne pollutants.[33] These datasets provide indicative background levels of a range of substances on a 1 km × 1 km grid basis. Table A1.7 below sets out the indicative background level of nitrogen dioxide, oxides of nitrogen, PM_{10} and $PM_{2.5}$ for the grid square containing the proposed development, and for the eight surrounding grid squares for 2014 to 2016.

Table A1.8: Indicative background levels from interpolated datasets

Co-ordinates of grid square centre		Indicative background level (µg/m³)			
		Nitrogen dioxide	Oxides of nitrogen (2014)	PM_{10} (2014)	$PM_{2.5}$ (2014)
Easting	**Northing**	2014			
406500	**442500**	17.70	25.56	14.57	10.27
407500	**442500**	14.62	20.52	13.63	9.74
408500	**442500**	12.27	16.89	12.99	9.32
406500	**441500**	19.85	29.16	15.18	10.73
407500	**441500**	16.36	23.34	14.13	9.94
408500	**441500**	13.33	18.49	13.42	9.51
406500	**440500**	13.50	18.78	13.64	9.64
407500	**440500**	11.48	15.70	12.99	9.23
408500	**440500**	10.93	14.88	12.69	9.07
2014 Maximum		19.85	29.16	15.18	10.73
2014 Average		14.45	20.37	13.69	9.72

[38] 2010 annual measured metal concentrations updated to reflect full 2010 calendar year, from UK-Air website, accessed June 2017.

Co-ordinates of grid square centre		Indicative background level (µg/m³)			
		Nitrogen dioxide	Oxides of nitrogen (2014)	PM_{10} (2014)	$PM_{2.5}$ (2014)
Easting	**Northing**	**2014**			
406500	**442500**	16.43	23.61	12.82	9.28
407500	**442500**	14.66	20.72	12.41	9.18
408500	**442500**	12.85	17.89	11.73	8.62
406500	**441500**	18.87	27.66	13.52	9.84
407500	**441500**	15.81	22.59	12.65	9.17
408500	**441500**	13.54	18.91	12.08	8.77
406500	**440500**	14.36	20.24	12.34	8.95
407500	**440500**	12.63	17.54	11.85	8.65
408500	**440500**	11.81	16.29	11.42	8.33
2015 Maximum		18.87	27.66	13.52	9.84
2015 Average		14.55	20.61	12.31	8.98
Easting	**Northing**	**2016**			
406500	**442500**	15.76	22.53	12.71	9.28
407500	**442500**	14.06	19.78	12.31	9.08
408500	**442500**	12.32	17.08	11.64	8.54
406500	**441500**	18.09	26.35	13.40	9.72
407500	**441500**	15.17	21.57	12.55	9.08
408500	**441500**	12.94	18.00	11.99	8.68
406500	**440500**	13.77	19.33	12.23	8.86
407500	**440500**	12.11	16.74	11.75	8.56
408500	**440500**	11.31	15.54	11.33	8.25
2016 Maximum		18.09	26.35	13.40	9.72
2016 Average		13.95	19.66	12.21	8.90

A1.8 Estimated background levels for use in air quality study

The information set out above was evaluated in accordance with the following principles to establish an estimated baseline level for each substance of potential concern:

- Local measurements are preferred over more distant measurements.
- Long-term average measurements are preferred over shorter time period measurements.
- Measurements made using fully validated methods (e.g. appropriate continuous analysers for nitrogen dioxide) are preferred over measurements made using indicative methods (e.g. diffusion tubes).
- Measurement data is preferred over interpolated data.
- Where a choice was required, a higher level was preferred over a lower level as representing a more conservative value.

Following this approach, the following long-term mean baseline levels were identified as being representative of the local area.

Table A1.9: Baseline air quality in the study area

Substance	Long-term baseline level	Basis
Particulate matter (PM_{10})	17 µg/m^3	Highest level measured at Keighley Centre monitoring station between 2009 and 2015. This level is higher than the interpolated map values.
Particulate matter ($PM_{2.5}$)	17 µg/m^3	Assumed to be the same as the measured PM_{10} level as a conservative approach. This level is higher than the value measured at Keighley Centre in 2015 and higher than the interpolated map values.
Benzene	0.71 µg/m^3	Highest level measured at Leeds Centre monitoring station between 2012 and 2016. The use of data from Leeds Centre is likely to be an overestimate for the vicinity of the proposed facility.
Hydrogen chloride	1.01 µg/m^3	Highest level measured at Ladybower monitoring station between 2010 and 2015.
Hydrogen fluoride	2.46 µg/m^3	Short-term peak level suggested by EPAQS[39].
Carbon monoxide	519 µg/m^3	Highest level measured at Leeds Centre monitoring station between 2012 and 2016. The use of data from Leeds Centre is likely to be an overestimate for the vicinity of the proposed facility.
Sulphur dioxide (annual mean)	2.53 µg/m^3	Highest level measured at Leeds Centre monitoring station between 2012 and 2016. The use of data from Leeds Centre is likely to be an overestimate for the vicinity of the proposed facility.
Sulphur dioxide (99.9th percentile of 15 minute mean concentrations)	87 µg/m^3	
Sulphur dioxide (99.7th percentile of 1 hour mean concentration)	34 µg/m^3	
Nitrogen dioxide	29 µg/m^3	Highest level recorded at Keighley Centre monitoring station between 2009 and 2015. This level is equivalent to the highest level recorded at diffusion tube locations in Keighley from 2010 to 2015, and is higher than the interpolated map values. Consequently, this level is likely to be conservative for assessment of the vicinity of the proposed development site.
Ammonia	1.16 µg/m^3	Highest level measured at the Ladybower survey site between 2010 and 2015. Levels on the edge of a town such as the proposed development location are if anything likely to be lower than those in a rural area because of the influence of agricultural sources. Consequently, this level is likely to be conservative for assessment of the vicinity of the proposed development site.
Dioxins and furans ITEQ	55 fgTEQ/m^3	Highest level measured at urban and rural locations in the UK between 2010 and 2012 (level recorded at Manchester, 2010).
PAHs (benz(a)pyrene)	0.143 ng/m^3	Highest level measured at any rural background location in the UK between 2012 and 2016 (level recorded at Stoke Ferry, 2012).
Metals		
Cadmium	0.12 ng/m^3	Levels measured at Manchester Wythenshawe as part of national survey in 2013. Likely to constitute an overestimate of baseline air quality levels in the study area.
Mercury	2.11 ng/m^3	
Arsenic	0.73 ng/m^3	

[39] Expert Panel on Air Quality Standards, "*Guidelines for Halogens and Hydrogen Halides in Ambient Air for Protecting Human Health against Acute Irritancy Effects*," 2006

Substance	Long-term baseline level	Basis
Lead	6.17 ng/m^3	
Chromium	4.51 ng/m^3	
Copper	42.8 ng/m^3	
Manganese	11.26 ng/m^3	
Nickel	1.44 ng/m^3	
Vanadium	1.16 ng/m^3	
Cobalt	0.16 ng/m^3	
Chromium VI	0.90 ng/m^3	Derived from total chromium measurement, on the basis of Environment Agency guidance that 20% of total chromium is in the form of chromium VI.[40]
Antimony	0.84 ng/m^3	Highest level recorded at the three closest monitoring stations between 2010 and 2013 (level recorded at Heigham Holmes, 2012).
Thallium		No national measurement. Baseline measurements used in relation to other developments[5] confirms that baseline levels are not significant in relation to the air quality standards and guidelines.

Short-term peak baseline concentrations for almost all substances were estimated as twice the long-term mean baseline level, in accordance with established procedures for a conservative assessment set out in Environment Agency guidance.[41] The exception was short-term peak sulphur dioxide levels, which were estimated on the basis of measured concentrations at Leeds Centre monitoring station as set out in Table A1.8, in order to ensure a robust assessment.

[40] Environment Agency, Environmental Risk Assessment Framework – H1 Annex F – Air Emissions, December 2011, https://consult.environment-agency.gov.uk/psc/ta6-6lq-mole-valley-feed-solutions-ltd/supporting_documents/Supporting%20Documents%20%20H1%20Annex%20F%20%20Air%20Emissions.pdf

[41] Environment Agency "*How to comply with your environmental permit Additional guidance for: Horizontal Guidance Note H1 - Annex (f)*," April 2010

Appendix 2: Modelled levels at individual receptor locations

Ref.	PM_{10} (annual mean)	PM_{10} (90.4th%ile of 24-hour means)	$PM_{2.5}$ (annual mean)	SO_2 (99.9th%ile 15-minute means	SO_2 (99.7th%ile hourly means)	SO_2 (99.2nd%ile of 24-hour means	NO_2 (annual mean)	NO_2 (99.79th%ile hourly means	Dioxins and furans (annual mean)
	µg/m³								
S1	0.011	0.030	0.011	40.79	15.55	0.54	0.09	15.15	8.91×10^{-11}
S2	0.019	0.060	0.019	36.23	18.72	0.54	0.18	15.94	1.74×10^{-10}
S3	0.021	0.100	0.021	35.84	19.77	0.54	0.20	15.62	1.89×10^{-10}
S4	0.040	0.164	0.040	27.79	18.98	0.86	0.40	13.40	3.83×10^{-10}
S5	0.034	0.142	0.034	25.15	17.30	0.87	0.35	12.24	3.37×10^{-10}
S6	0.034	0.133	0.034	23.28	15.94	0.80	0.35	11.33	3.36×10^{-10}
S7	0.026	0.108	0.026	21.91	14.68	0.72	0.27	10.37	2.55×10^{-10}
S8	0.022	0.094	0.022	23.79	15.69	0.84	0.23	11.16	2.18×10^{-10}
S9	0.024	0.104	0.024	22.04	14.78	0.69	0.25	10.57	2.42×10^{-10}
S10	0.016	0.069	0.016	30.10	15.74	0.40	0.15	13.56	1.38×10^{-10}
S11	0.010	0.038	0.010	27.70	13.46	0.31	0.08	10.58	7.56×10^{-11}
S12	0.031	0.120	0.031	18.76	12.00	0.68	0.32	8.48	3.07×10^{-10}
S13	0.043	0.166	0.043	25.49	16.88	0.95	0.44	11.92	4.16×10^{-10}
S14	0.025	0.106	0.025	19.13	12.33	0.50	0.25	8.81	2.43×10^{-10}
S15	0.027	0.091	0.027	19.33	12.66	0.66	0.28	8.97	2.66×10^{-10}
S16	0.016	0.049	0.016	31.95	16.70	0.45	0.15	13.37	1.40×10^{-10}
S17	0.005	0.015	0.005	8.31	1.74	0.08	0.01	1.73	9.96×10^{-12}
S18	0.010	0.027	0.010	2.18	0.11	0.04	0.01	0.14	4.84×10^{-12}
S19	0.029	0.117	0.029	32.63	13.23	0.49	0.27	10.86	2.57×10^{-10}
S20	0.082	0.237	0.082	23.88	16.42	1.14	0.79	11.68	7.56×10^{-10}
S21	0.028	0.102	0.028	23.45	12.18	0.44	0.24	9.27	2.25×10^{-10}
S22	0.041	0.146	0.041	22.42	15.02	0.69	0.42	10.82	3.98×10^{-10}
S23	0.108	0.344	0.108	27.56	18.97	1.09	1.12	13.47	1.07×10^{-9}
S24	0.089	0.259	0.089	22.70	14.84	0.79	0.93	10.51	8.82×10^{-10}
S25	0.024	0.089	0.024	25.20	15.90	0.59	0.25	11.54	2.36×10^{-10}
S26	0.019	0.069	0.019	23.52	14.16	0.42	0.19	10.33	1.86×10^{-10}
S27	0.024	0.109	0.024	21.92	13.64	0.57	0.25	9.93	2.34×10^{-10}

S28	0.038	0.126	0.038	25.87	16.72	0.83	0.39	11.93	3.67×10^{-10}
S29	0.002	0.006	0.002	3.04	1.09	0.04	0.02	0.89	1.49×10^{-11}
S30	0.001	0.006	0.001	3.17	1.12	0.04	0.02	0.98	1.45×10^{-11}
S31	0.002	0.008	0.002	4.42	1.44	0.04	0.02	1.22	1.80×10^{-11}

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