Net Zero Power Limited

Environmental Permit Variation

Appendix E: Air Quality Impact Assessment

Reference: EPR/PP3501LR

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List of Abbreviations

ADMS	Atmospheric Dispersion Modelling System
APIS	Air Pollution Information Service
AQAP	Air Quality Action Plan
AQMA	Air Quality Management Area
AQMAU	Air Quality Modelling and Assessment Unit
AQS	Air Quality Standard
ASR	Annual Status Report
BAT	Best Available Techniques
BAT-AELs	Best Available Techniques -Achievable Emission Levels
BATc	Best Available Techniques Conclusions document
BRef	BAT Reference document
CCGT	Combined Cycle Gas Turbine
CCS	Carbon Capture and Storage
CCSA	Carbon Capture and Storage Association
CERC	Cambridge Environmental Research Consultants
CL	Critical Level
CLd	Critical Load
CLRTAP	Convention on Long-range Transboundary Air Pollution
CMR	Carcinogen, Mutagen, Reproductive toxicant
CO	Carbon Monoxide
CO_2	Carbon Dioxide
EA	Environment Agency
EAL	Environmental Assessment Level
EDG	Emergency Diesel Generator
EE	Electrical Efficiency
EU	European Union
GET	Guidance on Emerging Techniques
IED	Industrial Emissions Directive
IAQM	Institute of Air Quality Management
LCP	Large Combustion Plant
LWS	Local Wildlife Site
MCPD	Medium Combustion Plant Directive
MEA	Monoethanolamine
MWth	Megawatt thermal
NDMA	N-nitrosodimethylamine
NH_3	Ammonia

NMOR	N-nitrosomorpholine (NMOR)
NO_2	Nitrogen Dioxide
NOx	Oxides of Nitrogen
OH	Hydroxy Radical
OS	Ordnance Survey
PC	Process Contribution
PCC	Post-combustion Carbon Capture
PCM	Pollution Climate Mapping
PEC	Predicted Environmental Concentration
Pz	Piperazine
RCBC	Redcar and Cleveland Borough Council
SCAIL	Simple Calculation of Atmospheric Impact Limits
SCR	Selective Catalytic Reduction
SO_2	Sulphur Dioxide
SAC	Special Area of Conservation
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
T&S	Transmission and Storage
UK	United Kingdom
UNECE	United Nations Economic Commission for Europe
UV	Ultraviolet

1. Introduction

This Appendix has been prepared in support of the Environmental Permit variation application for the Net Zero Teesside Power Station and Carbon Capture Plant (the 'Installation'). The purpose of this Appendix is to detail the Air Quality Impact Assessment that has been carried out for the Installation and to demonstrate that the emissions from the Installation's operation would not lead to the exceedance of any Air Quality Standards (AQS) objectives, Environmental Assessment Levels (EALs), Critical Levels (CLs) and Critical Loads (CLds), as appropriate.

The pollutants included in the assessment are those produced as a result of combustion processes i.e. oxides of nitrogen (NO_x), nitrogen dioxide (NO_2) and carbon monoxide (CO), and ammonia (NH_3) due to the potential for NH_3 slip to occur from the Selective Catalytic Reduction (SCR) abatement. Also assessed are the emissions of amines and amine degradation products resulting from the Post-combustion Carbon Capture (PCC) plant.

The assessment has considered the main operation of the Combined Cycle Gas Turbine (CCGT) operating with the PCC plant being operational, as this will be the normal mode of operation. An assessment of the CCGT operating without the PCC plant being operational has also been carried out, as there is potential for the Installation to operate in this mode at times when the Transmission and Storage (T&S) network is unavailable but when the CCGT is required to provide electricity to the grid.

In additional to the CCGT and PCC plant, there will be a number of emergency diesel generators (EDGs) to provide a short-term source of electricity, in the event of a simultaneous loss of power generation and external power supply, to provide power for essential and non-essential services (heating, ventilation and air conditioning (HVAC), telecoms, emergency lighting and plant control systems.) for up to 72 hours until external power can be re-established. Consideration of the impacts associated with the intermittent testing of the EDGs (<12 hours per year per EDG) are also included in the assessment.

The assessment includes:

- a summary of the air quality standards and guidance that are applicable;
- existing background air quality data;
- an outline of the assessment methodology, including the assessment of amines and their atmospheric degradation products;
- a detailed dispersion modelling assessment of the operation of the Installation including the CCGT and PCC plant, representing the normal mode of operation. An abnormal scenario of the CCGT plant operating without the PCC plant, for times when the T&S network is not available, has also been assessed;
- a Simple Calculation of Atmospheric Impact Limits (SCAIL) assessment of the operation of the EDGs.

The assessment has been carried out in accordance with the following guidance:

- Environment Agency (EA). Risk Assessments for Specific Activities: Environmental Permits guidance (Defra and EA, 2016) (the 'EA's Risk Assessment Guidance')[1];
- EA (Air Quality Modelling and Assessment Unit (AQMAU)) (2021). AQMAU recommendations for the regulation of impacts to air quality from amine-based post-combustion carbon capture plant' AQMAU-C2025-RP01[2] (the 'EA's Amine Modelling guidance');
- EA (AQMAU) (2023). Developing Environmental Assessment Levels for new carbon capture and storage compounds – Briefing on EALs for carbon capture activities that use amine-based solvents. Issued to the Carbon Capture and Storage Association (the 'EA's Amine EAL Briefing Note'); and

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[1] Environment Agency, 2025. Air emissions risk assessment for your environmental permit - GOV.UK. Available at: https://www.gov.uk/guidance/air-emissions-risk-assessment-for-your-environmental-permit [Accessed November 2025]

[2] Recommendations for the Assessment and Regulation of Impacts to Air Quality from Amine-Based Post-Combustion Carbon Capture Plants Guidance. Available at: https://ukccsrc.ac.uk/wp-content/uploads/2021/11/AQMAU-C2025-RP01.pdf [Accessed November 2025]

- EA’s AQMAU (2023). Proposed assessment method to include amines and degradation products in nutrient nitrogen deposition estimations at ecological sites[3].

The dispersion of emissions has been predicted using the latest version of the Atmospheric Dispersion Modelling System (ADMS) (currently version 6.0.2.5) supplied by Cambridge Environmental Research Consultants Limited (CERC).

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[3] AQMAU (2023) Proposed assessment method to include amines and degradation products in nutrient nitrogen deposition estimations at ecological sites. Available at: https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010103/EN010103-002888-Appendix%201%20-%20Main%20Letter%20-%20AQMAU%20Assessment%20Methodology.pdf [Accessed November 2025]

2. Assessment Criteria

2.1 Air Quality Legislation

2.1.1 Environment Act 2021

The Environment Bill became an Act (law) in November 2021 as the *Environment Act 2021*[4], which amends the *Environment Act 1995*[5]. Section 83 of the *Environment Act 1995* has been transposed into Schedule 11 of the *Environment Act 2021*:

> *"For local authorities to undergo a process of local air quality management and declare an Air Quality Management Area (AQMA) where pollutant concentrations exceed the national air quality objectives. Where an AQMA is declared, the local authority needs to produce an Air Quality Action Plan (AQAP) which outlines the strategy for improving air quality in these areas."*

The Act implements key parts of the government's Clean Air Strategy and include targets for tackling air pollution in the UK, specifically:

- for the Secretary of State to publish a report reviewing the Air Quality Strategy every five years;
- for local authorities' powers to be extended under the current Local Air Quality Management framework, including responsibilities to improve local air quality and to reduce public exposure to excessive levels of air pollution;
- for 'air quality partners' to have a duty to share responsibility for dealing with local air pollution among public bodies; and
- the introduction of a new power for the government to compel vehicle manufacturers to recall vehicles and non-road mobile machinery if they are found not to comply with the environmental standards that they are legally required to meet.

2.1.2 Air Quality Regulations 2010 (amended 2016)

The Air Quality Standards Regulations 2010 (as amended) defines the policy framework for air pollutants known to have harmful effects on human health or the natural environment.

Some pollutants have standards expressed as annual average concentrations due to the chronic way in which they affect health or the natural environment, i.e., effects occur after a prolonged period of exposure to elevated concentrations. Other pollutants have standards expressed as 24-hour or 1-hour average concentrations due to the acute way in which they affect health or the natural environment, i.e., after a relatively short period of exposure. Some pollutants have standards expressed in terms of both long and short-term concentrations.

AQS limit values and objectives apply to outdoor locations where people are regularly present and do not apply to occupational, indoor or in-vehicle exposure. The regulation sets out the national air quality standards for NO_2 and CO. Emissions of sulphur dioxide (SO_2) and particulates (PM_{10} and $PM_{2.5}$) from natural gas fired plant are at such low levels relative to the AQS objectives that they are considered negligible and the risk to the achievement of the relevant AQS objectives is considered negligible, therefore these have not been considered in the assessment.

The current AQS objectives applicable to this assessment for the protection of human health are presented in Table 2-1.

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[4] UK Parliament (2021) *Environment Act 2021*. [Online] Available at: https://www.legislation.gov.uk/ukpga/2021/30/contents/enacted [Accessed December 2025]

[5] UK Parliament (1995) *Environment Act 1995*. [Online]. Available at: https://www.legislation.gov.uk/ukpga/1995/25/contents [Accessed December 2025]

Table 2-1: Air Quality Strategy (AQS) Objectives – protection of human health

Pollutant	AQS Objective ($\mu g/m^3$)	Averaging Period
Nitrogen dioxide (NO_2)	40	Annual mean
	200	1-hour mean, not to be exceeded more than 18 times a year (99.79th percentile)
Carbon monoxide (CO)	10,000	Maximum daily running 8-hour mean

2.1.3 The Conservation of Habitats and Species Regulations 2017

These regulations transpose the European Council Directive 92/43/EEC (Habitats Directive) into law in England and Wales and is retained in UK law by The Conservation of Habitats and Species (Amendment) (EU Exit) Regulations 2019.

The Conservation of Habitats and Species Regulations 2017 requires the competent authority first to evaluate whether operation of the site is likely to give rise to a significant effect on the European site (Habitats Regulation Assessment screening). Where this is the case, it has to carry out an 'appropriate assessment' in order to determine whether the Project would adversely affect the integrity of the European site.

The impact of emissions from Installation on sensitive ecological receptors are quantified within this assessment in two ways:

- as direct impacts on plants physiology, growth and vitality arising due to increases in atmospheric pollutant concentrations, assessed against defined 'Critical Levels' (CLs); and
- as indirect impacts arising through deposition of acids and nutrient nitrogen to the ground surface, assessed against defined 'Critical Loads' (CLds).

CLs for the protection of vegetation and ecosystems have been adopted by, amongst others, the European Union and the United Nations Economic Commission for Europe (UNECE) Convention on Long-range Transboundary Air Pollution (CLRTAP). The annual average CL for NO_x has been transposed in the Air Quality Standards Regulations 2010 (as amended).

CLs are concentrations of pollutants in the atmosphere below which harmful effects are unlikely to occur. They apply to locations more than 20km from towns with more than 250,000 inhabitants or more than 5km from other built-up areas, industrial installations or motorways. In practice, however, assessment against CLs for vegetation is frequently undertaken to inform planning and permitting processes across the country, regardless of this definition. The objectives in the Air Quality Standards Regulations 2010 (as amended) are used to assess the potential impacts upon any sensitive ecosystems.

Additional values for daily NO_x and NH_3 are also generally used as regulatory standards, although these have not been formally adopted. The CLs applicable to this assessment for the protection of vegetation and ecosystems are presented in Table 2-2.

Table 2-2: Critical Levels (CLs) – protection of vegetation and ecosystems

Pollutant	Critical Level ($\mu g/m^3$)	Averaging Period	Other Information
Oxides of nitrogen (NO_x)	30	Annual mean	-
	75	Daily mean	The CL is generally considered to be 75µg/m³, but this only applies where there are high concentrations of SO_2 and ozone, which is not generally the current situation in the UK. Given the low UK SO_2 concentrations the Institute of Air Quality

Pollutant	**Critical Level ($\mu g/m^3$)**	**Averaging Period**	**Other Information**
			Management (IAQM) consider the higher value of 200 $\mu g/m^3$ can be used as a short-term CL.[6]
Ammonia (NH_3)	1	Annual mean	Annual mean, for sensitive lichen communities & bryophytes and ecosystems where lichens and bryophytes are an important part of the ecosystem's integrity
	3		Annual mean, for all higher plants (all other ecosystems)

Critical Loads (CLds) for the deposition of nutrient nitrogen and acidifying species are dependent on the habitat type and species present and therefore are specific to habitat types considered within the assessment. The relevant CLds for the habitats present within the identified ecological receptors considered in this assessment are defined on the Centre for Ecology and Hydrology Air Pollution Information System (APIS) website[7] and are detailed in Section 7.

CLds are provided as ranges of kilograms of nitrogen per hectare per year (kg N/ha/yr) or H+ kilogram equivalents (keq/ha/yr) for nitrogen and acid deposition respectively, which reflect the variation in ecosystem response across Europe. To ensure that a conservative assessment is carried out, it is usual for impacts to be determined against the lower end (i.e. the most stringent) of the CLd range.

2.2 Environmental Permitting

2.2.1 Industrial Emissions Directive

The United Kingdom (UK) is no longer a member of the European Union (EU). Most EU legislation as it applied to the UK on 31st December 2020 is now a part of UK domestic legislation, under the control of the UK's Parliaments and Assemblies as a form of domestic legislation known as 'retained EU legislation'. This is set out in Sections 2 and 3 of the *European Union (Withdrawal) Act 2018*. Section 4 of the *European Union (Withdrawal) Act 2018* ensures that most remaining EU rights and obligations, including directly effective rights within EU treaties, continue to be recognised and available in domestic law after exit.

The EU Industrial Emissions Directive (IED) provides operational limits and controls to which regulated plant must comply, including Emission Limit Values (ELV) for pollutant releases into the air.

The operator of a plant covered by the IED is required to employ Best Available Techniques (BAT) for the prevention or minimisation of emissions to the environment, to ensure a high level of protection of the environment as a whole. European BAT reference documents ('BRefs') are published for each industrial sector under the IED, and they include BAT-Associated Emission Levels (BAT-AEL) which are expected to be met through the application of BAT. These levels may be the same as ELVs published in the IED, or they may be more stringent. BRefs that were existing at the point of the *European Union (Withdrawal) Act 2018* remain applicable in the UK, where new BAT Guidance is required or BRefs are revised, UK BAT will apply.

The current version of the LCP BRef[8] and associated BAT Conclusions (BATc)[9] includes daily average and yearly average BAT-AELs for natural gas fired CCGT plant for NO_x and indicative values for yearly average carbon monoxide CO, which are more stringent than the ELVs included in the IED. As well as the combustion

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[6] IAQM (2020). A Guide to the Assessment of Air Quality Impacts on Designated Nature Conservation Sites. Available at: https://iaqm.co.uk/guidance/ [Accessed December 2025]

[7] Centre for Ecology and Hydrology Air Pollution Information System (APIS) website, 2025. Available at: www.apis.ac.uk. Accessed November 2025]

[8] Best Available Techniques (BAT), Reference Document for Large Combustion Plants Industrial Emissions Directive 2010/75/EU of the European Parliament and of the Council, July 2017. Available at: Large Combustion Plants | EU-BRITE [Accessed December 2025]

[9] Commission Implementing Decision Establishing Best Available Techniques (BAT) conclusions, under Directive 2010/75/EU of the European Parliament and of the Council, for Large Combustion Plants, European IPPC Bureau, November 2021. Available at: Large Combustion Plants | EU-BRITE [Accessed December 2025]

emissions, emissions of NH_3 will result, due to the application of SCR to meet the NO_x BAT-AELs. The LCP BATc include a BAT-AEL for NH_3.

In the UK, IED has been implemented through the Environmental Permitting (England and Wales) Regulations 2016 (as amended) (EP Regulations).

2.2.2 Environmental Permitting Regulations 2016 (as amended)

The EP Regulations apply to regulated installations and transpose the requirements of the IED into UK legislation. LCP and Carbon Capture and Storage (CCS) are listed activities under the EP Regulations, and therefore they require an Environmental Permit to operate, issued by the EA. Performance against the relevant ELVs or BAT-AELs, as defined in the IED and associated BREfs and BATc, will be regulated through the Environment Permit.

Where legislative AQS objectives are not specified for the pollutant species potentially released from the Installation, EALs, published in the EA's Risk Assessments for Specific Activities: Environmental Permits guidance, referred to as the 'EA's Risk Assessment Guidance' can be used to assess potential health effects on the general population. This includes an additional EAL for hourly concentrations of CO and EALs for NH_3.

From the PCC plant, emissions of amines and their breakdown products could occur as a result of amine slip from the absorber. It is known that some amines can potentially degrade (chemically react with oxygen) and form nitrosamines and nitramines (collectively referred to as N-amines) both during the carbon capture process itself, and also in the environment following release to the atmosphere and there is concern over the potential toxicity of such species. Therefore, the impacts of both directly released N-amines and the N-amines produced through atmospheric degradation of released amines have also been considered in the assessment.

Due to carbon capture being an emerging technology, there is currently no BRef or BATc to derive BAT-AELs or ELVs for amines and N-amines. The EA have published their Guidance on Emerging Techniques on how to prevent or minimise the environmental impacts of post-combustion carbon dioxide capture (PCC GET)[10], however this does not contain ELVs or BAT-AELs associated with its application, as it is intended that these will be developed following operation of PCC plants in the UK, and collated monitoring data can confirm suitable levels for which the BAT-AELs should be set.

There are limited published amine EALs available in the latest version of the EA's Risk Assessment Guidance; however, the EA is in the process of deriving EALs for both amine and N-amine species and six amine species now have published EALs. The PCC plant licensor has reviewed the toxicological data available for the three amine species within their CANSOLV DC-103 solvent, in order to determine suitable EALs for the assessment of potential impacts from the amines and their degradation products potentially present in the PCC plant emissions, and have identified two EALs which are considered to be relevant to the amine species within the CANSOLV DC-103 solvent.

The terms Amine 1, Amine 2 and Amine 3 have been used consistently throughout this report and in the Main Supporting Document for ease of reference to the different CANSOLV DC-103 amines species, to avoid confusion with the complicated naming of the individual amine species.

Information on the specific amine species and the supporting toxicological information is provided in Annex A and this demonstrates that two of the amine species present in the emission (Amine 1 and Amine 3) are likely to be less toxic than Monoethanolamine (MEA). MEA was the first amine that the EA derived EALs for. For these species therefore it is proposed to use the published MEA EALs as a proxy to ensure that a conservative assessment is carried out.

The toxicological information for the third amine species (Amine 2) indicates that the EAL for Piperazine (Pz) would be more appropriate, and therefore this has been used in the assessment for this amine species.

To date, the EA has derived only two EALs for N-amines, one for N-nitrosodimethylamine (NDMA) and one for N-nitrosomorpholine (NMOR). There is limited information available on the toxicity of individual N-amine species with which to derive suitable EALs however it is understood that NDMA has been used for an EAL because this is considered to be one of the most toxic nitrosamines, and therefore results in a conservative EAL. Due to the limited information available on the toxicology of other N-amines, the EA have issued a

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[10] Post-combustion carbon dioxide capture: emerging techniques - GOV.UK

briefing paper to the Carbon Capture and Storage Association (CCSA) (the EA's Amine ES Briefing Note), recommending that the total N-amine concentration from PCC plant emissions should be compared with the NDMA EAL as a proxy, although it should be recognised that some of the degradation products will be less harmful, and therefore this is a very conservative assumption. This is demonstrated by the more recent derivation of the NMOR EAL, which is an order of magnitude higher than that of NDMA.

Other degradation products, such as NH_3, amides, formaldehyde and acetaldehyde may also be present in the PCC plant emissions, and therefore these have also been included in the assessment. The EALs applicable for this assessment for the protection of human health are presented in Table 2-3.

Table 2-3: Environmental Assessment Levels (EALs)

Pollutant	EAL (µg/m³)	Averaging Period
Acetaldehyde	370	Annual mean
	9,200	Hourly mean as 100th percentile
Acrylamide	0.05	Annual mean
Ammonia (NH_3)	180	Annual mean
	2,500	Hourly mean as 100th percentile
Carbon monoxide (CO)	30,000	Hourly mean as 100th percentile
Formaldehyde	5	Annual mean
	100	30-minute mean
Monoethanolamine (MEA) (used as a proxy for Amine 1 and Amine 3)	100	Daily mean (long term)
	400	Hourly mean as 100th percentile
N-nitrosodimethylamine (NDMA)	0.0002	Annual mean
Piperazine (PZ) (used for Amine 2)	15	Daily mean (long term)

[1] EAL for Acrylamide used for the assessment of "Total Amides", as the lowest EAL of any amide listed in the EA Risk Assessment Guidance. It should be noted that acrylamide is classified as a carcinogen, mutagen, reproductive toxicant (CMR) chemical, whereas the amides formed from the degradation of the CANSOLV amines are not defined as CMR chemicals. It is therefore considered that the use of the acrylamide EAL is very conservative, a position that was agreed with the EA and UK HSA during the VPI Immingham CHP Power Plant PCC Permit variation determination.

2.3 Human Health Significance Criteria

The EA's Risk Assessment Guidance identifies a two-stage process for determining the impact of emissions to air from a process. The stage one screening criteria compares the process contribution (PC) (i.e. the modelled ground level pollutant concentration) with the relevant AQS objective or EAL. The criteria states that an emission may be considered to have an insignificant impact where:

- the long-term PC is <1% of the AQS objective or EAL; and
- the short-term PC is <10% of the short-term AQS objective or EAL.

If both criteria are met, no further assessment is required, but if they are not met, the second stage of screening is applied.

The second stage of screening considers the PCs in the context of the existing background pollutant concentrations; the predicted environmental concentration (PEC) (i.e. the PC plus the background concentration) is considered acceptable where:

- the long-term PEC is less than 70% of the AQS objective or EAL; or
- the short-term PC is less than 20% of the short-term AQS objective or EAL minus twice the annual mean background concentration.

The EA's Risk Assessment Guidance indicates that where AQS objective or EAL are likely to be breached as a result of contributions from an installation, or where installation releases constitute a major proportion of the AQS or EAL, such releases are likely to be considered unacceptable.

Where the PEC is not predicted to exceed the AQS objective or EAL and the proposed emissions comply with the BAT-AEL (or equivalent requirements) the emissions may be considered acceptable by the EA.

2.4 Ecological Significance Criteria

For European sites (Special Protection Areas (SPA), Special Areas of Conservation (SAC) or Ramsar sites) an assessment is made as to whether the emissions from an installation are 'likely to have a significant effect', and whether this could lead to an 'adverse effect on site integrity'. Sites within 15 km have been considered in the assessment, which has also included Sites of Special Scientific Interest (SSSIs).

The EA's Risk Assessment Guidance states that PCs may be considered to have an insignificant impact at the first stage of screening on these sites where:

- Short term PC is less than 10% of the CL; and,
- Long term PC is less than 1% of the CL.

If these requirements are not met for short term impacts, further assessment is required. For long term impacts, the PEC must be calculated and if it is less than 70% of the CL, the impacts are considered insignificant. When impacts cannot be screened out as being insignificant using the thresholds above, further evaluation of the significance requires advice from an ecologist.

For SPAs, SACs and Ramsar sites, there is also a requirement to consider the 'in combination' (combined) impact of all permissions, plans or projects that affect the site.

For local nature sites (such as Local Wildlife Sites (LWS)), the EA guidance notes that if the PC alone is less than 100% of the respective standard, then it can be concluded that the effects are not significant and no further assessment is required. If the PC exceeds the screening criteria, detailed modelling would be required.

The impact of point source emissions on ecological receptors, through deposition of nutrient nitrogen or acidity, has been evaluated using the EA's Risk Assessment Guidance insignificance criterion of 1% of CLd. However, it should be noted that impacts over the insignificance criterion of 1% are not consequentially significant, rather an indicator that further consideration of the impacts are required.

3. Assessment Methodology

3.1 Introduction

Emissions of all pollutants released from the Installation have been assessed using the EA's Risk Assessment Guidance in order to identify where emissions can be screened as having an insignificant impact. Detailed dispersion modelling using the atmospheric dispersion model ADMS 6 has been used to calculate the concentrations of pollutants at identified receptors. These concentrations have been compared with the AQS objectives, EALs and CLs and for each pollutant species that could be released from the Installation. Dispersion modelling calculates the predicted concentrations arising from the emissions to atmosphere, based on Gaussian approximation techniques. The model employed has been developed for UK regulatory use.

Emissions of sulphur dioxide (SO_2) and particulates (PM_{10} and $PM_{2.5}$) from natural gas fired plant are at such low levels relative to the AQS objectives that they are considered negligible and the risk to the achievement of the relevant AQS objectives is considered negligible, therefore these have not been considered in the assessment.

An assessment of nutrient nitrogen and acidification has been undertaken by applying published deposition velocities to the predicted annual average NO_2, NH_3 and amine concentrations at the identified statutory habitat sites, determined through dispersion modelling, to calculate nitrogen deposition rates.

These deposition rates have then been compared to the CLds for nitrogen published by APIS for the species present at each habitat site, taking into consideration the APIS reported baseline air quality.

Increases in acidity from deposition contributions of NO_2, NH_3 and amines from the process contribution have also been considered. The H^+ keq/ha/yr, have been derived from nitrogen deposition modelling values using standard conversion factors. The acidity deposition rates and baseline deposition rates have been used within the CLd Function Tool (APIS) to determine whether the contribution would result in exceedance of the defined acidity CLds for the most sensitive feature.

The main assessment has considered worst-case long-term and short-term emissions resulting from operation of the Installation assuming that the plant is operational, at full load, for 8,760 hours per year, as this represents the worst-case for annual average impacts and predicts the maximum short-term impacts from the worst-case meteorological data.

3.2 Sources of Information

A desk-based review of the following data sources has been undertaken to determine the baseline conditions of air quality in this assessment:

- the Redcar and Cleveland Borough Council (RCBC) 2025 Annual Status Report (ASR)[11];
- the UK Air Information Resource website[12];
- EA EP Regulations – Installations website[13];
- the Defra Local Air Quality Management website[14]; and

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[11] Redcar and Cleveland Borough Council (RCBC) 2025. 2025 ASR. Available at: https://www.redcar-cleveland.gov.uk/environment/environmental-protection/air-quality [Accessed December 2025]

[12] UK Air website. Available at: https://uk-air.defra.gov.uk/data/laqm-background-home [Accessed December 2025].

[13] EA, 2025. Environmental permitting regulations – installations website. Available at: https://environment.data.gov.uk/public-register/view/search-industrial-installations [Accessed December 2025]

[14] Defra, Air Quality Management Areas website, Available at: https://uk-air.defra.gov.uk/aqma/list [Accessed December 2025].

- the Air Pollution Information System (APIS) website[15].

3.3 NO_x to NO_2 Conversion

The model predicts NO_x concentrations which comprise nitric oxide (NO) and NO_2. NO_x is emitted from combustion processes, primarily as NO with a small percentage of NO_2. The emitted NO reacts with oxidants in the air (mainly ozone) to form NO_2.

This assessment has followed the methodology set out by the EA[16], which states it should be assumed as a worst-case scenario that 70% of long-term and 35% of short-term NO_x concentrations will convert to NO_2[17].

3.4 Deposition Conversion Factors

The dry deposition flux for each receptor has been calculated based on recommended deposition velocities[18], presented in Table 3-1.

Table 3-1: Deposition Velocities

Parameter	Habitat Type	Deposition Velocity (m/s)
Nitrogen Dioxide (NO_2)	Grassland	0.0015
	Forest	0.003
Ammonia (NH_3) and amines	Grassland	0.02
	Forest	0.03

For nitrogen deposition conversion factors are used to convert dry deposition flux from units of µg/m^2/s to kg/ha/yr or H+ keq/ha/yr are shown in Table 3-2.

Table 3-2: Factors to Convert Deposition to kg/ha/yr and to keq/ha/yr

Parameter	Conversion	Factor
Nitrogen Dioxide (NO_2)	µg/m^2/s N to kg/ha/yr	95.9
	kg of N to keq/ha/yr	0.071
Ammonia	µg/m^2/s N to kg/ha/yr	259.7
	kg of N to keq/ha/yr	0.071
Amine 1 and Amine 3	µg/m^2/s N to kg/ha/yr	67.9
	kg of N to keq/ha/yr	0.071
Amine 2	µg/m^2/s N to kg/ha/yr	102.7
	kg of N to keq/ha/yr	0.071

3.5 Assumptions and Limitations

3.5.1 Assumptions

The dispersion modelling for the main assessment includes several conservative assumptions, including:

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[15] Air Pollution Information System (APIS). Available at: https://www.apis.ac.uk/. [Accessed December 2025]

[16] Environment Agency (2024) *Environmental permitting: air dispersion modelling reports.* [Online]. Available at: https://www.gov.uk/guidance/environmental-permitting-air-dispersion-modelling-reports [Accessed December 2025]

[17] Environment Agency; Air Quality Modelling and Assessment Unit, Conversion ratios for NO_x and NO_2

[18] Institute of Air Quality Management (IAQM) (2020) A guide to the assessment of air quality impacts on designated nature conservation sites.

- Emission concentrations based on the use of the upper BAT-AELs for NO_x; in practice annual average emissions rates would be below this to enable continued compliance with Environmental Permit requirements;
- Maximum annual operation for the plant configuration assessed (8,760 hours, assuming the plant is used for baseloading as a worst-case, actual annual operating hours are likely to be approximately 6,094);
- Reporting of the worst-case results from the five years of meteorological data modelled;
- Conservative estimates of background concentrations at the receptor locations for the commencement of operation. Background concentrations have been assumed to be $0.0\mu g/m^3$ for formaldehyde, acetaldehyde, amines, N-amines and amides, in lieu of available data.

3.5.2 Limitations

Air quality dispersion modelling has inherent areas of uncertainty, including:

- Simplification in model algorithms and empirical relationships that are used to stimulate complex physical and chemical processes in the atmosphere;
- Spatial variability of model background concentrations;
- Spatial variability of meteorological data;
- Effects of terrain; and
- Emissions concentrations due to varying operating conditions.

The methodology used within this assessment is designed to provide a conservative assessment of potential impacts as far as is practicable, based on the data available. The assessment has aimed to reduce uncertainty by ensuring worst-case assumptions are taken into account and providing additional commentary based on professional judgement regarding the results.

4. Receptors and Baseline Air Quality

A 2km study area is generally considered to be appropriate to determine baseline conditions and to provide an adequate amount of data on the existing conditions and constraints. Existing air quality conditions in the vicinity of the Installation have been evaluated through a review of Local Authority air quality management reports, Defra published data and other sources.

4.1 Human Health Receptors

Receptors potentially affected by the emissions from the Installation, including local residential and amenity receptors, have been identified through site knowledge and desk study of local mapping. Isopleth figures of pollutant dispersion have been examined to identify the receptors that will receive the highest point source contributions and these receptors have been included in the model set up as discrete receptors. Individual receptor locations used in the model are shown in Table 4-1 and their locations are shown in Figure 1.

All human receptors were modelled at 1.5m height to represent the average height of human exposure.

Table 4-1: Identified Human Health Receptors

Receptor I.D.	Receptor Descriptor	OS Grid Reference		Distance and Direction from Installation
		x	y	
HH1	Houses off Tod Point Rd, Warrenby	457950	525045	600 m east
HH2	Cleveland Golf Links, Redcar (worst case location)	457835	525525	380 m east
HH3	South Gare Fisherman's Association and Marine Club	455620	527345	1.9 km north-west
HH4	Caravan Park, Redcar	458675	525415	1.2 km east
HH5	Houses at Dormanstown	457895	523735	1.4 km south-east
HH6	Houses at Coatham	458900	525060	1.5 km east
HH7	Dormanstown Primary Academy School	458250	523585	1.7 km south-east
HH8	Coatham Primary School	459195	524980	1.8 km east

Figure 1: Human Health Receptor Locations

4.2 Ecological Receptors

Ecological receptors potentially affected by the operation of the Installation have been identified through desk study of Defra Magic mapping and the APIS website. Statutory designated sites (including SPAs, SACs, Ramsar sites and SSSIs up to 15 km have been included in the assessment; and non-statutory designations such as LWS within 2km have been included in the assessment. Identified receptors are detailed in Table 4-2 and their locations are shown in Figure 2.

Given the size of the Teesmouth and Cleveland Coast designation, multiple receptor points were modelled for this site, and only the worst-case point presented in the results.

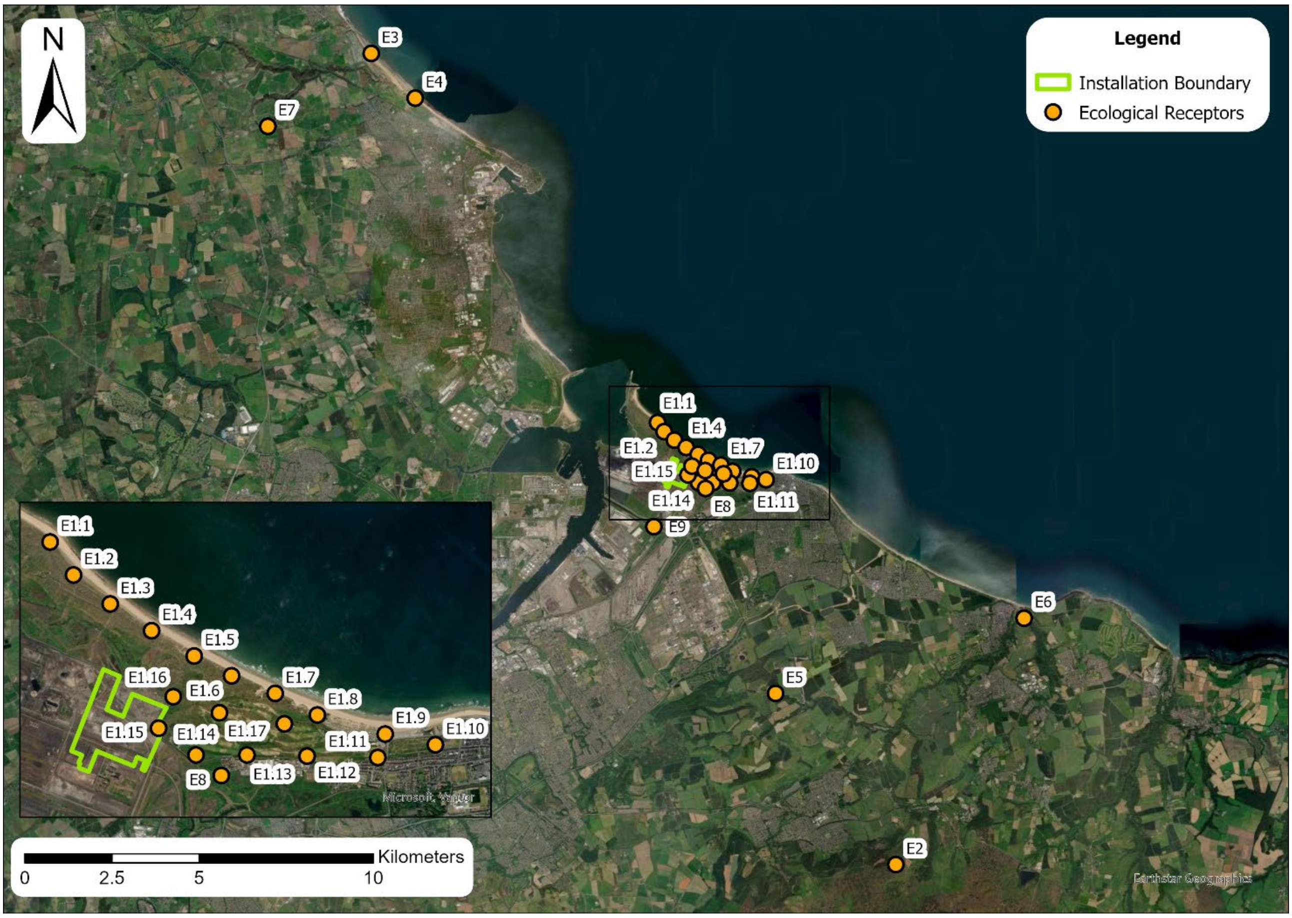
All ecological receptors were modelled at 0m height to represent ground level.

Table 4-2: Identified Ecological Receptors

Receptor I.D.	Receptor	Designation	OS Grid Reference		Distance and Direction from Installation
			x	y	
E1	Teesmouth and Cleveland Coast	Ramsar, SPA, SSSI	456475 - 459590	525135 - 526880	Adjacent north
E2	North York Moors	SAC, SPA, SSSI	463315	514190	11.5 km south-east
E3	Northumbria Coast	SPA, Ramsar	448260	537470	14.6 km north-west
E4	Durham Coast	SAC	449520	536190	14.6 km north-west
E5	Lovell Hill Pools	SSSI	459860	519100	6.3 km south-east
E6	Saltburn Gill	SSSI	467000	521265	10.3 km south-east
E7	Hart Bog	SSSI	445290	535380	14.9 km north-west
E8	Coatham Marsh	LWS	457860	524990	500 m east

Receptor I.D.	Receptor	Designation	OS Grid Reference		Distance and Direction from Installation
			x	y	
E9	Eston Pumping Station	LWS	456370	523890	1.0 km south

Figure 2: Ecological Receptor Locations



In addition, there are three further SSSIs within 15 km of the Installation (Roseberry Topping, Cliffe Ridge and Langbaurgh Ridge), which are designated due to their geological features. It is therefore considered that these sites will not be affected by emissions from the Installation, as the CLs and CLds assigned to such sites are for the protection of vegetation and ecosystems only, and therefore they have been screened from further assessment.

4.3 Industrial Processes

Industrial air pollution sources are regulated through a system of operating permits or authorisations, requiring stringent ELVs to be met, and ensuring that any releases to the environment are minimised or rendered harmless. Regulated industrial processes are classified as Part A (1), A (2), Part B or Medium Combustion Plant (MCP) processes and are regulated through the EP Regulations. The larger, more polluting processes are regulated by the EA and the smaller less polluting ones by the local authorities. Local authorities focus on regulation for emissions to air, whereas the EA regulates emissions to air, water and land.

There is one Part A(1) process within 2km of the Installation with releases to air according to the EA website[13]. Details of the process are provided in Table 4-3.

Table 4-3: Industrial Processes within 2km of the Installation

Facility and Operator	Schedule 1 Listed Activity	Approximate Distance from the Installation (at the Closest Point)
Redcar Energy Centre Redcar Holdings Limited	Section 5.4 Part A(1) (b) - The incineration of non-hazardous waste in a waste incineration plant with a capacity of 3 tonnes per hour or more. Section 5.4 Part A(1) (a) (iii) - Disposal of non-hazardous waste with a capacity exceeding 50 tonnes per day involving pre-treatment of waste for incineration. Section 5.4 Part A(1) (b) (ii) - Recovery or a mix of recovery and disposal of non-hazardous waste with a capacity exceeding 75 tonnes per day involving pre-treatment of waste for incineration. Section 5.4 Part A(1) (b) (iii) - Recovery or a mix of recovery and disposal of non-hazardous waste with a capacity exceeding 75 tonnes per day involving treatment of slags and ashes.	1.4km

4.4 Human Health Baseline

4.4.1 Air Quality Management Areas

As stated previously, the Environment Act 2021 requires local authorities to undertake an assessment of local air quality to establish whether the objectives are being achieved, and to AQMAs if improvements are necessary to meet the objectives.

There are no AQMAs in the RCBC area, and there are no AQMAs within 2km of the Installation according to the Defra website[14].

The nearest AQMA is the Scarborough AQMA, approximately 22km to the south-east of the Installation. The Scarborough AQMA was declared across the village of Staithes in 2004 for exceedances of the annual and 24-hour mean PM_{10} air quality objectives alongside the SO_2 15-minute, hourly and 24-hour mean air quality objectives caused by domestic heating. In 2018, the Scarborough AQMA was amended to cover the annual mean and 24-hour mean PM_{10} air quality objectives only. Given the distance to the AQMA, and the fact that it has been declared for pollutants that are not released from the Installation, it is considered that it would not be affected by the Installation.

4.4.2 Local Monitoring Data

Monitoring data within 2km of the Installation has been reviewed using the 2025 RCBC ASR[11]. RCBC operate both continuous monitoring with automatic monitors and passive monitoring with diffusion tubes. There is one automatic monitor and three diffusion tubes within 2km of the Installation. These monitoring sites are co-located with each other at the same location. Details of these monitoring sites are provided below in Table 4-4. These monitors are approximately 1.9km south-east of the Installation.

Local monitoring sites are shown in Figure 3.

Table 4-4: Details of Monitoring Sites within 2km of the Installation

Site ID	Type	Site type	Pollutants Monitored	OS Grid Reference	
				x	y
Dormanstown	Automatic	Suburban	NO_2, PM_{10}, $PM_{2.5}$, Ozone	458379	523486
R17, R18, R19	Diffusion tube	Suburban	NO_2		

Figure 3: Monitoring Sites within 2km of the Installation

4.4.3 NO₂ Concentrations

The latest years of available data are shown in Table 4-5 for annual mean NO_2. The annual mean NO_2 concentration recorded at Redcar Dormanstown in 2024 (the latest year with available monitoring data) was 8.6µg/m^3. In the last five years, no exceedances of the annual mean NO_2 AQAL of 40µg/m^3 were recorded. There were also no recorded exceedances of the hourly mean NO_2 AQAL of 200µg/m^3, not to be exceeded more than 18 times a year.

There are three diffusion tubes co-located with this automatic monitor, R17, R18, R19, all of which were well below the AQAL from 2020 to 2024.

The 2020 and 2021 monitoring results are not considered to be representative of typical conditions due to the Covid-19 pandemic, however, they are included for completeness.

Table 4-5: NO_2 Monitoring Data from 2020 to 2024 within 2km of the Installation

Monitoring Location	Type	NO_2 Concentration (µg/m^3)				
		2020	2021	2022	2023	2024
Dormanstown	Automatic	9.0	11.0	10.0	9.0	8.6
R17, R18, R19	Diffusion tube	13.2	11.5	11.7	11.6	10.3
AQAL: 40µg/m^3						

4.4.4 Defra Background Data

Defra's 2021-based background maps are available at a 1x1 km resolution for the UK and are projected forward to the year 2030. These projections of pollution concentrations across England are available for NO_2 and NO_x[12].

Annual average background concentrations from the Defra 2021-based background maps are presented for the year 2021 in Table 4-6, for the grid square in which the Installation is located (OS Grid Reference 457500, 525500) for NO_2 and NO_x. NO_2 data for 2021 has been used for the assessment to represent a conservative approach, as the typical trend shown in the Defra background mapping is that over the projected time period, concentrations of NO_2 and NO_x are decreasing. This corresponds to a reduction overtime of vehicle emissions as newer, cleaner vehicles replace older ones. Therefore, assuming no reduction occurs until the opening year of the Installation (anticipated to be 2028), is considered to represent a conservative approach, and is in line with advice from the EA on similar projects.

The equivalent 2021 monitored concentration from the nearest automatic monitor, Dormanstown, is also shown in Table 4-6. As the Defra background concentration is greater, Defra data has been used throughout for the background concentrations to provide a conservative assessment.

Recent background mapping of CO concentrations is not available for the most recent Defra maps, however Defra now advise using Pollution Climate Mapping (PCM) background maps in line with the Background Concentrations Maps User Guide[19].

For human receptors, ammonia background values were taken from the UKEAP National Ammonia Network, available from Defra[20] for the Ammonia monitoring site in Brompton, which is the nearest to the Installation. The network is used to quantify temporal and spatial changes in air concentrations and deposition in NH_3 and NH^{4+} on a long-term basis. The monitoring provides a baseline in the reduced nitrogen species ($NH_3 + NH^{4+}$).

Table 4-6: Defra Annual Average Background Concentrations

Pollutant	Background Concentration (µg/m^3)	Dormanstown Suburban 2021 Concentration (µg/m^3)
NO_x	15.2	-
NO_2	11.4	11.0
CO	214	-
NH_3	6.7	-

In line with the EA's Risk Assessment Guidance, short term background concentrations (hourly) are assumed to be twice the annual average concentration.

4.5 Ecological Receptors Baseline

The NOx, NH_3, nitrogen deposition and acid deposition background concentrations for ecological sites are available from the APIS website for designated SAC, SPA and SSSI sites.

It should be noted that the background data provided on the APIS website is generated by a combination of models and measurements, based on a 1 or 5 km grid resolution, depending on the pollutant. The website notes that for many pollutants there is real sub-grid variability which is not revealed in the 1 km or 5 km averages, and states that the uncertainties are particularly large for the concentrations of primary pollutants e.g. NH_3 and NO_x.

The website goes on to state that it is important to note that there is uncertainty attached to all these values, which has implications for the interpretation of the data including Cl and CLd values and exceedance, and depositions and concentration values.

The annual average concentrations present at the relevant habitat receptor sites for the period 2021 - 2023 are presented in Table 4-7.

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[19] Defra, 2024. Background Concentrations Maps User Guide. Available at: 2021-based-background-maps-user-guide-v1.0.pdf [Accessed December 2025]

[20] Defra, 2025. Interactive Monitoring Networks Map [website]. Available at: https://uk-air.defra.gov.uk/interactive-map?network=namn [Accessed December 2025]

Table 4-7: APIS Background Data

Receptor I.D.	Ecology Site	NO_x (µg/m³)	NH_3 (µg/m³)	Nitrogen Deposition (kg N/ha/yr)	Acid Deposition (Keq N/ha/yr)	Acid Deposition (Keq S/ha/yr)
E1	Teesmouth and Cleveland Coast	14.8 - 17.0	1.2	12.3	1.0	0.2
E2	North York Moors	6.3	0.9	14.7	1.1	0.2
E3	Northumbria Coast	7.0	1.0	13.4	1.1	0.2
E4	Durham Coast	8.7	1.0	9.0	0.8	0.2
E5	Lovell Hill Pools	9.6	1.2	13.5	No comparable habitat with established critical load for estimate available.	
E6	Saltburn Gill	7.8	1.1	21.8	1.7	0.1
E7	Hart Bog	8.1	1.4	14.8	1.2	0.2
E8	Coatham Marsh	20.9	1.3	12.5	1.0	0.2
E9	Eston Pumping Station	18.3	1.2	12.7	1.1	0.2

Although not explicitly stated in the EA's Risk Assessment Guidance, daily NO_x background concentrations have been assumed to be 1.5 times the annual average concentration, as this is in line with advice provided by the EA on other projects.

5. Dispersion Model Parameters

The final design of the PCC plant is now known, including the solvent to be used in the process. This report assesses the potential impacts and likely significant effects resulting from the operation of the PCC plant using this solvent and the effects of abnormal circumstances in the event of upset conditions. The modelled scenarios are as follows:

- Scenario 1 – Extreme Worst Case Normal Operation of the PCC plant. Assumes that emissions are at the upper BAT-AELs for NO_x, the IED ELV for CO and at the design guarantees for amine and degradation products. Operation assumed to be for 365 days a year 24 hours a day;
- Scenario 2 – Abnormal operations of the Power Plant, with no carbon capture taking place; and
- Scenario 3 – Likely Worst Case Normal Operation of the PCC Plant. Assessment carried out to determine more realistic worst case impacts of nitrogen deposition specifically, in line with ongoing discussions carried out with the EA and Natural England. Based on envisaged long term emission concentrations as advised by the technology provider and a more likely operating profile of approximately 6,094 hours per year.

5.1 Emissions Inventory

5.1.1 Scenario 1 - Extreme Worst Case Normal Operations – Emissions from the PCC Plant Stack (Emission Point A1)

The normal mode of operation for the Installation will be with the PCC plant operational. As such, emissions from the CCGT and PPC plant will occur via the PCC plant absorber stack (Emission Point A1).

The emissions from Emission Point A1 will comprise the combustion emissions of NO_x and CO, NH_3 from the SCR and emissions of amines present within the CANSOLV DC-103 solvent used within the PCC plants, and their potential degradation products that may also be present.

Combustion emissions will be released at the LCP BAT-AELs, which can have an uplift applied where the electrical efficiency (EE) of the CCGT is greater than 55%. As detailed in Section 5.1.1.1 of the Main Supporting Document, this has calculated on the basis that the CCGT would achieve at least 61% EE.

Furthermore, the normalisation of the LCP BAT-AELs for Carbon Dioxide (CO_2)-abated flue gas must take into account the reduction in volume of the gas from removal of CO_2 (comparable to referencing for O_2 at 15% dry v/v for gas turbines). It is proposed that this calculation is based on an assumed 3.4% of CO_2 in the flue gas (based on stoichiometric calculations) and that this is corrected to account for CO_2 removal of 95%. A methodology and example calculation for this was provided in the original Environmental Permit application.

Emissions of CO have been assessed at the IED ELV of $100mg/Nm^3$ (with the EE and CO_2 correction factors applied) as detailed in Section 5.1.1.1 of the Main Supporting Document, as it is considered that the indicative annual BAT-AEL may not be achievable based on the modes of operation of the Installation. This issue has been discussed with the EA following the issue of the original Environmental Permit and was summarised in a note issued to the EA on 21st October 2024. Following the discussions, the EA issued a Compliance Assessment Report (CAR) form on 22nd October 2024 which stated that the EA would undertake a review of the annual average CO emission limit value as part of this Environmental Permit variation application. In any case, it should be noted that AQS and EAL for CO are set for 8-hour rolling averages and for hourly averages respectively and therefore assessment of an annual limit against these averaging periods would not be considered appropriate.

The proposed NH_3 ELV has been based on emissions of NH_3 that are considered to be achievable from the PCC plant process. The PCC plant Direct Contact Cooler will remove the majority of the NH_3 present in the flue gas coming from the CCGT before it enters the PCC plant, and therefore the LCP BATc BAT-AEL is not considered relevant to emissions from the PCC plant.

As there are currently no BAT-AELs relating to the PCC process itself, emissions of amines and degradation products from the PCC plant are based on levels have been advised by the solvent provider, as achievable ELVs from their PCC process.

Although there are three amine species within the CANSOLV DC-103 solvent, Shell have reported that Amine 3 is not normally found to be present in the emissions. As the proxy EALs for Amine 1 and Amine 3 are the same, these species have therefore been grouped together for the purpose of assessment.

Only two N-amine species (N-amine 1 and N-amine 2) are shown to occur as a direct emission from the PCC plants stacks, which are the degradation products of Amine 1 and Amine 2 respectively. Amine 3 is a tertiary amine which degrades to a primary amine and as such, it does not form stable nitrosamines. Due to the minute quantities of Amine 3 potentially present in the emission, and the fact that is does not form stable nitrosamines, the amine assessment only considers atmospheric processes concerning Amine 1 and 2.

5.1.2 Scenario 2 - Abnormal Operation – Emissions from the HRSG Stack (Emission Point A2)

If the CCGT is required to operate without the PCC plant (i.e. during periods when the T&S network is not available, but electricity is still required by the grid) emissions will occur via the HRSG stack (Emission Point A2). During such times only combustion emissions of NO_x and CO will occur, together with NH_3 from the SCR. It is considered unlikely that operation in this mode would occur for prolonged periods, however assessment of long term operation assuming operation for 8,760 hours per year in this mode has been carried out for information.

5.1.3 Scenario 3 - Likely Worst Case Normal Operations of the PCC Plant (Emission Point A1)

Due to ongoing discussions with the EA and Natural England over the impacts associated with nitrogen deposition on the sensitive sand dune receptor in close proximity to the Installation, a more realistic worst case operating case of the PCC Plant has been carried out.

The scenario has been carried out to determine the nitrogen deposition impacts only, and is based on lower annual NO_x and NH_3 emission concentrations, rather than the assumption that emissions will be at the BAT-AELs and ELV. In order to ensure ongoing compliance with the ELVs in the Environmental Permit, actual operation of the plant would result in emissions below the permit ELVs, otherwise the Operator would be at constant risk of exceeding the ELVs and therefore non-compliance with the Environmental Permit conditions. These more realistic annual emission concentrations have been advised by the PCC plant licensor.

Additionally, as the Installation will operate as a dispatchable plant (as detailed in the Main Supporting Document Section 4.2.2), operation for 8,760 hours per year is extremely unlikely to occur. As such, the long term deposition impacts have been prorated to account for a more likely operating profile of approximately 6,094 hours per year.

The data provided in Table 5-1 shows the proposed emission parameters for the three operating scenarios assessed.

Table 5-1: Modelled Emission Parameters

Scenario	Scenario 1		Scenario 2		Scenario 3	
Description	Extreme Worst Case Normal Operation - PCC Plant		Abnormal Operation – HRSG Stack		Likely Worst Case Normal Operation – PCC Plant Nitrogen deposition impacts only	
Emission Point	A1		A2		A1	
Location (NRG)	457012, 525348		457076, 525323		457012, 525348	
Stack height (m)	128		78		128	
Approx. flue diameter (m)	7.0		9.0		7.0	
Actual volumetric flow (Am^3/hr)	2,514,600		3,999,600		2,514,600	
Average efflux velocity (m/s)	18.2		17.5		18.2	
Oxygen content (%)	8.84		12.2		8.84	
Moisture content (%)	9.85		9.5		9.85	
Temperature (°C)	65		88		65	
Normalised volumetric flow (Nm^3/s)	1,006		1,127		1,006	
Emission Limit Values	**Concentration (mg/Nm^3)**	**Release Rate (g/s)**	**Concentration (mg/Nm^3)**	**Release Rate (g/s)**	**Concentration (mg/Nm^3)**	**Release Rate (g/s)**
NO_x (annual average)	34.4	34.6	33.3	37.7	10.0	10.1
NO_x (daily average)	45.8	46.0	44.4	50.3	-	-
CO	114.6	115.3	111	125.6	-	-
NH_3	3.0	3.0	3.0	3.4	2.5	2.5
Amine 1 and Amine 3	0.90	0.91	-		0.90	0.91
Amine 2	0.10	0.10	-		0.10	0.10
N-amine 1	0.0004	0.0004	-		0.0004	0.0004
N-amine 2	0.003	0.003	-		0.003	0.003

Scenario	Scenario 1		Scenario 2	Scenario 3	
Formaldehyde	0.50	0.50	-		
Acetaldehyde	5.3	5.3	-	-	-
Total Amides	0.03	0.03	-	-	-

Stack heights provided are above ordnance datum

Normalised conditions: standard temperature (0°C) and pressure (101.3kPa), dry gas, 15% O_2. CO_2 correction applied to A1 for the removal of 95% of CO_2 from an assumed flue gas content of 3.4% CO_2 (i.e. ELV x (1-0.0017)/(1-0.034).

For plants with a net electrical efficiency (EE) greater than 55%, a correction factor may be applied to the higher end of the BAT-AEL range, e.g. for the annual average AEL - 30mg/m^3 x 61 / 55 = 33.3mg/Nm^3.

In addition to the PCC plant (Emission Point A1) and the HRSG stack (Emission Point A2) there will also be additional emission points associated with six EDGs (Emission Points A3 – A8).

Although the specific diesel generators have yet to be selected, there will be two approximately 5 MWth units, two approximately 4 MWth units, one approximately 3.2 MWth unit and one approximately 2.5 MWth unit. As such, the EDGs would fall under the Medium Combustion Plant Directive (MCPD) requirements of the EP Regulations.

The EDGs will be optimised to reduce emissions ('emissions optimised') with NO_x emissions meeting the 2g TA Luft and United States Environment Protection Agency Tier 2 (or equivalent) standards.

The EDGs purpose is to provide a short-term source of electricity, in the event of a simultaneous loss of power generation and external power supply, for up to 72 hours until external power can be re-established. Such emergency operations are excluded from the MCPD, however in order to ensure that the EDGs remains fit for purpose monthly testing will be carried out for up to 1 hour per month (i.e. <12 hours per year per EDG). As the annual operation will be <50 hours per year, the EDGs will be exempt from compliance with the MCPD ELVs.

All Emission Points, including the EDGs (A3-A8), are shown in Figure 4.

It is considered that due to the small size of the EDGs and the low annual running hours it is unlikely that it would have a discernible impact at the receptor locations. However, the SCAIL tool, has been used to undertake an assessment of the EDG to demonstrate this. The details of the SCAIL assessment are provided in Annex B.

5.2 Buildings and Terrain

Buildings can have a significant effect on the dispersion of pollutants and have been included within the model set-up. The complex building geometry has been simplified for inclusion in the model, which only accepts rectangular or circular building shapes.

The building heights were obtained from NZT and are the height above ground level. Details of the modelled buildings are outlined in Table 5-2. The modelled buildings are shown in Figure 4.

The new 'auto' function of the ADMS dispersion model has been used, as this allows the model to define the main building as opposed to the user, and accounts for meteorological conditions in addition to building proximity.

Table 5-2: Modelled Buildings

Name	Building Centre		Height (m)	Width (m)	Length (m)	Angle of Building Length to North (degrees)
	x	y				
HRSG	457099	525315	56.0	40.0	40.0	21
PCC Plant Absorber	457012	525348	74.5	20.0	30.0	21

Sensitivity of the model to the inclusions of buildings is provided in Annex C.

Figure 4: Modelled Buildings and Emission Points

5.3 Meteorological Data

The meteorological site used in the assessment is Durham Tees Valley Airport and the most recent five years of hourly sequential meteorological data has been used in the assessment to account for recent climate change and interannual variability. The meteorological data used in this assessment is for 2020 to 2024.

This site was chosen as it is the closest to the Installation and is approximately 22km south-west and at a flat airfield in a principally agricultural area, and therefore a surface roughness of 0.3m (representative of 'Agricultural areas – max') has been selected for the meteorological site within the model.

Defra's LAQM.TG22 guidance[21] recommends that the meteorological data file is tested in a dispersion model and the relevant output log file checked to confirm the number of missing hours and calm hours that cannot be used by the dispersion model. This is important when considering predictions of high percentiles and the number of exceedances. The guidance recommends that meteorological data should only be used if the percentage of usable hours is greater than 85%.

The 2020-2024 datasets include usable data corresponding to 100%, 100%, 100%. 98.2% and 95.1% respectively. This is above the 85% threshold, so meets the requirements of the Defra guidance and is adequate for the dispersion modelling. Figure 5 shows the wind roses for Durham Tees Valley Airport for 2020 to 2024. It can be seen that the predominant wind direction is from the south/ south-west.

Sensitivity of the model to the different meteorological data is provided in Annex C.

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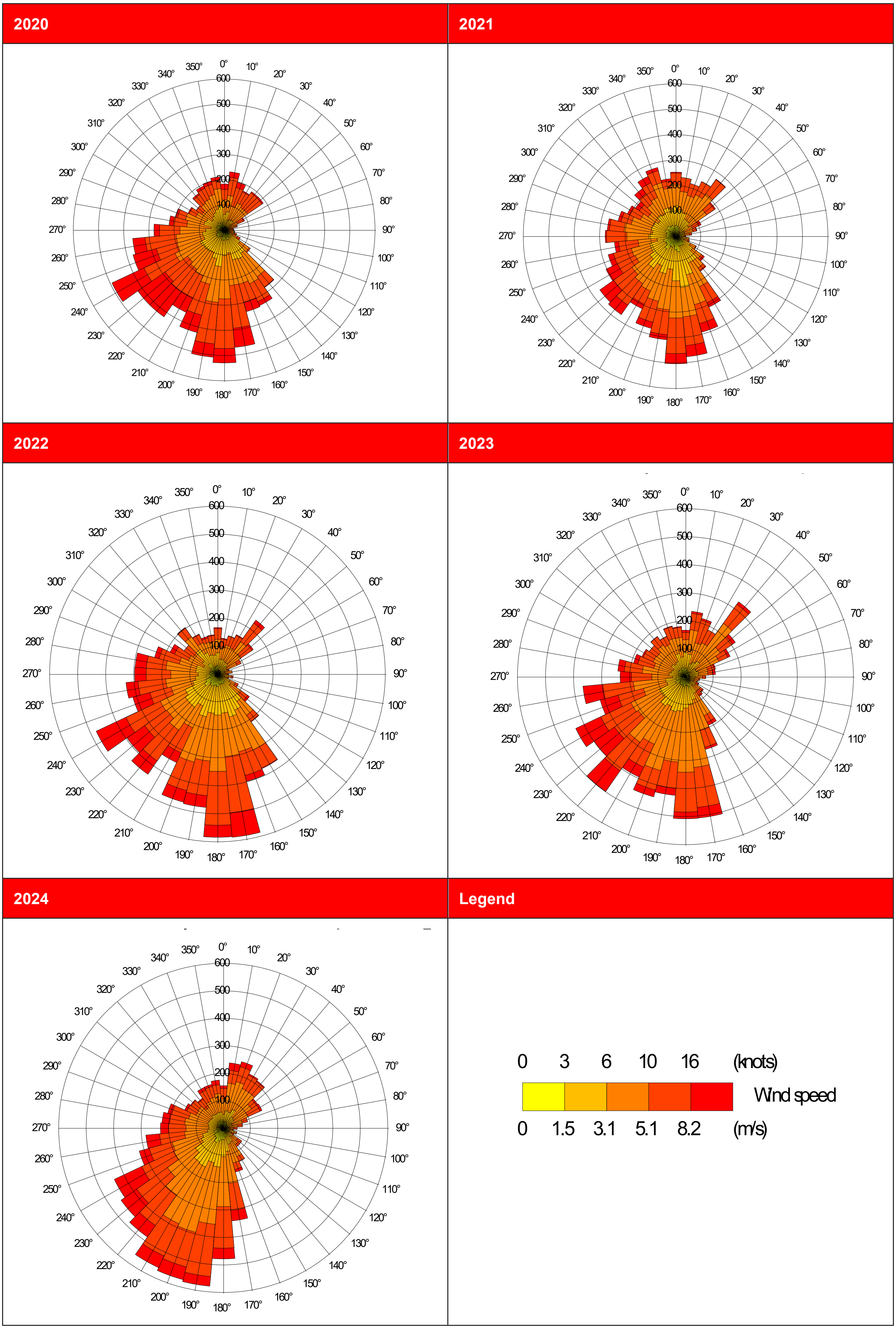
[21] Defra (2022) LAQM.TG(22). Available at: https://laqm.defra.gov.uk/wp-content/uploads/2022/08/LAQM-TG22-August-22-v1.0.pdf [Accessed April 2025].

Figure 5: Wind roses for Durham Tees Valley Airport for 2020 to 2024



2020

2021

2022

2023

2024

Legend

5.4 Other Model Parameters

A cartesian grid system was also included in the model to allow the production of contour plots. The grid resolution was approximately 75m by 75m over a 6x6km grid domain and was set at 1.5m in height to represent average human exposure, in line with the discrete point human receptors.

Site-specific terrain data has not been used in the model, as typically terrain data will only have a marked effect on predicted concentrations where hills with gradient of more than 1 in 10 are present in the vicinity of the source. There are no potentially significant changes in gradient within the study area.

The local area immediate to the Installation is predominantly flat agricultural land and some nearby industry. A surface roughness of 0.3m, corresponding to ‘Agricultural areas (max)’, has been used in the assessment to represent the local terrain for both the dispersion site and the meteorological site.

Sensitivity of the model to the different surface roughness is provided in Annex C.

6. Modelling of Amines and N-amines

6.1 Introduction

As stated previously, the amine-based solvent used to remove the CO_2 within the flue gas stream from the CCGT can result in ‘amine slip’, meaning that direct emissions of amines from the absorber stack can occur. Over time, the amine solvent used in the PCC plant can degrade, through for example, reaction with NO_2 within the flue gases, which can result in the generation of N-amines within the amine solvent in the PCC plant.

Degradation is minimised through continuous solvent replenishment, monitoring and process control, as detailed in the Main Supporting Document. Nevertheless, the amine slip emission from the PCC plant is likely to include a very small fraction of N-amines. Additionally, released amines and N-amines can further degrade following their release to the atmosphere, therefore it is necessary to assess the impacts associated with both N-amine generation pathways to determine the potential impacts in the environment, especially given the concern over the potential toxicity and carcinogenicity of some N-amine species.

Whilst the assessment methodology for combustion emissions and other known potential degradation products (e.g. NH_3, amide, formaldehyde and acetaldehyde) has been covered in Sections 3 and Section 5, the assessment method for assessing the atmospheric reactions that occur in amines and N-amines post release is more complex and requires additional modelling steps which are not normally considered in general modelling practices.

The atmospheric chemistry of amines and N-amines is dependent on atmospheric ozone and NO_2 concentrations, and with the generation of hydroxyl (OH) radical intermediates and other unstable intermediate species in ultraviolet (UV) light, and therefore is complex, however the principal mechanisms are understood, and many studies have been made of the primary reaction rates and subsequent interactions between degradation products and these atmospheric species.

The ADMS model developers, CERC, have developed a specific Amine Chemistry module to simulate the atmospheric chemistry of amines and N-amines following their release from stacks. The chemistry scheme is based on the reactions initiated by the attack of an emitted gaseous amine or N-amine by a OH radical and predicts the subsequent formation of nitrosamine and nitramines.

This section details the amine chemistry mechanisms likely to occur following release of amines and N-amines from the PCC plant absorber stack, and the specific parameters used for the modelling assessment for N-amines impacts from the Installation.

6.2 Discussion of Amines and N-Amines

6.2.1 Introduction to Amines and N-amines

The group of chemicals known as amines are hydrocarbon derivatives of NH_3. Primary amines (e.g. MEA or 2-amino-2-methyl-propanol (AMP)) have one hydrogen (H) atom replaced with an organic (hydrocarbon-based) functional group; secondary amines (e.g. Dimethylamine (DMA) or Pz) have two H atoms replaced; and tertiary amines (e.g. trimethylamine) have three H atoms replaced. Whether an amine is classified as primary, secondary or tertiary has important implications for amine reaction mechanisms and rates.

Nitrosamines are nitroso- (-NO) compounds of the original amine. The stability of the N-amines produced through amine degradation varies. For example, primary amines MEA and AMP are not considered to form stable nitrosamines, such that, following formation, the nitrosamine either reverts to the amine radical intermediate or rapidly isomerises (changes structure) and then reacts very quickly with oxygen (O_2) to form an imine (R-N group). However, MEA can degrade to the nitrosamine N-Nitrosodiethanolamine (NDELA) via the secondary amine Diethylamine (DEA). Secondary amines can form more stable nitrosamines, as can tertiary amines although they are less likely to do so than secondary amines. Tertiary amines must first degrade to a primary or secondary amine, through elimination of a hydrocarbon group, before further reaction to N-amine or other species can occur. Therefore, as other competing reactions may also occur, the likelihood of forming N-amine is much lower than for a secondary amine.

6.2.2 Potential Toxicity of N-Amines

Many nitrosamines and nitramines are known or potential carcinogens. Whilst there is toxicity data available for a few of the more generally researched substances (e.g. NDMA and NDELA), the environmental toxicity of many of the other individual compounds is not well understood[22].

NDMA is understood to be the most mutagenic (having the ability to cause a permanent change in an organism's genes) of the nitrosamines tested[23]. The World Health Organisation (WHO) has published a Concise International Chemical Assessment Document on NDMA[24], which states that laboratory studies have shown that exposure to NDMA results in tumours in all species examined; it is metabolised (in the body turned into new cells, energy and waste products by chemical processes) and does not bioaccumulate (build up within the tissues of an organism).

NDMA can be produced during water treatment processes involving chlorination and is also found in low levels in some pharmaceutical products, cured meat, fish, beer and tobacco smoke, and therefore the general public are likely to be regularly exposed to very low levels of NDMA, although the WHO state that photolysis is the major pathway for the removal of NDMA from surface water, air, and land and that it is unlikely to be transported over long distances in air or to partition to soil and sediments.

There is less information available on the toxicity of nitramines, which include nitro (-NO_2) compounds of the amine, such as dimethylnitramine (DMNA), however it is generally considered that they are of lower toxicity than nitrosamines. Although they are suspected carcinogens, none are classified as such by the International Agency for Research on Cancer (IARC). Animal carcinogenicity studies have indicated that DMNA is at least 6 times less toxic than NDMA[25]. This paper goes on to state that further quantitative evaluation of relevant nitramines is required to rank them against nitrosamine toxicity, in order that more refined and less conservative assessments, where currently all N-amines are assumed to be as toxic as the most toxic nitrosamine, can be carried out.

Detailed toxicology data is not currently available for the N-amines that may be formed by the degradation of the amines within the CANSOLV DC-103 solvent, in terms of testing to derive No Adverse Effect Levels (NOAEL), which the EA recommends for the derivation of new EALs. Such testing is required for REACH registration and therefore is scheduled to be carried prior to importation of the solvent to the UK. Once complete, the results of this testing can be used to derive species specific EALs for the CANSOLV-DC103 amines and N-amines to provide assurance that the predicted level of impacts are acceptable to protect human health.

In the meantime however, Shell have carried out a bacterial reverse mutation assay (or Ames test) for the CANSOLV DC-103 N-amines. Such tests are widely employed as an initial screening to determine the mutagenic potential of new chemicals and drugs. In the test, bacterial cells are exposed to the test chemical in the presence and absence of metabolic activation. Mutations are determined by scoring bacterial growth (revertant colonies) on selective agar plates lacking the essential amino acid.

Tests carried out for the N-amines potentially formed by degradation of the CANSOLV-DC103 solvent amines, compared their mutagenic potential with the mutagenic potency of NDMA. The tests concluded that the toxicity of the N-amines potentially formed from CANSOLV-DC103 is significantly lower than NDMA. The report detailing these conclusions is provided in Annex A and the results are summarised here. The nitrosamines formed from the use of the proposed CANSOLV-DC103 solvent are named as 'Cansolv N-1' and 'Cansolv N-3' in the report (which correspond to N-amine 1 and N-amine 2 in this assessment) in the report, a further N-amine 'Cansolv N-2' is also referenced, however this is not formed from the CANSOLV-DC103 solvent and therefore is not relevant to this application.

The study found that NDMA was an exceedingly potent mutagen. Cansolv N-3 (N-amine 2) was found to be a clear mutagen, but approximately 50 times less potent than NDMA. Cansolv N-1 (N-amine 1) was found to be a very weak mutagen with a mutagenic potency approximately 2,000 times less than that of NDMA.

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[22] Scottish Environmental Protection Agency (SEPA) (2015). Review of amine emissions from carbon capture systems, Version 2.01. 2015

[23] Wagner, Osiol, Mitch and Plewa (2014). Comparative in Vitro Toxicity of Nitrosamines and Nitramines Associated with Amine-based Carbon Capture and Storage.

[24] World Health Organisation. (2002). Concise International Chemical Assessment Document 38, N-Nitrosodimethylamine.

[25] Gjernes E, Helgesen L I, Maree Y (2013) Health and environmental impact of amine based post combustion CO_2 capture.

However, in order to ensure that a worst-case assessment is carried out, it has been assumed that N-amine emissions occur solely as NDMA and therefore comparison of the predicted process contributions to the NDMA EAL is considered to be very conservative.

6.2.3 Amine Atmospheric Chemistry

The majority of N-amines present in the atmosphere from releases from the PCC plants are considered to form through reactions in the atmosphere post release. These atmospheric reactions are complex, and the rate of N-amine formation and subsequent destruction depends upon a range of factors.

The amine and N-amine degradation process in the atmosphere requires the presence of either an OH or a nitrate (NO_3) radical. The primary method for formation of N-amines in the atmosphere is a two-step process:

- an OH radical (daytime) or an NO_3 radical (night-time) removes a single hydrogen atom in the amine molecule to form a highly unstable amine radical; then
- the amine radical reacts with either an NO group to form a nitrosamine, or an NO_2 group to form a nitramine.

A variety of competing reactions can also take place, preventing the formation of N-amines:

- the amine can degrade to other radical species via removal of a non-amine hydrogen, or methyl group (this potential is known as the branching ratio);
- the amine radical can undergo competing reactions, with NO_2 and O_2 to form an imine (stable, and not toxic[26]; and
- the nitrosamine or nitramine can undergo further degradation or reverse reaction back to the radical.

During daylight hours, atmospheric amine degradation is initiated by reaction with the OH radical (generated by photolysis of water by the action of UV light from sunlight. At night, in the absence of UV light, no OH radical is generated. Night-time reactions instead proceed by the much slower pathway of NO with ozone (O_3) to form NO_2 and subsequent reaction of NO_2 with O_3 to form the NO_3 radical; amine degradation is then initiated by reaction with the NO_3 radical to form N-amines. The nitrate radical is rapidly photolyzed (decomposed or separated by the action of light) in daylight and does not represent a likely reaction pathway during the daytime.

The concentration of NO_x and O_3 available in the atmosphere therefore influences the reaction of amine to N-amines. The night-time reactions are typically slower than the daytime reactions as a result of the intermediate reaction step, therefore a higher rate of formation of N-amines results from daytime reactions.

The steady state concentration of N-amines can be calculated using reaction rate constants, usually derived through experimental studies undertaken by various investigators, with some experiments dating back to the 1970's. Reaction rate constants are kinetic parameters that define the chemical reaction rate equations and transformation of reagents. They have traditionally been measured empirically, by experimental measurement methods. In recent years, they have also been calculated by theoretical, computational methods, although experimental measurements maintain a vital role. The computational methods include quantum chemical methods and theoretical kinetic methods.

Such studies have indicated that not all amines released would convert to N-amines in the atmosphere, and the conversion of those amines that would degrade in the atmosphere to N-amines can take many hours to occur. Typical conversion rates are <1% although chamber experiments show a range of between 0 and 10%.

The ratio of reaction coefficients in the formation of (1) the amine radical (that can proceed to N-amine formation) or (2) an alternative species radical (that does not form N-amine) is described as the branching ratio; and for several amine species these have been published, although values range between published sources. The higher the branching ratio of the amine, the more likely it is to form N-amines. The range of relevant amine branching ratios from different studies are outlined in Table 6-1. As can be seen in Table 6-1, there is a large range in the reported branching ratios.

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[26] Helgesen/ Gjernes (2016). A way of qualifying Amine Based Capture Technologies with respect to Health and Environmental Properties.

Table 6-1: Amine Branching Ratios

Amine	Branching Ratio
Monoethanolamine (MEA)	0.08 – 0.47
Piperazine (Pz)	0.01 – 0.34

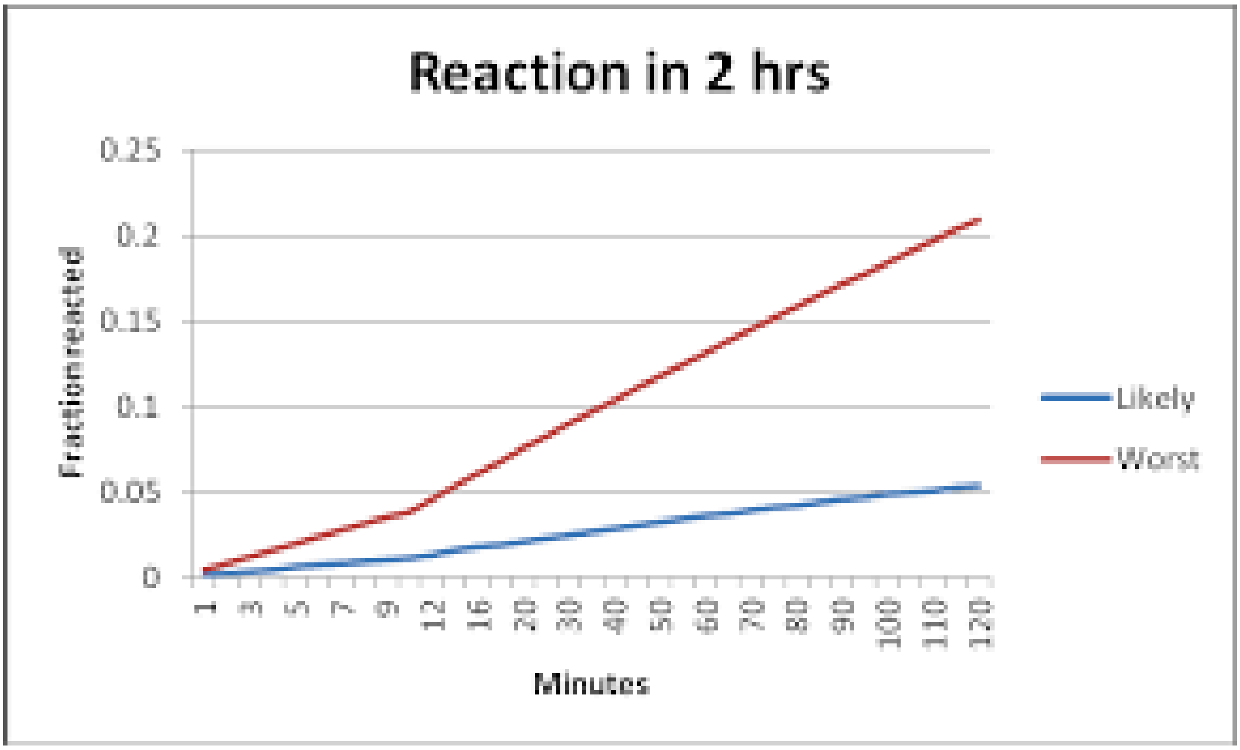
In addition to the branching ratios, the concentration of ambient NO_x also influences the generation of N-amines from amines. From laboratory tests, it is known that when more NO_2 is present, more amines are converted into N-amines. This function is called the 'amino radical/ NO_2 reaction rate constant [k4]'.

In the flue gas emitted from the PCC plant, the NO_x is composed of around 90-95% NO to 5-10% NO_2. Once in the atmosphere, the NO will react with OH to form NO_2. The reaction of the OH radical in the atmosphere is preferential with NO rather than the amine as NO is more reactive. Therefore, as NO concentrations decrease spatially due to reaction with OH, there become more available OH radicals to react with the amines, so the amine reaction will occur at greater distance from the stack. The details of this process are uncertain to be accurately represented in the ADMS amines chemistry model and therefore the model does not include this time-delay in the initiation of the amine degradation reaction, assuming that this occurs instantly on release, therefore potentially resulting in higher concentrations predicted in close proximity to the stacks.

The time delay of the amine reaction is described by the work carried out by Tonnesen[27], which demonstrated that less than 5% of the amines that would convert to N-amines would have done so in the first 10 minutes after release. After 2 hours, only 20% of the amines that would convert to N-amine would have done so. The work then goes on to estimate that it would take in the order of 10 hours for 100% conversion to occur. A graph showing this process is provided in Figure 6.

The fact that this time-delay is not taken into account in the ADMS amines chemistry module therefore is considered to result in an over-prediction in the process contributions at receptor locations predicted by the model. As such, the model results should be considered to be conservative.

Figure 6: Conversion of Amines to N-Amine in the Atmosphere Over Time



At night-time the NO_3 radical is formed from the reaction of O_3 with NO, and then NO_2. Therefore, the reaction of NO to NO_2 is likely to be preferential to the reaction of NO_2 to NO_3 or NO_3 reacting with amines, which

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[27] Tonnesen. (2011). Update and improvement of dispersion calculations for emissions to air from TCMs amine plant Part II – Likely case nitrosamines, nitramines and formaldehyde.

again will slow down the formation of N-amines. These details again are too uncertain to be accurately represented in the amines chemistry module and therefore are not included. As the slower night time reaction is not taken into account, this is again considered to lead to a potential over-prediction in the N-amine process contributions at receptor locations.

Only a proportion of the N-amines released or generated will remain as N-amines, as during daylight hours, N-amines are degraded to more basic amines, amides, ethanoic acid, ketones and simple nitrogen compounds in the presence of sunlight. At night no destruction of N-amines occurs.

6.3 Amines and N-Amines Assessment Methodology

6.3.1 Model Selection

ADMS is a modern dispersion model that has an extensive published validation history for use in the UK. This model has been extensively used throughout the UK to demonstrate regulatory compliance.

CERC has generated a specific amine chemistry module for use with the ADMS software, for the assessment of emissions of amines and their atmospheric degradation products. The model calculates the rate of amine degradation taking into account the reaction of amines with other species present in the exhaust gas (i.e. NO_2) and also with OH radicals in the atmosphere.

The ADMS Amines chemistry module is currently the only commercially available modelling software for evaluating the potential impacts of amines and amine degradation products. Whilst the ADMS model itself has been validated, the specific amines module has not been, and therefore the results should be regarded as indicative rather than definitive.

The module is based on established science considering published research on mechanisms of formation of toxic compounds. Although the module has not been validated, the ADMS air dispersion modelling algorithms are continually validated against real world situations, field campaigns and wind tunnel experiments.

The EA's AQMAU recognise in their evaluation of the ADMS amines module, provided in the EA's Amine Modelling guidance state, state that *"There are various aspects of the current version of the module that suggest the estimation of toxic products might be conservative, however, the level of uncertainties in other input parameters can counteract this."*

Within the ADMS amines chemistry module, it is necessary to specify the amine, nitrosamine, nitramines and radical species that are being modelled. The module also requires the amine-specific branching ratio and the kinetic constants, k values (specific to each subsequent reaction rate). As previously stated, the rates of reaction may be derived through scientific research through experimental observation, for the more stable intermediate reaction species, or through theoretical computational calculations such as Transition State Theory.

Shell has provided specific k values for Amine 1 and Amine 2 found within the CANSOLV DC-103 solvent, which have been determined by Professor Claus Nielson of the University of Oslo[28][29] the leading authority on amine atmospheric chemistry. Professor Nielson has carried out a comparison of the characteristics of the Amine 1 within the CANSOLV DC-103 solvent with published data for other amine species with similar characteristics. The specific k values for Amine 2 have been sourced from literature for the specific amine species.

Amine 3 is a tertiary amine which Shell have found to not always be present in the emission. It degrades to a primary amine and as such, it does not form stable nitrosamines. Due to the minute quantities of Amine 3 potentially present in the emission, and the fact that is does not form nitrosamines, the assessment only considers atmospheric processes concerning Amine 1 and 2.

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[28] Neilson, C. (2014). Modelling Nitrosamine and Nitramine Formation in the Atmospheric Gas Phase Photo-oxidation of Cansolv DC103 amine. **Report provided**

[29] Shell and Neilson, C. (2025). Support for Proposed ADMS Amine Chemistry Parameters used for Dispersion Modelling of Flue Gas from Cansolv units. **Report provided**

6.3.2 Dispersion Model Input Parameters

As discussed above, the treatment of chemistry within the ADMS amines model requires a suite of reaction rate parameters. The parameters required by the model in order to simulate amine chemistry for a specific amine are detailed in Table 6-2.

Table 6-2: Amine Information for ADMS Model Set-up

Parameter	Units	Notes
Ratio of NO_x to NO_2 in the exhaust gas	%	Sensitivity tested at 5% and 10%, shows no change to results.
k1 = Amine/OH radical reaction rate constant	ppb/s	Rate constants from literature for the reaction of the amine with the hydroxyl radical (‘●’) (OH●).
k2 = Amino radical/O_2 reaction rate constant	ppb/s	Rate constants from literature for the reaction of the amine● with O_2 (to form imine).
k3 = Rate constant for formation of nitrosamine	ppb/s	Rate constants from literature for formation of nitrosamine from amine● and NO.
k4a = Rate constant for formation of nitramine	ppb/s	Rate constants from literature for formation of nitramine from amine● and NO_2.
k4 = Amino radical/NO_2 reaction rate constant	ppb/s	Rate constants from literature for the reaction of the amine● with NO_2 (to form imine or nitramine).
Branching ratio	dimensionless	Branching ratios from literature for the amine/ OH● reaction – representing the reaction split, in formation of amine radical (amine● which further reacts to nitrosamine/ nitramine) and alternative hydrocarbyl radical species.
Ratio of J (nitrosamine) to NO_2	dimensionless	The ratio of the photolysis rate constants for the nitrosamine and NO_2 - representing the relative atmospheric fluctuations of NO_2 and nitrosamine formation as a result of UV light action.
c = OH concentration constant	s	OH concentration constant, derived for typical daytime atmosphere for the Sites’ location.
NO_x baseline	µg/m^3	Hourly values obtained from Domanstown continuous monitor for NO_x, NO_2 and O_3 for the years of meteorological data used in the model (2020 – 2024).
NO_2 baseline	µg/m^3	
O_3 baseline	µg/m^3	

These parameters are entered into an ADMS Additional Information (AAI) file, which characterises the amine chemistry for the amine or N-amine species being assessed. Table 6-3 details the constants that have been used for the assessment.

Table 6-3: Amine Chemistry Model Set-up

Parameter	Units	Amine 1	Amine 2	Source
k1 = Amine/OH radical reaction rate constant	ppb/s	6.25[28]	5.95[29]	As provided in footnotes.
k2 = Amino radical/O_2 reaction rate constant	ppb/s	1.25e-9	1.25e-9	Based on k2/k4$_a$[31]
k3 = Rate constant for formation of nitrosamine	ppb/s	0.0135	0.0135	Based on k3/k4$_a$[31]

Parameter	Units	Amine 1	Amine 2	Source
k4a = Rate constant for formation of nitramine	ppb/s	0.00795	0.00795	Lazarou et al. (1994)[30], as detailed in Uni of Oslo's prepare (Ref). This is the same value as used in the original assessment, however the conversion of $cm^3.molecule^{-1}.s^{-1}$ to $ppb.s^{-1}$ has been updated from $2.46x10^{10}$ to $2.5x10^{10}$ in line with current CERC guidance.
k4 = Amino radical/NO_2 reaction rate constant	ppb/s	0.00795	0.00795	As above.
Branching ratio	Dimensionless	0.17[29]	0.18	Amine 1 - k_{1a}/k_1, based on a value of k_{1a} of 1.0575[31] Amine 2[28]
Ratio of J (nitrosamine) to NO_2	Dimensionless	0.34	0.34	[29]
c = OH concentration constant	s	0.00066		Site specific value calculated following the derivation of J (NO_2), based on the average of the 5 years of meteorological data used in the assessment.

The model includes an option to take into account the effects of dilution of pollutant species and the entrainment of background pollutants. This 'dilution and entrainment' effect can be switched on and off, however it is recommended that it is switched on for all model runs involving amine chemistry. This is employed in the ADMS chemistry module (and recommended by CERC for the low concentration plumes for the amines module) to represent slower mixing of the ambient air within the plume – rather than instantaneous mixing with an ambient air 'parcel' at plume release. The dilution and entrainment option has therefore been included for the main assessment for conservatism.

In addition, the amine module includes an option for modelling unstable nitrosamines, which can be employed when modelling primary amines that do not form stable nitrosamines. In effect, this means that the model results generated when this option is selected include no nitrosamine component, with only nitramines being predicted to form. This option has not been included in the assessment, as it is not considered relevant for the Amine 1 and Amine 2 species modelled.

Sensitivity of the Amine Chemistry module to different inputs is include in Annex C.

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[30] Lazarou, Y.G., K.G. Kambanis, and P. Papagiannakopoulos, *Gas-Phase Reactions of $(CH_3)_2N$ Radicals with NO and NO_2*. Journal of Physical Chemistry, 1994. **98**(8): p. 2110-2115.

[31] For a 1ppb NO mixing ration in the surrounding air, the estimated upper k1a value for the total formation of aminyl radicals in 0.8013. For a 100ppb NO mixing ration in the surrounding air, the estimated upper limit k1a value for the total formation of aminyl radicals is 1.4038 based

7. Predicted Results

7.1 Introduction

The PCs of pollutants from the dispersion modelling for human health impacts, and for impacts at designated statutory and non-statutory ecological receptors, are presented in this section. The PCs are compared against the relevant AQS objectives, EALs, CL, CLds and screening criteria, as per the EA's Risk Assessment Guidance.

7.2 Scenario 1 Extreme Worst Case Normal Operation – Emissions from the PCC Plant

7.2.1 Human Health Impacts

The impact of the Installation's PCs at human health receptors during extreme wosrt case normal operation, has been determined from the maximum model output that occurs anywhere beyond the Installation boundary, as it has been possible to demonstrate that the impacts at this location are insignificant. The results at the identified human health receptors are therefore lower than the maximum results reported, and therefore are also considered to be insignificant.

The results for all pollutant species are detailed in Table 7-1.

Nitrogen Dioxide Impacts

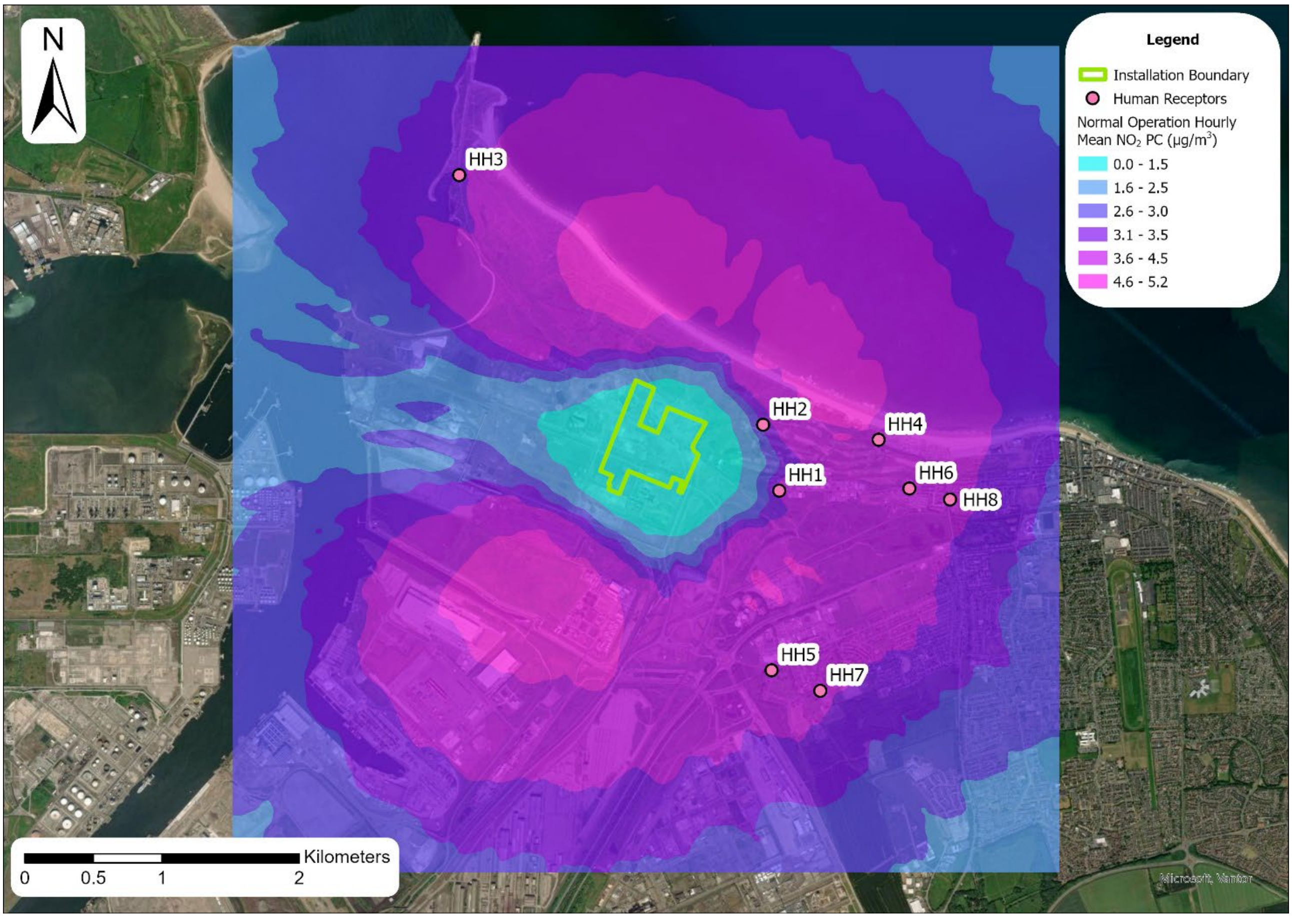
The highest predicted annual mean NO_2 PC that occurs anywhere is 0.3µg/m^3, which represents 0.8% of the AQS objective (40µg/m^3). This is below the first EA screening criteria as the PC is less than 1% of the AQS objective. The impacts can therefore be considered to be insignificant at all human health receptors.

The highest predicted hourly mean NO_2 PC predicted was 5.3µg/m^3, which is 2.6% of the AQS objective (200µg/m^3). This is below the first EA screening criteria of 10% for short-term impacts, and therefore can be screened out as insignificant**.** The maximum PEC for hourly mean NO_2 was 28.1µg/m^3, which is well below the AQS objective.

Isopleth figures of the annual and daily NO_2 PCs are shown in Figure 7 and Figure 8.

Figure 7: Scenario 1 – Extreme Worst Case Normal Operation. Isopleths of the Predicted Annual Mean NO_2 PCs (µg/m^3)

Figure 8: Scenario 1 – Extreme Worst Case Normal Operation. Isopleths of the Predicted Hourly Mean NO_2 PCs (µg/m^3)



Carbon Monoxide Impacts

The predicted maximum CO 8-hour rolling mean PC is 36.2µg/m^3, which is 0.4% of the AQS objective (10,000µg/m^3) and as such it is below the first EA screening criteria and can be considered to be insignificant. The maximum PEC is 464.2µg/m^3, well below the AQS objective.

The predicted maximum hourly mean CO PC is 56.0µg/m^3, which is 0.2% of the EAL (30,000µg/m^3), and is below the first EA screening criteria and can be considered to be insignificant. The maximum PEC is 484.0µg/m^3, and therefore well below the AQS.

Ammonia Impacts

The predicted maximum annual mean NH_3 PC is 0.04µg/m^3, which is 0.02% of the EAL (180µg/m^3). This is below the EA first screening criteria and can be considered to be insignificant as a result. The maximum PEC is 6.7µg/m^3, well below the EAL.

For the predicted hourly mean NH_3, the maximum PC is 1.5µg/m^3, which is 0.1% of the EAL (2,500µg/m^3), well below the first EA screening criteria of 10% for short term impacts. This can be considered to be insignificant as a result. The maximum PEC is 14.9µg/m^3, well below the EAL.

Amines

The predicted maximum daily mean PC and PEC for Amine 1 and Amine 3 is 0.2µg/m^3, which represents 0.2% of the EAL for MEA (100µg/m^3), used as a proxy for this amine species, based on toxicological information provided by the CANSOLV licensor, and as detailed in Annex A. On other Environmental Permit applications for CANSOLV based plants it has been noted that the EA recommended comparing the impacts of Amine 1 and Amine 3 against the Pz EAL (15µg/m^3), and should this be applied, the PC and PEC for Amine 1 and Amine 3 represents 1.4% of the Pz EAL at the location of maximum impacts, and therefore only slightly over the first stage screening threshold. Although this is not considered to be insignificant at the first level of screening, it is still well below the second EA screening criteria of 70%. Against both EALs, Amine 1 and 3 daily mean concentrations can therefore be considered to be insignificant.

The Amine 2 daily mean predicted maximum PC is 0.02µg/m^3, which is 0.2% of the Pz EAL (15µg/m^3), advised by the CANSOLV licensor for use as a proxy for this amine species. This is therefore well below the first EA screening criteria and therefore can be considered to be insignificant.

The predicted maximum Amine 1 hourly mean (100th percentile) PC is 0.4µg/m^3, which is 0.1% of the MEA EAL (400µg/m^3) and therefore less than the first EA screening criteria. This is considered to be insignificant as a result.

N-amines

The predicted maximum annual mean PC for N-amines 1 (i.e. the sum of the associated nitrosamines and nitramines) is 0.09ng/m^3, which represents 46.6% of the EAL for NDMA (0.2ng/m^3). This is above the first EA screening criteria, however as the maximum PEC is also considered to be 0.09ng/m^3, 46.6% is less than 70% of the EAL and can be considered insignificant as a result.

Due to the coastal location of the Installation, these maximum impacts are predicted to occur at sea, at a distance of approximately 2.5km from the Installation. To demonstrate how conservative these impacts are therefore, the impacts at the worst-case human health receptor included in the model have also been determined.

The receptor where the maximum N-amines 1 PC is predicted to occur is HH4, the Caravan Park, which has a predicted PC of 0.04ng/m^3, representing 18.1% of the conservative NDMA EAL that has been used as a proxy for N-amines in this assessment. Whilst this remains over the first screening criteria of 1%, it is significantly below the second screening criteria of 70%.

The maximum annual mean N-amines 2 PC is 0.05ng/m^3, which is 23.0% of the NDMA EAL (0.2ng/m^3). This is over the first EA screening criteria of 1%, however, as the PEC is also 23.0% of the EAL, it is below the second EA screening criteria. This can be considered as insignificant as a result. As with N-amines 1, these maximum impacts are predicted to occur at sea, at a distance of 3.0km from the Installation. The receptor where the maximum N-amines 2 PC is predicted to occur is HH4, the Carvan Park, which has a predicted PC of 0.03ng/m^3, representing 12.6% of the conservative NDMA EAL that has been used as a proxy for N-amines in this assessment. Whilst this remains over the first screening criteria of 1%, it is significantly below the second screening criteria of 70%.

Even when the predicted impacts of N-amine 1 and N-amine 2 at the worst-case human health receptor are summed and compared to the conservative NDMA EAL, they only represent 35.6%. As stated in Section 6.2.2, it is considered that the N-amines associated with the CANSOLV solvent are significantly less toxic than NDMA, and therefore it is considered that the impacts will be much lower than indicated in this assessment.

Other Degradation Products

The predicted maximum PC for annual mean Formaldehyde is 0.01µg/m^3, which is 0.1% of the EAL (5µg/m^3). This is less than the first EA screening criteria of 1% and therefore can be considered to be insignificant. The PEC was 0.01µg/m^3, well below the EAL.

For the Formaldehyde 30-minute mean, the predicted maximum PC is 0.3µg/m^3, which is 0.3% of the EAL (100µg/m^3). This is below the first EA screening criteria and can be considered as insignificant. The PEC was 0.3µg/m^3, well below the EAL.

For annual mean Acetaldehyde, the predicted maximum PC is 0.07µg/m^3, representing 0.02% of the EAL (370µg/m^3) and therefore below the first EA screening criteria. This can be considered to be insignificant. The PEC is 0.07µg/m^3, well below the EAL.

The hourly mean Acetaldehyde predicted maximum PC is 2.6µg/m^3, which is 0.03% of the EAL (9,200µg/m^3) and below the first EA screening criteria. This is considered to be insignificant. The PEC is 2.6µg/m^3, well below the EAL.

The maximum annual mean for total amides is <0.01µg/m^3, which is 0.8% of the EAL (0.05µg/m^3). This is below the first EA screening criteria and is therefore considered to be insignificant. The PEC is also <0.01µg/m^3, well below the EAL.

Table 7-1: Scenario 1 – Extreme Worst Case Normal Operation Human Health Impacts – Maximum Impacts Beyond the Installation Boundary

Species	AQS (µg/m^3)	PC (µg/m^3)	PC/AQS	1st Stage Screened as Insignificant?	BC (µg/m^3)	PEC (µg/m^3)	PEC/AQS	PC/(AQS – 2 x BC)	2nd Stage Screened as Insignificant?
NO_2 hourly mean (as the 99.79th percentile)	200	5.3	2.6%	**Yes**	22.8	28.1	14.0%	3.0%	-
NO_2 annual mean	40	0.3	0.8%	**Yes**	11.4	11.7	29.3%	-	-
CO 1-hour mean (as the 100th percentile)	30,000	56.0	0.2%	**Yes**	428.0	484.0	1.6%	0.2%	-
CO 8-hour rolling mean	10,000	36.2	0.4%	**Yes**	428.0	464.2	4.6%	0.4%	-
NH_3 hourly mean (100th percentile of hourly mean)	2,500	1.5	0.1%	**Yes**	13.4	14.9	0.6%	0.1%	-
NH_3 annual mean	180	0.04	0.02%	**Yes**	6.7	6.7	3.7%	-	-
Amine 1 and Amine 3 (100th percentile of hourly mean)	400	0.4	0.1%	**Yes**	0.0	0.4	0.1%	0.1%	-
Amine 1 and 3 daily mean	100	0.2	0.2%	**Yes**	0.0	0.2	0.2%	-	-
Amine 2 daily mean	15	0.02	0.2%	**Yes**	0.0	0.02	0.2%	-	-
N-amine 1 annual mean (max)	0.2 ng/m^3	0.09	46.6%	**No**	0.0	0.09	46.6%	-	**Yes** PEC <70% AQS objective
N-amine 1 annual mean (receptor)		0.04 ng/m^3	18.1%	**No**	0.0	0.04 ng/m^3	18.1%	-	
N-amine 2 annual mean (max)	0.2 ng/m^3	0.05	23.0%	**No**	0.0	0.05	23.0%	-	**Yes** PEC <70% AQS objective
N-amine 2 annual mean (receptor)		0.03 ng/m^3	12.6%	**No**	0.0	0.03 ng/m^3	12.6%	-	
Formaldehyde (30-minute mean)	100	0.3	0.3%	**Yes**	0.0	0.3	0.3%	0.3%	-
Formaldehyde annual mean	5	0.01	0.1%	**Yes**	0.0	0.01	0.1%	-	-
Acetaldehyde (100th percentile of hourly mean)	9,200	2.6	0.03%	**Yes**	0.0	2.6	0.03%	0.03%	-
Acetaldehyde annual mean	370	0.07	0.02%	**Yes**	0.0	0.07	0.02%	-	-

Species	AQS (µg/m³)	PC (µg/m³)	PC/AQS	1st Stage Screened as Insignificant?	BC (µg/m³)	PEC (µg/m³)	PEC/AQS	PC/(AQS – 2 x BC)	2nd Stage Screened as Insignificant?
Total amides	0.05	<0.01	0.8%	**Yes**	0.0	<0.01	0.8%	-	-
PC = Process Contribution, AQS = Air Quality Standard objective or EAL, BC = Background Concentration, PEC = Predicted Environmental Concentration									

7.2.2 Ecological Results

The impact of the Installation's PCs at the individual ecological receptors identified has been determined from the output and is presented in the sections and tables below.

Oxides of Nitrogen – Critical Levels

The highest PC for annual mean NO_x was predicted at E1.6 (Teesmouth and Cleveland Coast) and is 0.3µg/m^3, which is 1.1% of the CL and therefore just exceeds the first EA screening criteria of 1%. The corresponding PEC is 16.9µg/m^3, which is 56.2% of the CL and therefore less than 70% of the second EA screening criteria. The effects of annual mean NO_x can be considered insignificant as a result.

Annual mean NO_x impacts at all other receptors were predicted to be less than 1% of the CL, and therefore are considered to be insignificant.

The highest PC for daily mean NO_x was predicted at E1.6 and is 9.3µg/m^3, which is 12.4% of the daily CL. This exceeds the first EA screening criteria, however, the PEC is 34.1µg/m^3 at this receptor, which is 45.4% of the CL. This is well below the CL, and so it can be considered not significant.

Daily mean NO_x impacts at all other receptors were predicted to be less than 10% of the CL, and therefore are considered to be insignificant at the first level of screening.

A summary of the ecological annual and daily mean NO_x results for the extreme worst case normal operation is presented in Table 7-2.

Ammonia – Critical Levels

The relevant CLs levels for determining the impacts at ecological receptors for NH_3 were obtained from APIS. The PCs were less than 1% or less of the relevant CL at all ecological receptors modelled for Scenario 1. The impact of the Installation on NH_3 CLs is therefore considered to be insignificant.

The ammonia results for each ecological receptor are presented below in Table 7-3 for the extreme worst case normal operation of the Installation.

Table 7-2: Scenario 1 - Extreme Worst Case Normal Operation NO_x Dispersion Modelling Results for Ecological Receptors

Receptor I.D.	Site	CL (µg/m^3)	PC (µg/m^3)	PC/CL	1st Stage Screened as Insignificant?	BC (µg/m^3)	PEC (µg/m^3)	PEC % of CL	2nd Stage Screened as Insignificant?
E1.6*	Teesmouth and Cleveland Coast SPA, Ramsar and SSSI	30	0.3	1.1%	No	16.5	16.9	56.2%	**Yes**
		75	9.3	12.4%	No	24.8	34.1	45.4%	**Yes**
E2	North York Moors SAC, SPA, SSSI	30	< 0.1	0.2%	**Yes**	6.3	6.4	21.2%	-
		75	1.1	1.4%	**Yes**	9.5	10.5	14.0%	-
E3	Northumbria Coast SPA, Ramsar	30	< 0.1	0.1%	**Yes**	7.0	7.1	23.5%	
		75	0.8	1.1%	**Yes**	10.5	11.4	15.1%	-
E4	Durham Coast SAC	30	< 0.1	0.2%	**Yes**	8.7	8.8	29.3%	
		75	0.9	1.2%	**Yes**	13.1	14.0	18.7%	-
E5	Lovell Hill Pools SSSI	30	0.1	0.3%	**Yes**	9.6	9.7	32.3%	
		75	1.6	2.1%	**Yes**	14.4	16.0	21.3%	-
E6	Saltburn Gill SSSI	30	< 0.1	0.2%	**Yes**	7.8	7.8	26.0%	
		75	1.1	1.4%	**Yes**	11.6	12.7	16.9%	-
E7	Hart Bog SSSI	30	< 0.1	0.1%	**Yes**	8.1	8.1	27.1%	
		75	1.0	1.3%	**Yes**	12.2	11.8	15.7%	-
E8	Coatham Marsh LWS	30	0.1	0.3%	**Yes**	20.9	21.0	69.9%	
		75	3.6	4.7%	**Yes**	31.3	34.9	46.5%	-
E9	Eston Pumping Station LWS	30	0.2	0.8%	**Yes**	18.3	18.6	61.9%	
		75	5.4	7.2%	**Yes**	27.5	32.9	43.9%	-

PC = Process Contribution, CL = Critical Level, BC = Background Concentration, PEC = Predicted Environmental Concentration

* Several receptors were included across the Teesmouth and Cleveland Coast designations, and the results for the worst-case receptor are presented here.

Table 7-3: Scenario 1 – Extreme Worst Case Normal Operation NH_3 Dispersion Modelling Results for Ecological Receptors

Receptor I.D.	Site	CL ($\mu g/m^3$)	PC ($\mu g/m^3$)	PC/CL	1st Stage Screened as Insignificant?	BC ($\mu g/m^3$)	PEC ($\mu g/m^3$)	PEC/CL
E1.6*	Teesmouth and Cleveland Coast SPA, Ramsar and SSSI	3	< 0.01	0.1%	**Yes**	1.2	1.2	41.4%
E2	North York Moors SAC, SPA, SSSI	1	< 0.01	0.4%	**Yes**	0.9	0.9	88.4%
E3	Northumbria Coast SPA, Ramsar	3	< 0.01	0.1%	**Yes**	1.0	1.0	32.1%
E4	Durham Coast SAC	3	< 0.01	0.1%	**Yes**	1.0	1.0	32.7%
E5	Lovell Hill Pools SSSI	3	0.01	0.2%	**Yes**	1.2	1.2	41.2%
E6	Saltburn Gill SSSI	3	< 0.01	0.1%	**Yes**	1.1	1.1	35.5%
E7	Hart Bog SSSI	1	< 0.01	0.2%	**Yes**	1.4	1.4	136.2%
E8	Coatham Marsh LWS	3	0.01	0.3%	**Yes**	1.3	1.3	42.9%
E9	Eston Pumping Station LWS	3	0.02	0.7%	**Yes**	1.2	1.2	39.7%

PC = Process Contribution, CL = Critical Level, BC = Background Concentration, PEC = Predicted Environmental Concentration

* Several receptors were included across the Teesmouth and Cleveland Coast designations, and the results for the worst-case receptor are presented here.

Nitrogen Deposition

In line with previous assessments carried out for the Installation (i.e. during determination of the original Environmental Permit application and continued ongoing discussions with Natural England), the impacts of nitrogen deposition have been based on the average result over the 5-years of meteorological data modelled, rather than the single year that results in the worst-case impacts. This is because the vegetational changes that could result from increased nitrogen deposition caused by the Installation are considered to be a long term process, that would occur over a number of years, rather than as a result of a peak increase that occurs only over the period of one year. This approach has therefore been applied to the results presented in this assessment.

Whilst for screening assessments it is recognised best practice to apply the lowest CLd provided for any habitat type on the APIS website to determine whether there are likely to be any significant effects, it is also important that a realistic assessment of impacts is carried out, in order to not overestimate the potential for impacts to occur.

Historically the CLd range for Coastal stable dune grassland (calcareous type) of 10kg N/ha/yr to 15 kg N/ha/yr was considered to be applicable to Coatham Dunes, which form part of the Teesmouth and Cleveland Coast SSSI adjacent to the north of the Installation. The CLd ranges provided in APIS were updated in 2022 (i.e. since the original Environmental Permit application), such that the lowest, and therefore most conservative CLd range for the Teesmouth and Cleveland Coast SSSI dune type habitat is now listed as Coastal dune grasslands (grey dunes), with a CLd range of 5 – 15 kg N/ha/yr.

The German Environment Agency, Review of Empirical Critical Loads of Nitrogen for Europe document[32] states that where phosphorous limitation is a factor, nitrogen deposition may lead to fewer botanical responses in calcareous dunes compared with other dune sites. The higher end of the CLd range for Coastal dune grasslands (grey dunes), with a CLd range of 5 – 15 kg N/ha/yr therefore is more relevant to calcareous rich locations where there is phosphorous limitation.

The majority of the dunes at Coatham have formed in the lee of the South Gare, which was constructed with tipped slag from the steel works during the 1860s. It is therefore considered that the dunes are calcareous in nature due to the base-rich nature of the iron slag. This is documented in the Natural England's Supporting Information on the Teesmouth and Cleveland Coast SSSI[33]which also states that Coatham Dunes "*Represent the largest dune system with calcareous substrate in the area of search.*" Further the report states that the plants present *"includes a number of calcicoles (i.e. a plant that grows best in calcareous soil) such as yellow-wort Blackstonia perfoliata and blue fleabane Erigeron acer."*

Therefore, whilst the calcareous nature of the dunes seems certain, there is no information available as to whether they are phosphorous limited. As such, NZT are currently looking into carrying out a sampling and monitoring campaign at Coatham Dunes, and more widely across the Teesmouth and Cleveland Coast SSSI area, in order to obtain this information. This would enable the sensitivity of the dunes to potential impacts of nitrogen deposition to be better understood.

Table 7-4 shows the nitrogen deposition impacts at the ecological receptors considered in the assessment. The results at all receptors, except for the Teesmouth and Cleveland Coast SSSI are less than 1% of the relevant CLd, or in the case of the Easton Pumping Station LWS less than 100% of the CLd applied, and therefore can be considered to be insignificant.

The worst-case nitrogen deposition PC that is predicted to occur over the Teesmouth and Cleveland Coast SSSI is 0.17 kg N/ha/yr, which represents 1.7% of the CLd applied, and therefore can not be screened as insignificant. In addition, the background nitrogen deposition is already exceeding the CLd, representing 123.4% of it.

According to the background data available on the APIS website, the interannual variations that can occur in the nitrogen deposition concentrations can be as much as 1.48 kg N/ha/yr a year, which is predicted to have occurred between 2019 and 2020, as shown in Figure 9. More typically however, the variance between years

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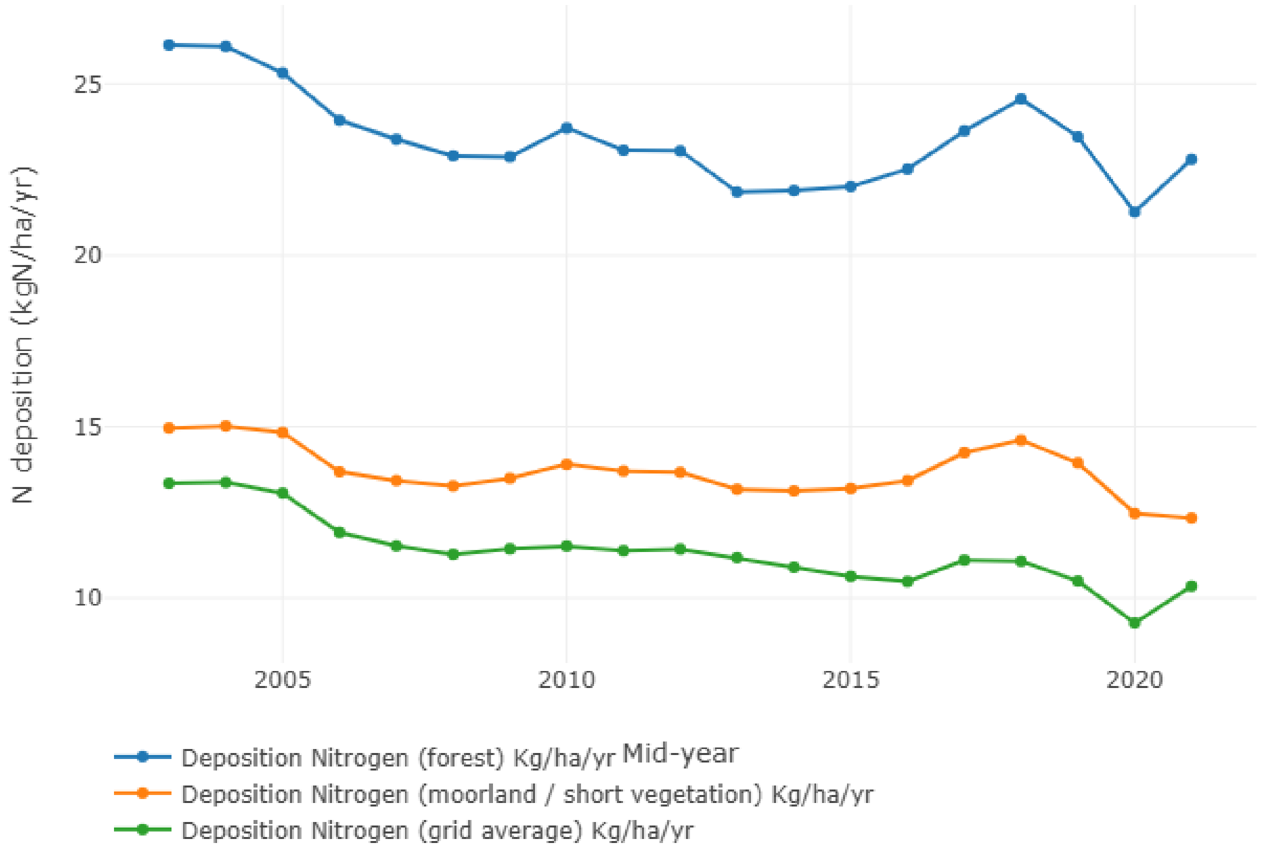
[32] Available at: Review and revision of empirical critical loads of nitrogen for Europe

[33] Natural England (2018). Teesmouth and Cleveland Coast SSSI Supporting Information – A supplement to the notification document. Available at: SSSI supporting info Blackmore Vale Commons and Moors [Accessed December 2025]

is an average of 0.15 kg N/ha/yr. It is therefore considered that the 0.17 kg N/ha/yr predicted for Scenario 1 is in line with the average variance experienced year on year at the dunes, and represents only 11% of the largest variance that has occurred since 2003.

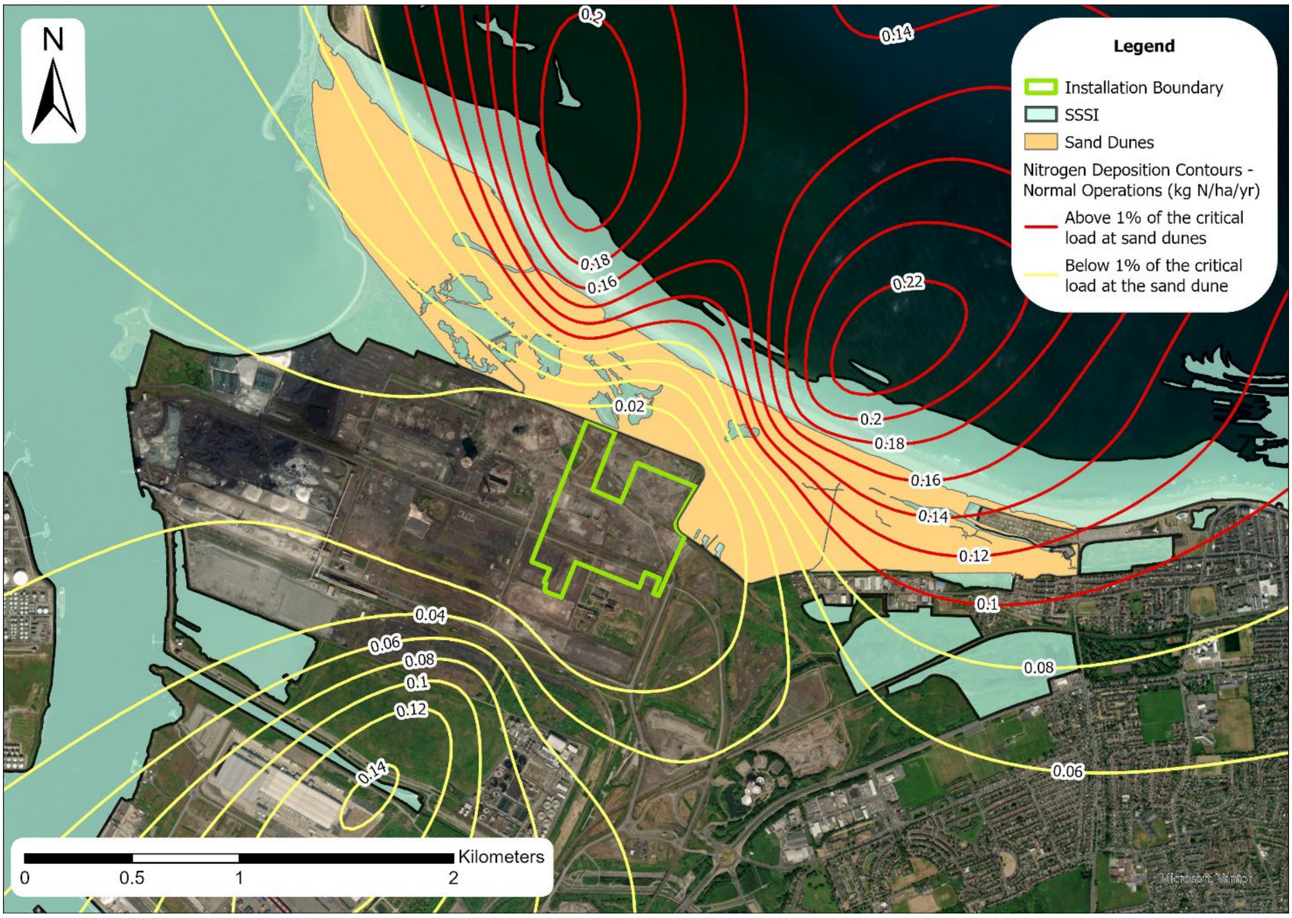
Figure 9: Historic Nitrogen Deposition for the Location of Coatham Dunes (from APIS)



The worst-case impact is predicted to occur on the northern most edge of the dune area, as can be seen in Figure 10. The figure shows the area where dunes are present (in orange), and the area where the 1% threshold is predicted to be exceeded is shown with red contours. The majority of the area where the 1% threshold is exceeded is over the Cleveland Links Golf Course, and therefore it is considered that much of vegetation in this area will be heavily managed in the upkeep of the golf course, which is likely to have a far greater impact that the operation of the Installation.

In addition to the above, Scenario 1 represents an extreme worst-case scenario of operation at the ELVs and continuous throughout the year. As detailed in Section 5.1.3, a more realistic worst case has also been assessed, with predicted annual emission concentrations and operating hours. The results of this are presented in Section 7.4.

Figure 10: Scenario 1 – Extreme Worst Case Normal Operation Isopleths of the Nitrogen Deposition Impacts at Coatham Dunes (kg N/ha/yr)



Acid Deposition

The predicted PCs are less than the CLd and no exceedances are predicted to occur at any of the ecological receptors assessed. Acid deposition impacts are therefore considered to be insignificant.

Acid deposition results are presented below in Table 7-5 for the extreme worst case normal operation.

Table 7-4: Scenario 1 – Extreme Worst Case Normal Operation Nutrient Nitrogen Deposition (kg N/ha/yr) Results

Receptor ID	Site Name	BDep (kg N/ha/yr)	Lowest CLd Class Applicable	Lower Value of CLd Range	PC (kg N/ha/yr)	PC % CLd	PEC (kg N/ha/yr)	PEC % CLd
E1.6	Teesmouth and Cleveland Coast SPA, Ramsar and SSSI	12.3	Coastal dune grasslands (grey dunes)	10	0.17	1.7%	12.4	125.1%
E2	North York Moors SAC, SPA, SSSI	14.7	Raised and blanket bogs	5	< 0.1	0.4%	14.7	293.6%
E3	Northumbria Coast SPA, Ramsar	13.4	Coastal dune grasslands (grey dunes)	5	< 0.1	0.4%	13.4	269.0%
E4	Durham Coast SAC	9.0	Coastal dune grasslands (grey dunes)	5	< 0.1	0.4%	9.0	180.8%
E5	Lovell Hill Pools SSSI	13.5	No comparable habitat with established critical load for estimate available.	-	< 0.1	-	13.6	-
E6	Saltburn Gill SSSI	21.8	Carpinus and Quercus mesic deciduous forest	15	< 0.1	0.3%	21.8	145.3%
E7	Hart Bog SSSI	14.8	Raised and blanket bogs	5	< 0.1	0.2%	14.8	295.6%
E8	Coatham Marsh LWS	12.5	Calcareous grassland	10	< 0.1	0.4%	12.5	125.0%
E9	Eston Pumping Station LWS	12.7	Calcareous grassland	10	0.1	1.0%	12.8	128.4%

PC = Process Contribution, CLd = Critical Load, BDep = Background Deposition, PEC = Predicted Environmental Concentration
* Several receptors were included across the Teesmouth and Cleveland Coast designations, and the results for the worst-case receptor are presented here.

Table 7-5: Scenario 1 – Extreme Worst Case Normal Operation Acid Deposition N (Keq/Ha/Yr) Results

Receptor ID	Site Name	Acid Deposition				PC Acid Deposition (keq/ha/yr)		
		CLd (keq/ha/yr)	BDep (keq/ha/yr)	Lowest CLd Class Applicable	Baseline % of CLd	PC	PC % of CLd	PEC% of CLd
E1	Teesmouth and Cleveland Coast SPA, Ramsar and SSSI	No CLd assigned in APIS						
E2	North York Moors SAC, SPA, SSSI	Min CL Min N: 0.321 Min CL Max N: 0.504 Min CL Max S: 0.183	N: 1.05 S: 0.15	Bog	238.1%	< 0.01	0.2%	238.3%
E3	Northumbria Coast SPA, Ramsar	Min CL Min N: 0.856 Min CL Max N: 4.856 Min CL Max S: 4.000	N: 0.96 S: 0.17	Calcareous grassland (using base cation)	23.3%	< 0.01	< 0.01%	23.3%
E4	Durham Coast SAC	Min CL Min N: 0.856 Min CL Max N: 4.856 Min CL Max S: 4.000	N: 0.96 S: 0.17	Calcareous grassland (using base cation)	23.3%	< 0.01	< 0.01%	23.3%
E5	Lovell Hill Pools SSSI	No CLd assigned in APIS						
E6	Saltburn Gill SSSI	Min CL Min N: 0.142 Min CL Max N: 2.59 Min CL Max S: 2.448	N: 1.55 S: 0.17	Unmanaged Broadleafed/Coniferous Woodland	66.4%	< 0.01	0.1%	66.5%
E7	Hart Bog SSSI	Min CL Min N: 0.321 Min CL Max N: 0.469 Min CL Max S: 0.148	N: 1.06 S: 0.17	Bogs	260.1%	< 0.01	0.1%	260.3%
E8	Coatham Marsh LWS	Min CL Min N: 0.438 Min CL Max N: 4.518 Min CL Max S: 4.080	N: 0.89 S: 0.17	Calcareous grassland (using base cation)	23.5%	< 0.01	0.1%	23.5%
E9	Eston Pumping Station LWS	Min CL Min N: 0.438 Min CL Max N: 4.518 Min CL Max S: 4.080	N: 0.91 S: 0.18	Calcareous grassland (using base cation)	24.1%	0.01	0.2%	24.3%
PC = Process Contribution, CLd = Critical Load, BDep = Background Deposition, PEC = Predicted Environmental Concentration								

7.3 Scenario 2 - Abnormal Operation – Emissions from the HRSG Stack (Emission Point A2)

7.3.1 Human Health Impacts

The impact of the Installation's PCs at human health receptors during abnormal operation, has been determined from the maximum model output that occurs anywhere beyond the Installation boundary.

The abnormal operation scenario would only occur over short periods of time, and since it is not a planned routine event, it has not been compared to the annual air quality standards.

Nitrogen Dioxide Impacts

The maximum hourly mean NO_2 PC predicted is 35.7µg/m^3, which is 17.9% of the AQS objective (200µg/m^3). This is above the first EA screening criteria. The maximum PEC for hourly mean NO_2 was 58.5µg/m^3, well below the AQS objective. The PC compared to the AQS objective minus twice the annual background concentration (at 16.5%) however is below the second screening criteria of 20%, and therefore the impact can be considered not significant.

Impacts at the discrete human receptor locations included in the model are much lower. The highest PC for hourly mean NO_2 was predicted at HH2 (Cleveland Golf Links) and is 18.3µg/m^3, which is 9.1% of the AQS objective and is therefore below the first EA screening criteria. The corresponding PEC is 41.2µg/m^3, which is 20.6% of the AQS. The effects of hourly mean NO_2 can be considered insignificant as a result.

Isopleth figures of the daily NO_2 PCs are shown in Figure 11.

Figure 11: Scenario 2 – Abnormal Operation Isopleths of the Predicted Hourly Mean NO_2 PCs (µg/m^3)

Carbon Monoxide Impacts

The maximum 8-hour rolling mean PC is 272.0µg/m^3, which is 2.7% of the AQS objective (10,000µg/m^3) and as such it is below the first EA screening criteria and can be considered to be insignificant. The maximum PEC is 700.0µg/m^3, well below the AQS objective.

The maximum hourly mean CO PC is 288.3µg/m^3, which is 1.0% of the EAL (30,000µg/m^3), and is below the first EA screening criteria and can be considered to be insignificant. The maximum PEC is 716.3µg/m^3, well below the AQS objective.

Ammonia Impacts

For hourly mean NH_3, the maximum PC is 15.6µg/m^3, which is 0.6% of the EAL (2,500µg/m^3), below the first EA screening criteria. This can be considered to be insignificant as a result. The maximum PEC is 29.0µg/m^3, well below the EAL.

Table 7-6: Scenario 2 - Abnormal Operation Human Health Impacts – Maximum Impacts Beyond the Installation Boundary

Species	AQS ($\mu g/m^3$)	PC ($\mu g/m^3$)	PC/AQS	1st Stage Screened as Insignificant?	BC ($\mu g/m^3$)	PEC ($\mu g/m^3$)	PEC/AQS	PC/(AQS – 2 x BC)	2nd Stage Screened as Insignificant?
NO_2 hourly mean (as the 99.79th percentile) as the maximum	200	35.7	17.9%	No	22.8	58.5	29.3%	16.5%	**Yes** PC <20% of the AQS objective minus twice the long-term background concentration.
NO_2 hourly mean (as the 99.79th percentile) at HH2		18.3	9.1%	**Yes**	22.8	41.2	20.6%	10.3%	-
CO 1-hour mean (as the 100th percentile)	30,000	288.3	1.0%	**Yes**	428.0	716.3	2.4%	1%	-
CO 8-hour rolling mean	10,000	272.0	2.7%	**Yes**	428.0	700.0	7.0%	3%	-
NH_3 hourly mean (100th percentile of hourly mean)	2,500	15.6	0.6%	**Yes**	13.4	29.0	1.2%	1%	-

PC = Process Contribution, AQS = Air Quality Standard objective or EAL, BC = Background Concentration, PEC = Predicted Environmental Concentration

7.3.2 Ecological Results

The impact of the Installation's PCs at the individual ecological receptors identified has been determined from the model output and is presented in the sections below.

Again, as for the human health results, the abnormal operational scenario would only occur over a short period of time, and would be dependent on the T&S network availability. Due to the fact that this would only occur for short periods of time it has not been compared to the annual CLs or CLds.

Oxides of Nitrogen – Critical Levels

The highest PC for the daily mean NO_x was predicted at E1.16 and is 61.0µg/m^3, which represents 81.3% of the CL (75µg/m^3). This exceeds both of the EA screening criteria. The PEC is 85.8µg/m^3, which exceeds the CL.

The IAQM guidance on Nature Sites[6] details that in areas with low SO_2 and ozone (i.e. where they are below their CLs), a daily NO_x CL of 200µg/m^3 can be used. It is considered that both SO_2 and ozone concentrations are below their CLs and therefore it is considered that the higher daily NO_x CL of 200µg/m^3 is appropriate to use for assessment. When comparing the highest PC to the 200µg/m^3 CL, the PC is 30.5% of the CL. This exceeds the first EA screening criteria, although the PEC is 42.9% and therefore well below the CL. This can be considered as not significant as a result.

A figure showing the isopleths of the daily NO_x concentrations as a result of the abnormal operation is shown in Figure 12

Figure 12: Scenario 2 – Abnormal Operation Isopleths of the Predicted Daily Mean NO_x PCs (µg/m^3)

Table 7-7: Scenario 2 - Abnormal Operation NO_x Dispersion Modelling Results for Ecological Receptors

Receptor I.D.	Site	CL (µg/m^3)	PC (µg/m^3)	PC % of CL	1st Stage Screened as Insignificant?	BC (µg/m^3)	PEC (µg/m^3)	PEC % of CL	2nd Stage Screened as Insignificant?
E1.16*	Teesmouth and Cleveland Coast	75	61.0	81.3%	No	24.8	85.8	114.4%	No. Exceedance of CL.
		200		30.5%	No			42.9%	No. However no exceedance of the CL predicted.
E2	North York Moors SAC, SPA, SSSI	75	1.3	1.8%	**Yes**	9.5	10.8	14.4%	-
E3	Northumbria Coast SPA, Ramsar	75	0.9	1.2%	**Yes**	10.5	11.4	15.2%	-
E4	Durham Coast SAC	75	1.0	1.3%	**Yes**	13.1	14.1	18.8%	-
E5	Lovell Hill Pools SSSI	75	2.0	2.7%	**Yes**	14.4	16.4	21.9%	-
E6	Saltburn Gill SSSI	75	1.4	1.9%	**Yes**	11.6	13.1	17.4%	-
E7	Hart Bog SSSI	75	1.0	1.3%	**Yes**	12.2	13.1	17.5%	-
E8	Coatham Marsh LWS	75	17.8	23.7%	No	31.3	49.1	65.4%	No. However no exceedance of the CL predicted.
		200		8.9%	**Yes**			24.5%	-
E9	Eston Pumping Station LWS	75	9.6	12.9%	No	27.5	37.2	49.5%	No. However no exceedance of the CL predicted.
		200		4.8%	**Yes**			18.6%	-

PC = Process Contribution, CLd = Critical Load, BDep = Background Deposition, PEC = Predicted Environmental Concentration

* Several receptors were included across the Teesmouth and Cleveland Coast designations, and the results for the worst-case receptor are presented here.

7.4 Scenario 3 – Likely Worst Case Normal Operation – Emissions from the PCC Plant

As all the impacts for Scenario 1 are acceptable for human health impacts and for ecological impacts against the relevant CLs, Scenario 3 has only been carried out for the nitrogen deposition impacts at the Teesmouth and Cleveland Coast SSSI, which is the only receptor with impacts predicted to be over the 1% threshold for insignificance.

When more realistic emission concentrations and running hours are taken into consideration, the effect on nitrogen deposition at the Teesmouth and Cleveland Coast SSSI is 0.9% of the relevant CLd, and therefore it is considered that the impacts are not significant. Nutrient nitrogen deposition results are presented in Table 7-4.

A figure showing the isopleths of the likely worst case nitrogen deposition concentrations as a result of the likely worst case normal operation is shown in Figure 13, which demonstrates that there is no exceedance of the CLd applied over the area of sand dunes.

Figure 13: Scenario 3 – Likely Worst Case Operation Isopleths of the Nitrogen Deposition Impacts at Coatham Dunes

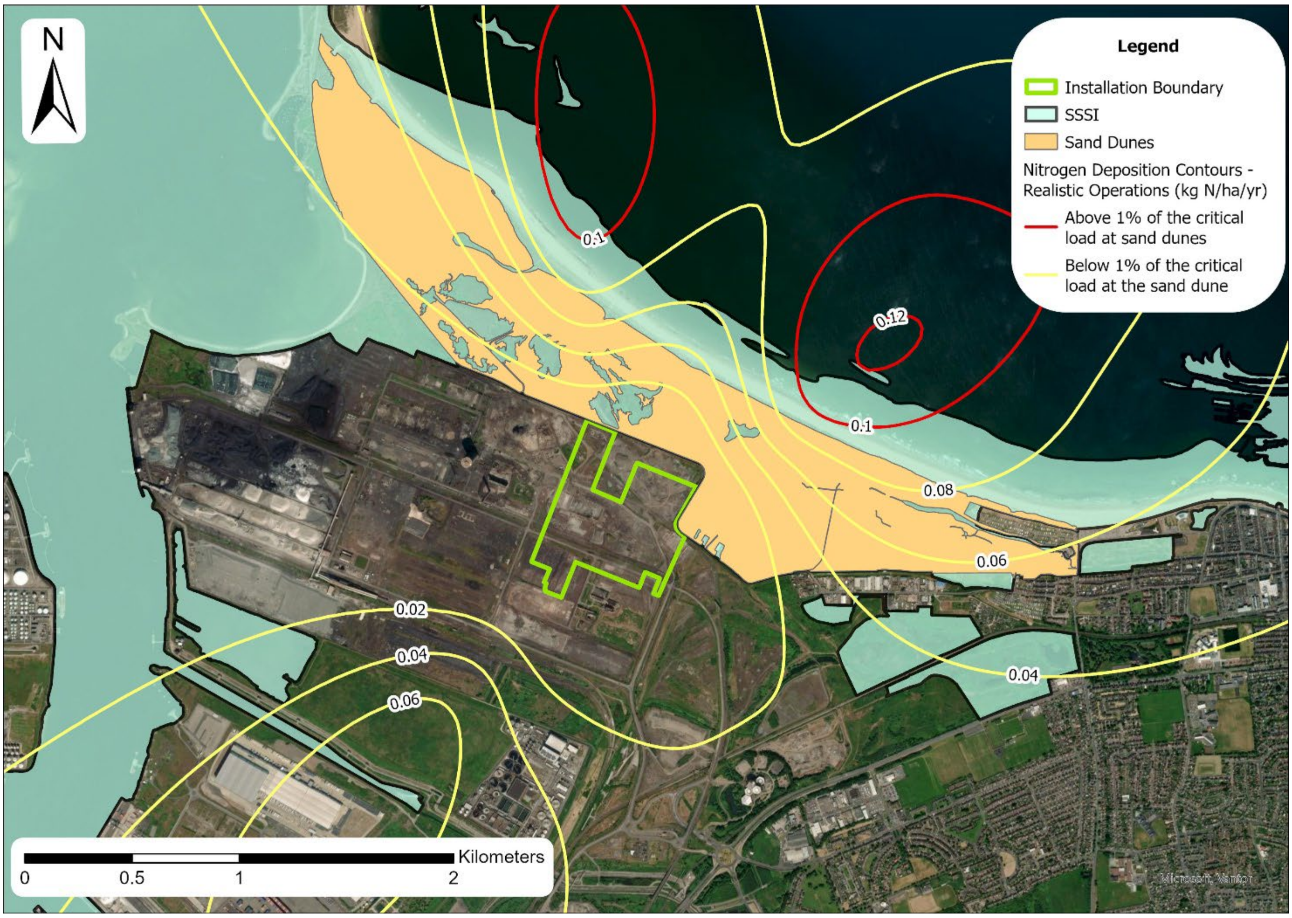


Table 7-8: Scenario 3 – Likely Worst Case Normal Operation Nutrient Nitrogen deposition (kg N/ha/yr) results

Receptor ID	Site Name	BDep (kg N/ha/yr)	Lowest CLd Class Applicable	Lower Value of CLd Range	PC (kg N/ha/yr)	PC % CLd	PEC (kg N/ha/yr)	PEC % CLd
E1.6	Teesmouth and Cleveland Coast SPA, Ramsar SSSI,	12.3	Coastal dune grasslands (grey dunes)	10	0.1	0.9%	12.4	124.3%

8. Conclusions

An Air Quality Impact Assessment has been carried out for the Installation to demonstrate that the emissions from the Installation's operation would not lead to the exceedance of any AQS objectives, EALs, CLs and CLds, as appropriate.

The assessment has included a review of the relevant legislation and guidance in the context of the Installation, and the baseline air quality conditions have been determined for the surrounding area. The local monitoring data and Defra background data are all well below the relevant AQS objectives and there are no AQMAs in the area.

Detailed dispersion modelling has been carried out to determine predicted pollutant concentrations resulting from the operation of the Installation under both normal and abnormal operating conditions against both human and ecological sensitive receptors.

The assessment shows that there are no significant effects for human receptors under extreme worst case operating conditions (Scenario 1), for any of the pollutants assessed. Similarly for ecological receptors, there are no significant effects for any of the pollutants assessed, against the CLs or Acid CLds.

Impacts of nutrient nitrogen deposition could not be screened as insignificant for the extreme worst case operating scenario at the Teesmouth and Cleveland Coast SSSI receptor, where impacts of up to 1.7% of the CLd were predicted to occur over the dune area. A review of the nitrogen deposition background data however shows that the predicted PCs from the Installation are unlikely to be significant in terms of the interannual variations that occur in background nitrogen deposition concentrations. Additionally, a more likely worst case normal operation (Scenario 3), indicates that the actual predicted impacts would be much lower, and represent only 0.9% of the CLd. It is therefore considered that the actual impacts will be insignificant.

Discussions with the EA and Natural England have been ongoing on this issue since the original Environmental Permit was issued, and the nitrogen deposition impacts that are presented in this assessment have already been shared and discussed with both parties. During these discussions, NZT have agreed with Natural England that compensation will be applied in line with the precautionary principle to reduce the potential for long-term nitrogen deposition impacts. It is envisaged that the specifics of the mitigation will be secured via a pre-operational and improvement condition within the varied Environmental Permit. Suggested wording for these conditions has been discussed with Natural England, as follows:

Pre-Operational Condition:

Prior to the commencement of the operational phase of the installation the operator will submit a plan for nutrient nitrogen deposition compensation measures to Natural England for approval to support the dune habitats (the "Nutrient Nitrogen Deposition Compensation Measures). Implementation of the Nutrient Nitrogen Deposition Compensation Measures will begin before the operational phase of the development commences and will continue to be implemented during the first three years of normal operation.

Improvement Condition:

An updated air quality assessment will be submitted to confirm if nutrient nitrogen deposition has exceeded 1% of the lower end of the critical load during the first three years from the start of operations. If deposition is less than 1%, the "Nutrient Nitrogen Deposition Compensation Measures" will be discontinued and this condition will no longer apply. If deposition is greater than 1% the measures agreed with Natural England will be reviewed and extended for a further period of three years and, if necessary, enhanced to ensure they remain adequate. The process outlined in this condition will be repeated until such time as deposition is less than 1%.

For the abnormal operations (Scenario 2), effects were considered for the short term averaging periods only, as abnormal operations are not planned to occur over long periods of time. No significant effects were identified for this scenario, for human receptors for any pollutants. In terms of ecological receptors, the NO_x

daily CL 75µg/m^3 was exceeded at one location, however the IAQM guidance for Nature Conservation outlines that a less stringent CL of 200µg/m^3 can be used in areas where the SO_2 and ozone are likely to be low. When comparing the results with the 200µg/m^3 CL, there are no exceedances or significant effects.

Annex A – CANSOLV DC-103 Supporting Information

This Annex sets out:

- The DC-103 solvent composition, chemistry and list of components generated/ emitted to atmosphere.
- Information on available environmental properties of the solvent amines and resulting nitrosamines.
- The proposed methodology to derive indicative EALs for the amines emitted from the PCC plant. Amines, nitrosamines/ nitramines (collectively referred to as N-amines) and amides are considered separately.

Solvent Composition and Chemistry

Virgin (starting) Solvent Amine Components

The CANSOLV DC-103 solvent is used as a 50%wt amine aqueous solution, comprising the amine components shown in Table A1.

Table A1: DC-103 Solvent Amine Components

Component	Chemical name	CAS number
Amine 1	1-Piperazineethanol (also referred to as Hydroxyethylpiperazine or HEP)	103-76-4
Amine 2	Piperazine	110-85-0
Amine 3	1,4-Piperazinediethanol (also referred to as 1,4 Di-hydroxyethylpiperazine or DiHEP)	122-96-3

Amine 1 and Amine 2 are secondary amines, whereas Amine 3 is a tertiary amine.

Chemistry and Degradation Products

The solvent chemistry leading to the formation of degradation compounds potentially emitted to the atmosphere involves mainly the following processes:

- Oxidative degradation:
  - Oxidation of amine or hydroxyl functionalities, leading primarily to low molecular weight organic acids and ammonia.
  - Formation of heavier molecular weight species by reaction with oxygen, free radicals or organic acids, leading to non-alkaline compounds such as formamides or ketone-type species such as amides.
- Formation of nitrosamines by reaction with NO_2^- (nitrite).

Note tertiary amines will not form nitrosamines, and therefore there is no nitrosamine associated with Amine 3.

The list of potential degradation products is provided in Table A2.

Table A2: DC-103 Solvent Degradation Products

Status	Type	Components	Chemical name (2)	CAS number (2)
Confirmed degradation products	-	N-amine 1	4-Nitroso-1-piperazineethanol (3)	48121-20-6
		N-amine 2	1-nitrosopiperazine	5632-47-3
		Amide 1	4-(2-Hydroxyethyl) piperazin-2-one	23936-04-1
		Formamide 1	1-formyl-4-(2-hydroxyethyl) piperazine	25209-64-7
		Amide 2	Piperazin-2-one	5625-67-2
		Formamide 2	1-formylpiperazine	7755-92-2
		Ammonia	-	-
	Organic acids	Formate	-	-
		Glycolate	-	-
		Oxalate	-	-
		Acetate	-	-
		Sulfamate	-	-
Possible degradation products (1)	-	Formaldehyde	-	-
		Acetonitrile	-	-
		Acetaldehyde	-	-
		Ethanol	-	-
		Acetone	-	-
		MEA	Monoethanolamine	141-43-5

Note 1: compounds not linked to an established degradation pathway but detected in some instances in the absorber treated gas in amounts that indicate at least a partial origin in solvent chemistry.

Note 2: For DC-103 specific components.

Note 3: also referred to as 1-Nitroso-(4-hydroxyethyl)-piperazine (Nitrso-HEP) depending on nomenclature used (Plewa et al. University of Illinois 2013)

Note 4: Total Amides in the assessment includes Amide 1, Amide 2, Formamide 1 and Formamide 2

Emissions to Atmosphere

The solvent components and degradation compounds detailed in Table A1 and A2 above will have a zero vapour pressure over the solvent if they are ionised. This will be the case for the organic acids.

The other components have the potential to be present in the emissions from the absorber, and water wash systems can be used to control the amounts emitted to the atmosphere to low levels.

In the case of the CANSOLV DC-103 system, the oxidative degradation pathways favour the formation of heavier compounds that will have a low vapor pressure which have been shown to be effectively controlled with a single stage water-wash (as demonstrated in the operating units of Boundary Dam and Brothers CISA, and in further pilot campaigns). The low amounts of lighter products, in particular ammonia, are also well controlled with this water wash system and usually do not mandate the addition of an acid wash stage, as justified in Main Supporting Document, Section 4.2.4.3.

Monitoring of the emissions of the Boundary Dam unit has included the amine and nitrosamine emissions, relevant to the concern of nitrosamine levels in the environment.

An advanced PTR-TOF-MS instrument, with full spectrum analysis capabilities, has been used on several pilot and demonstration scale campaigns, to detect the confirmed and suspected degradation products mentioned in Table A2 in the treated gas (instrument installation, calibration, maintenance and data analysis performed by specialists at the University of Oslo, also owner of the PTR-TOF-MS instrument).

Concurrent extractive sampling with impinger trains followed by LCMS analysis has been used to confirm emission levels for targeted components.

The components known to be potentially emitted to atmosphere, includes the solvent components (Table A1) as well as the degradation products (Table A2), with the exception of organic acids that are not volatile in their ionised form).

The possible degradation products identified (acetonitrile, ethanol and acetone) that have not been included in the impact assessment, have been picked up in some monitoring results, but are not considered to be linked to an established degradation pathway of the CANSOLV DC-103 solvent.

The expected maximum concentrations of these substances as a 24-hour average based on monitoring data are very low levels:

- Acetonitrile - 0.100ppm (0.17mg/m^3)
- Ethanol - 0.001ppm (0.002mg/m^3)
- Acetone - 0.02ppm (0.05mg/m^3)

The EALs for acetonitrile, ethanol and acetone are detailed in Table A3, noting that there is no current EAL for ethanol in the EA's Risk Assessment Guidance and therefore the value that was provided in the previous H1 Guidance (now withdrawn) has been referenced in the absence of a current EAL.

Table A3: Additional Environmental Assessment Levels

Pollutant	Concentration µg/m^3	Measured as	Source
Acetonitrile	12,100	Hourly mean	EA Risk Assessment guidance
	680	Annual mean	
Acetone	362,000	Hourly mean	
	18,100	Annual mean	
Ethanol	576,000	Hourly mean	Old H1 Guidance
	19,200	Annual mean	

An alternative EAL for ethanol, using the BDML$_{10}$ method used to derive NDMA EAL has also been considered. The BDML$_{10}$ of ethanol is 1,400 mg/kg. Converting this to mg/m^3, assuming 70kg and 20m^3/day breathing rate is 4,900mg/m^3.

The BMDL$_{10}$ of 4,900mg/m^3, modelled from the Klein et al. (1991)[34] data, is adjusted for continuous exposure by multiplying by (4/7) days and (4/24) hours to give a final Point of Departure (POD) of 466.7mg/m^3.

A long-term EAL of 0.047mg/m^3 (or 47µg/m^3) is then obtained by dividing the POD by 10,000, which is considered to be a suitable margin of safety for minimal risk for a genotoxic carcinogen (COC 2018)[35]. This is significantly lower than the old H1 Guidance annual mean EAL for ethanol.

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[34] KLEIN R.G., JANOWSKY I., POOL-ZOBEL B.L., SCHEMZER P., HERMANN R., AMELUNG F., SPIEGELHALDER B., ZELLER W.J., 1991. Effects of long-term inhalation of N-nitrosodimethylamine in rats. IARC SCIENTIFIC PUBLICATIONS, 105, 322 – 328.

[35] https://www.gov.uk/government/consultations/environmental-assessment-levels-eals-used-in-air-emissions-risk-assessments/public-feedback/appendix-c-summary-of-toxicological-evidence-for-mea-and-ndma

It can be seen that the acetonitrile and acetone EALs are comparatively high values compared to some of the EALs that were used in the assessment (acetaldehyde for example, which has EALs of 9,200µg/m^3 and 370µg/m^3 for hourly and annual impacts respectively).

The impact assessment assessed the impacts of acetaldehyde at an emission concentration of 0.2mg/m^3, and the predicted impacts were less than 0.1% of both the hourly and annual EALs. It therefore follows that modelling of acetonitrile, ethanol and acetone at the maximum expected concentrations (all less than 0.2mg/m^3) would also lead to impacts that are insignificant, especially considering the higher EALs that are associated with these species. Impacts of ethanol at a release concentration of 0.002mg/m^3 would also be considered insignificant against the lower proposed EAL of 47µg/m^3.

These species were therefore not included in the main impact assessment.

CANSOLV DC-103 Amines and Nitrosamines – Environmental Information

For risk assessments, predicted no-effect concentration (PNEC) values are developed as a threshold believed to cause *de minimus* impact to the environment. They are then compared against predicted environmental concentrations (PEC) to determine the risk ratio (PEC:PNEC) if the ratio is greater than 1 there is an indication of a potential risk.

The PNEC values for CANSOLV DC-103 were derived from any available experimental data (internal and EU REACH data) as well as modelled data from quantitative structure activity relationships (QSARs). The models used were the US EPA ECOSAR v 2 and Vega to predict acute and chronic freshwater toxicity to three trophic levels (fish, freshwater invertebrate daphnia, and algae). The PNEC values were derived by using the value for the most sensitive species, in all cases the chronic value for the daphnia. An assessment factor of 10 was applied to the values. The marine value was derived by adding another safety factor of 10 which is used for European chemicals regulations. The sediment and soil values were derived from the freshwater values using standard equilibrium partitioning modelling (EPM) methods also used in European chemicals regulations.

Table A4: Environmental PNEC Values for CANSOLV DC-103 in Various Environmental Compartments

Non-confidential Chemical Name	Freshwater (mg/l)	Intermittent (mg/l)	Seawater (mg/l)	Sediment – Freshwater (mg/kg dw)	Sediment – Marine (mg/kg dw)	Soil (mg/kg dw)
Amine 1	2.37	4.31	0.24	1.87	0.19	0.29
Amine 2	0.59	0.93	0.06	0.47	0.05	0.08
Amine 3	5.00	9.48	0.50	3.92	0.39	0.60
Nitrosoamine 1	0.99	1.64	0.01	0.80	0.08	0.13
Nitrosoamine 2	0.26	0.41	0.03	0.26	0.03	0.07
Formamide of Amine 1	20.40	26.20	2.48	16.00	1.60	2.42
Formamide of Amine 2	5.20	6.34	0.52	4.13	0.41	0.66
Amide of Amine 1	15.30	19.40	1.53	12.00	1.20	1.84
Amide of Amine 2	3.77	4.51	0.38	3.05	0.31	0.52

To predict the fate of chemicals in the environment chemical half-life information in different environmental compartments is used. These values predict how long it will take for a chemical to reach 50% of its original concentration. Half-life values were derived using chemical estimation model (QSAR; USEPA EpiSuite; https://www.epa.gov/tsca-screening-tools/epi-suitetm-estimation-program-interface) and presented in Table A5.

Table A5: Estimated Chemical Half-life in Environmental Compartments

Non-confidential Chemical Name	Air (hours)	Water (days)	Soil (days)	Sediment (days)
Amine 1	1.4	15.0	30	135
Amine 2	1.5	15.0	30	135
Amine 3	1.3	37.5	75	337.5
Nitroso- Amine 1	2.1	37.5	75	337.5
Nitroso- Amine 2	2.4	37.5	75	337.5
Formamide of Amine 1	2.4	37.5	75	337.5
Formamide of Amine 2	2.8	15.0	30	135
Amide of Amine 1	1.9	37.5	75	337.5
Amide of Amine 2	2.1	15.0	30	135

Derivation of Environmental Assessment Levels for CANSOLV DC-103 Amines

Among the components that can be released from the absorber stack, amines and nitrosamines are of special interest, due to the potential carcinogenicity of nitrosamines. These can be emitted directly or formed in the atmosphere from the emitted amines.

This section describes the proposed methodology to derive indicative EALs for the amines and nitrosamines emitted from a PCC plant using the CANSOLV DC-103 solvent. Amines, nitrosamines/ nitramines (N-amines) and Amides are considered separately.

Reference: Monoethanolamine (MEA)

The EA have derived the following EALs for monoethanolamine (MEA):

- 1-hour: 400 µg/m^3
- 24-hour: 100 µg/m^3

This is based upon a No Observed Adverse Effect Concentration (NOAEC) value of 10 mg/m^3 (Environment Agency, 2020). To derive the EAL, a safety factor of 25 has been applied to derive the 1-hour EAL, and a safety factor of 100 has been applied to derive the 24-hour EAL.

MEA is a strong respiratory, ocular and skin irritant, there are equivocal indications that MEA could have skin and respiratory sensitising properties, but MEA is currently not classified for these endpoints (European Chemicals Agency (ECHA) Registration Dossier MEA).

For derivation of the short-term EAL, the critical effect considered is localised respiratory irritation. The pivotal study for derivation of a short-term EAL is the sub-acute duration rodent study submitted as evidence in support of an application under REACH (HSE 2016) with a NOAEC of 10 mg/m^3. No correction for continuous exposure was applied because irritation is considered a concentration-dependent effect.

For derivation of the long-term EALs the critical health effects from long-term inhalation exposure to MEA are considered to be respiratory irritation and neurobehavioral toxicity. The pivotal study for derivation of a long-term EAL is the same sub-acute rodent study used for the short-term EAL (HSE 2016). No Uncertainty Factor (UF) for sub-acute to chronic duration is required because irritation is considered a concentration-based effect. An additional UF was included to take account of uncertainty over long-term effects.

The monoethanolamine REACH dossier also contains Derived No Effect Levels (DNEL) for the general population for local and systemic effects, and these are 280 and 180 µg/m^3, respectively. These are in the same order of magnitude as the EA's derived EALs.

CANSOLV DC-103 Amines - General

The amines in the CANSOLV DC-103 solvent are structural analogues, consisting of a heterocyclic di-amine (Amine 2), with an alkanol group substitution on one (Amine 1) or both (Amine 3) amine functions.

Amine 1 has low vapor pressure and is considered to be a strong ocular and skin irritant.

Amine 2 has low vapor pressure and is considered to be a strong ocular and skin irritant. It is classified for respiratory sensitisation and reproductive toxicity.

Amine 3 is a minor component of the DC-103 solvent with low volatility and is generally not detected at stack. Amine 3 is an amine with low vapor pressure, and is considered to be a strong ocular and skin irritant.

Evaluation

Due to their common active group (the amine group), the overall toxicity of all aliphatic amines is similar, with some potency differences depending on the aliphatic parts. Based on a review of the toxicological properties of alkanol-amines, cyclic amines and aliphatic amines, supplemented with modelling of the structure-activity relationship, the following can be summarized regarding the toxicity of these compounds in the human body:

- Amines are metabolised by oxidation into the corresponding aldehydes, a process accompanied by the release of ammonia. The aldehydes are then metabolised into carboxylic acids and, ultimately, into CO_2 (that is subsequently exhaled).
- Aliphatic amines and alkanolamines are of relatively low acute toxicity, with LD_{50} levels (Lethal Dose for 50% of the test animals) in the order of grams per kilogram bodyweight. The cyclic amines have a lower threshold of toxicity (LD_{50} levels in the order of 100s of milligrams per kilogram bodyweight), but are still of relatively low acute toxicity.
- Except for tertiary amines, the range of aliphatic amines, alkanolamines, as well as cyclic amines are to some degree corrosive or highly irritating to the skin, eyes and/or respiratory tract.
- With the exception of piperazine, amines are not respiratory sensitisers.
- Overall, amines are not mutagenic or carcinogenic and, with exception of piperazine, amines are not expected to affect human development or reproduction.

Overall, amines will pose minimal risk to members of the general public. However, due to their corrosive properties risk management measures need to be in place for workers.

Based on available data, as well as QSAR modelling data, all CANSOLV DC-103 amines are expected to be of low systemic toxicity with no alerts for carcinogenicity, mutagenicity or reproductive toxicity. Like MEA, the main effect would be local irritation.

It should be noted also that all chemicals imported to the UK are subject to the UK REACH regulation. OECD 422 tests were performed to support registration of Amine 1, and resulted in no adverse findings, pointing to a NOAEL above 1,000 mg/kg bw.

CANSOLV DC-103 Amine 1 – Toxicological Information

The main amine present in the PCC plant emission is Amine 1

Due to the low vapor pressure of Amine 1 compared to MEA, exposure levels are estimated to be well below the EAL, and this has been demonstrated by the dispersion modelling carried out for the project.

To date, a NOAEL has not been derived for Amine 1, however based on structural similarity with Amine 2 and Amine 3, Amine 1 is expected to have a systemic NOAEL of the same order of magnitude. Given that the NOAELs for Amine 2 and 3 are higher than that derived for MEA, it is reasonable to assume that for systemic effects, the EAL derived for MEA would represent a worst-case, and that the EAL protective for systemic effects from exposure to MEA, should also be protective for systemic effects of all three of the CANSOLV DC-103 amines.

Data on Amine 1 has been obtained from the REACH registration dossier:

Classification

H315: Causes skin irritation.

H318: Causes serious eye damage.

Acute Toxicity

Based on an acute oral toxicity in rats equivalent to OECD TG 401, the LD_{50} was ca. 4,000 mg/kg bw for male and female animals.

In an acute inhalation hazard test equivalent to OECD TG 403 male and female rats (strain not specified) were exposed to saturated vapours of the test substance in air (concentration not determined) for a period of 8 hours. No mortality occurred and no clinical signs were observed. To verify the results, the test was repeated once with new groups of animals. Necropsy of all animals was performed. No mortality occurred and no clinical signs were observed. Only one animal showed chronic bronchitis and bronchiectasis in the right lobe of the lung. No LC50 was determined. In an acute dermal toxicity study conducted in rats the LD_{50} value was found to be greater than 5,000 mg/kg bw.

Irritation

The substance was concluded to be irritating to skin. In an eye irritation study in rabbits, the test substance was shown to be severely irritating and led to irreversible effects.

Sensitisation

Based on the results of the DPRA and LuSENS assays, the substance is not peptide reactive and does not activate keratinocytes *in vitro*. Applying the evaluation criteria, the substance is predicted not to be a skin sensitiser based on the *in vitro* testing strategy. These results are supported by the results of a Guinea Pig Maximisation Test according to Magnusson that demonstrate that the substance does not meet criteria for classification and is therefore not classified as a skin sensitiser *in vivo*. This also addresses the concern of Amine 1 exposure leading to piperazine exposure via "*in vivo* transformation".

Genetic Toxicity

The substance was tested negative in the Ames test, the HPRT test, and the Chromosome aberration assay.

Repeated dose toxicity

No repeated dose toxicity studies are available.

Results from QSAR modelling (OECD Toolbox)

The OECD Toolbox was used to perform Quantitative Structure-Activity Relationship (QSAR) modelling of CANSOLV DC-103 Amine 1. In addition, the data available for the specific end points for MEA has been added for comparison. The results are show in Table A6.

Table A6: Amine 1 QSAR Modelling

Endpoint	Amine 1 QSAR Prediction	Amine 1 Experimental Data	MEA data
Acute toxicity (oral)	LD_{50} = 1,500 – 3,000 mg/kg	LD_{50} = ~4,000 mg/kg	LD_{50} = ~1,089 mg/kg
Acute toxicity (inhalation)	Not Available	No mortality at saturated vapours	LC_{50} = for 6 hours 1,300 mg/m^3, for 4 hours of 1,487 mg/m^3.
Acute toxicity (dermal)	Not Available	LD 50 > 5,000 mg/kg	LD_{50} = 2,504 mg/kg
Skin irritation/ corrosion	Positive	Skin irritant Cat 2	Skin corrosion Cat 1B
Eye irritation/ corrosion	Undefined	Eye irritant Cat 1	Eye damage Cat 1
Respiratory irritation	Positive *	No data	Positive

Endpoint	Amine 1 QSAR Prediction	Amine 1 Experimental Data	MEA data
Skin sensitisation	No alert found	Negative	Negative
Respiratory sensitisation	No alert found	No data	Negative
Repeated dose toxicity (oral)	Not categorised	No data	Negative
Repeated dose toxicity (inhalation)	Not categorised	No data	Negative
Repeated dose toxicity (dermal)	Not categorised	No data	No data
Genetic toxicity	Negative	Negative	Negative
Carcinogenicity	Negative	No data, expect to be negative	No data, expect to be negative
Toxicity to reproduction	Negative	No data	Negative
Developmental toxicity	Negative	No data	Negative

* the prediction came from the latest developed QSAR tools: link https://respiratox.item.fraunhofer.de/index.php

From the data presented above it is clear to see that there is no end point where amine 1 is a greater hazard in comparison to MEA and that QSAR modelling predicts that Amine 1 will have respiratory irritation as a common end point with MEA.

CANSOLV DC-103 Amine 2 – Toxicological Information

Amine 2 is piperazine, and therefore has an EAL that has been derived by the EA, which has been used in the assessment presented.

CANSOLV DC-103 Amine 3 – Toxicological Information

As stated previously, Amine 3 is a minor component of the CANSOLV DC-103 solvent with low volatility and is generally not detected at stack.

Data on Amine 3 has been obtained from the REACH registration dossier: Piperazine-1,4-diethanol 100.004.170 | bb3f9837-a88c-40f2-9e5b-6ff07eaf0db0 - ECHA CHEM

Acute Toxicity

Based on an acute oral toxicity study in rats following OECD TG 401, the LD_{50} by oral route was >15,000 mg/kg for males and females respectively. LD_{50} by dermal route was > 10 ml/kg in rabbits.

Irritation

In an irritation study in rabbits according OECD Guideline 404 (Acute Dermal Irritation/ Corrosion), the substance was found not irritating to skin. In another study in rabbits the study was found corrosive to the eyes.

Sensitisation

No data available

Genetic Toxicity

The substance was tested negative in the Ames test.

Repeated dose toxicity

Based on the results of a combined 28-day repeated dose toxicity study with the reproduction/ developmental toxicity screening test in rats, the Parental, Reproduction and Developmental NOAEL for the substance were established to be at least 1,000 mg/kg/day (Charles River (2019)[36].

CANSOLV DC-103 Summary Toxicological Information

Analysis of the No Observed Adverse Effect Levels (NOAEL) of the CANSOLV DC-103 Amines and MEA, support that there is no concern for systemic toxicity from the DC-103 amines. The NOAELs for Amine 2 and Amine 3 are ~ 600 and 1,000 mg/kg bw/d for systemic effects, which is above the systemic NOAEL of MEA of 300 mg/kg bw/d.

Amine 2 is classified as a respiratory sensitiser, however, based on its REACH registration dossier, the substance could be considered an asthmagen (causing asthma by non-immunological mechanism) rather than a respiratory allergen (causing asthma by an immunological mechanism). Amines 1 and 3 have the same local irritating effects as MEA. It is therefore reasonable to assume that the EAL protective for local irritating effects from exposure to MEA, should also be protective for local irritating effects of CASOLV DC-103 amines.

Table A7: Summarised Toxicity Data for MEA and CANSOLV DC-103 Amines

Amine	Irritation	Sensitization	Geno-toxicity	NOAEL (mg/kg bw/day)	NOAEC (mg/m^3)	STEL (mg/m^3)	OEL or DNEL (mg/m^3)
Mono-ethanol Amine (MEA)	H314	Not classified	Negative	300	10	7.6	2.5 0.28* 0.18**
Amine 1	H315 H318 No clinical signs after exposure to saturated vapours	Not classified	Negative	N/A	***	N/A	N/A
Amine 2	H314	H334 H317	Negative	~ 600	N/A	0.3	0.1
Amine 3	H318	N/A	Negative	1000	***	N/A	N/A

* General population DNEL local effects
** General population DNEL systemic effects
*** Due to the low vapor pressure it is unlikely that the substance will be available as a vapor.
STEL – Short-term Exposure Limit, OEL = Occupational Exposure Limit

Suitability of MEA as a Read-across for Amine 1 and Amine 3

There is only one study available for Amine 1 using the inhalation route, which was a non-GLP acute inhalation study with saturated vapour (concentration not determined) following a protocol similar to OECD 403 (BASF, 1967, (summary available in the ECHA registration dossier)[37]. Six rats per sex were exposed for 8 hours to vapours generated by bubbling 200 l/h of air through a substance column. Clinical signs were documented over a period of 8 days. No mortality was observed, one animal showed chronic bronchitis and bronchiectasis in the right lobe of the lung. To verify the results, the test was repeated once with new groups of animals. In

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[36] Charles River (2019). Combined 28-Day Repeated Dose Toxicity Study with the Reproduction/ Developmental Toxicity Screening Test of DiHEP Aqueous Solution by Oral Gavage in Rats. FINAL REPORT Test Facility Study No. 20172120 – **Report provided**

[37] https://chem.echa.europa.eu/100.002.857/dossier-view/de660874-6fbf-4943-9ddc-104ce090e253/IUC5-18747f92-b8a0-4d26-96da-f97f818f65e7_869eca37-0690-4471-98a6-70157cf1db67?searchText=103-76-4

summary, no clinical signs were observed that would indicate any irritation or other systemic effects occurred post exposure to Amine 1 vapours.

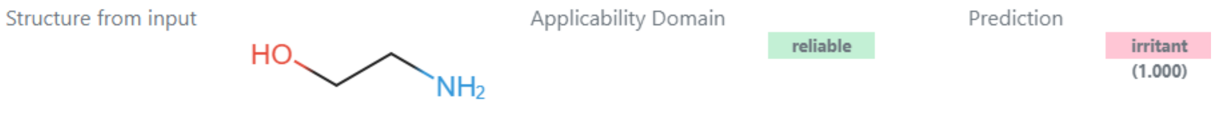
A set of Adverse Outcome Pathway (AOP) New Approach Methodologies (NAMs) were conducted to assess whether Amine 1 is a sensitiser. These assays show definitive evidence that Amine 1 is not a sensitiser. Results of the Direct Peptide Reactivity Assay (DPRA) (OECD442C and D) and LuSENS[38] assays show that Amine 1 is not peptide reactive and does not activate keratinocytes *in vitro* and thus is not predicted to be a skin sensitiser. Finally, data is available for skin and eye irritation for Amine 1, which concludes that Amine 1 is non-irritating to skin, but it is category 1 irritating to eyes.

Modelling of Respiratory Effects

The RespiraTox project developed a QSAR model for identifying potential human respiratory irritants using a novel in silico strategy. Using the RespiraTox modelling software for respiratory irritation and tissue damage the model returned the following results for MEA, Amine 1, and Amine 3: for Amine 1 the database was able to run models against available data in the ECHA database for acute toxicity and used the existing data for Amine 1 to model.

Both Amine 1 and Amine 3 returned positive irritation predictions at high confidence levels, p=0.96 and p=0.87, respectively. Due to data availability for the specific end point, MEA has a confidence level of p=1. It is to be noted that Amine 1 in the RespiraTox database is classified as a non-irritant (based on available data in the ECHA chemical database), however, RespiraTox is programmed to return a worst-case scenario where positive neighbouring substances are available. Such as in the case of Amine 1, where the compound itself is classified as non-irritating but with the additional evidence of similar compounds it is designated as irritant by the program. This does not change our position, as we are using the irritation of MEA as the POD.

RepiraTox prediction of respiratory irritation for MEA:

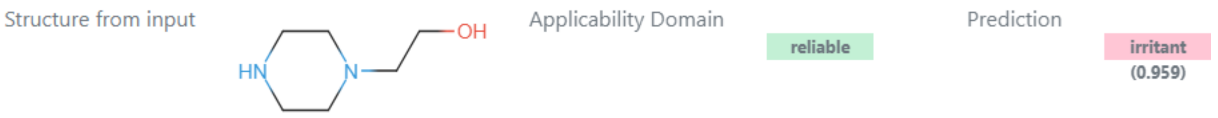


Structure from input

Applicability Domain: reliable

Prediction: irritant (1.000)

RepiraTox prediction of respiratory irritation for Amine 1:

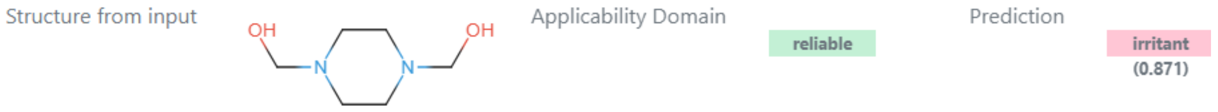


Structure from input

Applicability Domain: reliable

Prediction: irritant (0.959)

RepiraTox prediction of respiratory irritation for Amine 3:

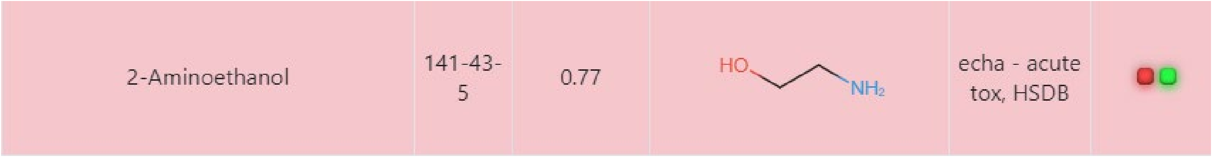


Structure from input

Applicability Domain: reliable

Prediction: irritant (0.871)

Similarity of MEA and Amine 1:



2-Aminoethanol	141-43-5	0.77		echa - acute tox, HSDB	🟥🟩

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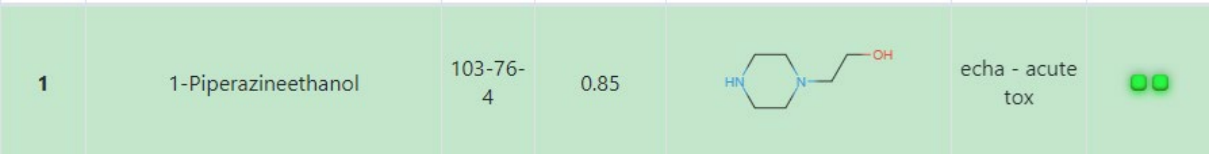
[38] The LuSens assay uses a luciferase reporter cell line (LuSens cells) based on the activation of the antioxidant response element that can be used to assess the intracellular cysteine reactivity of a substance.

Similarity of Amine 1 and Amine 3:



1	1-Piperazineethanol	103-76-4	0.85		echa - acute tox	● ●

The model returned a 77% similarity between Amine 1 and MEA, while Amine 1 and Amine 3 share 85% similarity. This similarity coupled with the shared end point of respiratory irritation as a POD for EAL calculation supports the proposal of using MEA as the read across for both Amine 1 and Amine 3.

Summary EALs Amines

In summary, based on the absence of significant systemic toxicity and similar local effects (irritation) the proposed EALs for the CANSOLV DC-103 amines are similar to those of MEA, which is 400 µg/m^3 and 100 µg/m^3 for short-term and long-term exposure, respectively. For Amine 2, the piperazine EAL of 15 µg/m^3 has been used for long term impacts.

The CANSOLV DC-103 amine EALs are summarised in Table A8.

Table A8: Environmental Assessment Level (EAL) for MEA and CANSOLV DC-130 Amines

Amine	1-hour EAL (µg/m^3)	24-hour EAL (µg/m^3)
Monoethanolamine	400	100
Amine 1	400	100
Amine 2	-	15
Amine 3	400	100

Nitrosamines EAL Derivation

N-amine 1 and N-amine 2 may be released from the PCC plant.

The EA have derived an EAL for N-nitrosodimethylamine (NDMA) of:

- Annual mean: 0.0002 µg/m^3

This is based on a Dose Level (BMDL10) of 0.023 mg/m^3. The EA also state: "NDMA is one of the most potent nitrosamines [in terms of carcinogenic potential]" and also state that NDMA is one of the most widely studied of the nitrosamines, recognising that toxicology data for other nitrosamines is scarce, particularly for carcinogenic potential.

N-amine 1 has no carcinogenic data currently available. N-amine 2 has been studied for carcinogenic potential and it has been demonstrated to be 45 times less potent than NDMA[39].

The mutagenic potency of N-amine 1 (referred to as Cansolv N-1 in the Plewa report), N-amine 2 (referred to as Cansolv N-2 in the Plewa report) and NDMA (as a positive control) have been investigated by the solvent provider in a modified Ames test detailed in the Plewa report, using bacterial strains sensitive to nitrosamines. The mutagenic potency of N-amine 1 was found to be 2,000 times less than that of NDMA, and the mutagenic potency of N-amine 2 was found to be 50 times less than that of NDMA.

An overview of the data presented in the Plewa report is provided in Table A9.

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[39] Plewa et al. University of Illinois. (2013). Technical Service Report on the Mutagenicity Analyses of CANSOLV Nitrosamine Samples – **Report Provided**

Table A9: Mutagenic and Carcinogenic Potency of NDMA and CANSOLV DC-103 Nitrosamines

Nitrosamine	Mutagenic potency $(\mu mol)^{-1}$	Carcinogenic potency based on animal data $(mmol/m^3)^{-1}$
NDMA	1	300
N-amine 1	0.00048	N/A
N-amine 2	0.001	6.6

Summary Evaluation of the CANSOLV DC-103 N-Amines

NDMA is one of the best-studied nitrosamines, and also one of the nitrosamines with the highest carcinogenic potential. Based on the available data, the EA have derived an EAL of 0.2 ng/m^3 (annual mean). Based on available data on the mutagenic and carcinogenic potency of the CANSOLV DC-103 nitrosamines and NDMA, it is expected that NDMA is the most potent mutagen and carcinogen. Hence, the EAL for NDMA of 0.2 ng/m^3 (annual mean) would serve as a very conservative EAL for the CANSOLV DC-103 nitrosamines.

EAL Derivation Methodology for CANSOLV DC-103 Total Amides

The EAL for Acrylamide has been used for the assessment of "Total Amides", as the lowest EAL of any amide listed in the EA Risk Assessment Guidance. It should be noted that acrylamide is classified as a carcinogen, mutagen, reproductive toxicant (CMR) chemical, whereas the amides formed from the degradation of the CANSOLV amines are not defined as CMR chemicals. It is therefore considered that the use of the acrylamide EAL is very conservative, a position that was agreed with the EA and UK HSA during the VPI Immingham CHP Power Plant PCC Permit variation determination.

In terms of formamide specifically, the established carcinogenicity data in the registration dossier, which can be used as a read-across for Formamide 1 (1-formyl-4-(2hydroxyethyl) piperazine), has a NOAEL of 20 mg/kg bw/day. The calculations from the EAs "Derivation of new Environmental Assessment Levels (EALs) to air consultation" have been applied[40]:

The oral route NOAEL needs to be converted to an inhalation route, assuming 70kg and breathing at a rate of 20m^3/day:

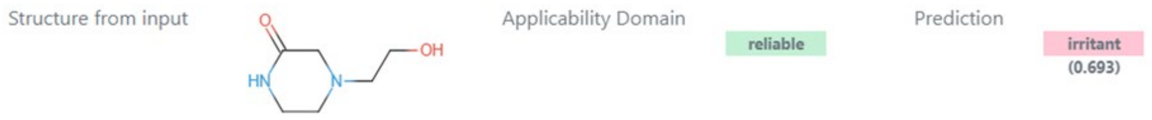
$$20 \text{ mg/kg bw/day} = 70 \text{ mg/m}^3$$

The recommended Uncertainty Factor (UFs) = 10 for inter-species, 10 for inter-individual, 10 for severity of effect are then applied:

$$\underline{\text{Recommended long term EAL for formamide} = 0.07 \text{ mg/m}^3 \text{ or } 70\mu\text{g/m}^3}$$

No short term EAL is recommended due to its chronic (rather than acute) toxicity. The proposed EAL is significantly higher than that of acrylamide, used in the assessment, and therefore it is considered that the use of the acrylamide EAL (0.05µg/m^3) is very conservative.

Amide 1 it is predicted to cause respiratory irritation by the Resipratox QSAR[41] model:



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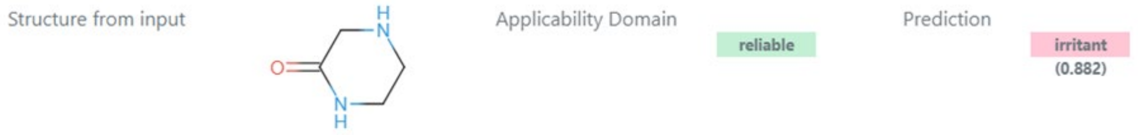
[40] https://assets.publishing.service.gov.uk/media/5f510e86d3bf7f329285a027/Derivation_of_new_EALs_to_air.pdf

[41] https://respiratox.item.fraunhofer.de/index.php

Based on the POD (respiratory irritation), and considering the lack of data available, it is considered justifiable to read-across the EALs for MEA, which is considered to be conservative.

There is also no data available for Amide 2, however it is predicted to cause respiratory irritation by the Resipratox QSAR model:



Structure from input

Applicability Domain reliable

Prediction irritant (0.882)

Based on the POD (respiratory irritation) and considering the lack of data available it is again justifiable to read-across to MEA for suitable EALs.

As above for formamide, it is considered that the use of the acrylamide EAL for Total Amides, is very conservative.

Annex A References:

ECHA Registration dossier Monoethanolamine: 2-aminoethanol 100.004.986 | bbbc7157-d338-419d-b0e9-fe9687bc18d4 - ECHA CHEM

ECHA Registration dossier Amine 1, reviewed December 2023:

2-piperazin-1-ylethanol 100.002.857 | de660874-6fbf-4943-9ddc-104ce090e253 - ECHA CHEM

Appendix AECHA Registration dossier Amine 2: Piperazine 100.003.463 | 3994d289-6fa4-4f57-8e26-f3e6a7d8a4bb - ECHA CHEM

Appendix BECHA Registration dossier Amine 3: Piperazine-1,4-diethanol 100.004.170 | bb3f9837-a88c-40f2-9e5b-6ff07eaf0db0 - ECHA CHEM

Annex B – SCAIL Assessment

SCAIL Assessment

SCAIL Methodology

The SCAIL combustion tool has been used to assess the potential for air quality impacts to occur as a result of the operation of the proposed six EDGs (Emission Point A3 to A8) to be installed as part of the Installation.

SCAIL is a screening tool that uses the atmospheric dispersion model AERMOD to predict impacts of emissions from small and medium combustion sources. The model estimates the impacts of emissions on sensitive habitat sites and can also be used to assess impacts at human receptors.

The final EDGs have yet to be selected, however data available for comparably sized EDGs has been used to carry out the assessment. Based on the fact that EDGs run for a maximum of 12 hours per year it is unlikely that any substantial impacts will occur, which is why the SCAIL screening tool has been used rather than detailed dispersion modelling.

Receptors

For ecological receptors, the SCAIL tool determines relevant ecological receptors within a given radius dependent on the plant capacity and fuel type. For the proposed EDGs, a search radius of 2km was determined by the SCAIL tool.

The Teesmouth and Cleveland Coast SPA and SSSI were the only ecological receptors identified by the tool, at approximately 120m from the EDG location. The identified ecological receptors included are detailed below in Table B-1.

Human health receptors were also added to the SCAIL tool, in line with the receptors used in the main assessment as per Table 4-1. The closest human health receptor is HH2 (Cleveland Golf Links).

Table B-1: Ecological Receptors Included in the SCAIL Tool

Receptor Name	Receptor Type	X	Y
Teesmouth and Cleveland Coast SPA	Ecological receptor - SPA	457333	525687
Teesmouth and Cleveland Coast SSSI	Ecological receptor - SSSI	457361	525426

Emission Parameters

The parameters outlined in Table B-2 were used in the SCAIL tool for the EDGs. Only emissions of NO_x have been included in the assessment, as the combustion of low sulphur gas oil is not anticipated to lead to significant emissions of SO_2 or particulates, which is why there are no emission limits applied for these pollutants from gas oil engines in the MCPD.

Table B-2: SCAIL Input Parameters for the EDGs

Parameters	A3	A4	A5	A6	A7	A8
Stack location	456670, 525355	456915, 525260	456680, 525380	456905, 525225	457255, 525490	456705, 525180
Stack height (m)	5.0	5.0	5.0	5.0	5.0	5.0
Stack diameter (m)	0.7	0.7	0.5	0.5	0.35	0.35
Flues (No#)	1	1	1	1	1	1
Exhaust temp (°C)	370	370	370	370	370	370
Exhaust velocity (m/s)	24.3	24.3	38.2	38.2	62.3	48.7
Plant capacity	5MWth	5MWth	4MWth	4MWth	3.2MWth	2.5MWth
NO_x (g/s)	4.2	4.2	3.3	3.3	2.7	2.1

Assessment Scenarios

The SCAIL assessment has been carried out for both a general testing scenario for the EDGs and for a potential emergency scenario.

As the EDGs are intended for emergency use only they will not be in continuous operation. The EDGs are only intended to undergo periodic testing for maintenance procedures. It is anticipated that each generator will operate for a maximum of 12 hours per year for testing (i.e. 72 hours in total for the six proposed EDGs). The Environmental Permit already includes a condition that only one EDG will be tested at a time, therefore in order to provide a conservative assessment, the EDG location closest to the receptors (A7) has been used for the testing scenario, with the parameters for the largest of the EDGs that is proposed (i.e. A3/ A4 the 5MWth EDGs).

Each of the EDGs is expected to run for 12 hours, and therefore this totals up to 72 hours of EDG operation over the year. Again, to ensure a conservative assessment is carried out, it has been assumed that all 72 hours of operation would occur at the EDG location closest to the receptors (A7) to further provide a conservative assessment.

There is no specific guidance for an emergency operating window for emergency generators. Best practice guidance has been drawn on from the data centre sector, whereby a 72-hour operating window is recommended to be used by the EA[42]. This provides a highly conservative assessment due to national grid reliability and in-built design resilience. For this assessment, a period of 72 hours has been used for the emergency scenario and it has been assumed that all six EDGs are operating concurrently during this time.

Meteorological Data

The SCAIL tool uses meteorological data from nearby weather stations and can be run in one of three modes.

The conservative mode uses the source to receptor bearing that will rotate the habitat site so that it is in the prevailing wind direction and hence receives the highest amount of pollutant concentrations.

The hybrid mode provides concentrations from the conservative method with an arc of +/- 40 to +/-10 at the receptor.

The realistic mode uses the actual position of the receptor and bearing to the source. It is most suitable for sources spread across a wide geographical area.

In order to provide a conservative assessment, only the conservative mode has been used to assess the impacts of the EDG, as it is considered that this would be most likely to lead to the highest predicted impacts.

SCAIL Results

Human Health Receptors

The results for NO_2 for the testing and emergency scenarios are shown below in Table B-3 for the nearest human receptor: HH2 (Cleveland Golf Links).

The annual mean PC was less than 1% of the AQS objective for the testing scenario and therefore can be considered to be insignificant according to the EA screening criteria and therefore no further assessment is required. The emergency scenario is not considered against the annual mean AQS objective as it is not a planned activity and the likelihood of it occurring at all is low.

The hourly mean NO_2 PCs for the testing and emergency scenarios are both 0.2% or less of the hourly mean NO_2 AQS objective. The impacts are therefore below the screening threshold of 10% for short term impacts and can therefore be considered insignificant.

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[42] Environment Agency, 2022. working draft BAT guidance document specifically for data centres: 'Data Centre FAQ Headline Approach v21' (November 2022)

Table B-3: SCAIL Results for Testing and Emergency Scenarios - NO_2 Impacts at Closest Human Receptor HH2

AQS (µg/m^3	NO_2 background (µg/m^3)	Testing Scenario				Emergency Scenario			
		PC (µg/m^3)	PC % of AQS	Screening	PEC (µg/m^3)	PC (µg/m^3)	PC % of AQS	Screening	PEC (µg/m^3)
40	12.37	0.03	0.1%	Insignificant	12.4	-	-	-	-
200	24.74	0.28	0.1%	Insignificant	25.0	0.38	0.2%	Insignificant	25.1

Ecological Receptors – Oxides of Nitrogen Critical Levels

For the testing scenario, the PC is less than 1% of the Critical Level and the PEC is below the AQS (30µg/m^3) for annual mean NO_x at both receptors assessed. As a result, this is considered to be insignificant. The results are shown below in Table B-4.

Table B-4: NO_x Concentrations for the Ecological Receptors for the Testing Scenario

Receptor	Critical Level (µg/m^3)	Background Concentration (µg/m^3)	PC (µg/m^3)	PC % of Critical Level	PEC (µg/m^3)
Teesmouth and Cleveland Coast SSSI	30	16.96	0.10	0.3%	17.1
Teesmouth and Cleveland Coast SPA		16.96	0.10	0.3%	17.1

Ecological Receptors - Deposition Impacts

The results for nitrogen deposition for the testing scenario at ecological receptors are shown in Table B-5.

The percentage of the PC of the relevant critical loads is less than 1% at both receptors for both nitrogen and acid deposition for both the testing scenario and therefore can be considered to be insignificant.

The emergency scenario is not compared to the annual AQS as it is not a planned maintenance activity.

Table B-5: Nitrogen and Acid Deposition for the Testing Scenario

Receptor	N Deposition (kg N/ha/yr)					Acid Deposition (keq H/ha/yr)				
	PC	Background Concentration	PEC	Critical Load	PC % of Critical Load	PC	Background Concentration	PEC	Critical Load	PC % of Critical Load
Teesmouth and Cleveland Coast SSSI	0.014	12.34	12.4	5	0.3%	0.001	1.06	1.06	Min CL Min N: 0.856 Min CL Max N: 4.856 Min CL Max S: 4.000	0%
Teesmouth and Cleveland Coast SPA	0.014	12.34	12.4	5	0.3%	0.001	1.06	1.06		0%

Summary and Conclusions

A screening assessment has been undertaken using the SCAIL tool for the proposed EDGs to be installed as part of the Installation for emergency use. The assessment has considered both testing and potential emergency scenarios.

Following the methodology set out in the EA Risk Assessment Guidance, the impact on human receptors is considered to be insignificant.

For ecological receptors, the results in terms of the critical level and critical loads can all be considered to be insignificant. The overall effect of the EDGs in relation to air quality is therefore considered to be insignificant.

Annex C - Model Sensitivity

Sensitivity to General Model Inputs

The maximum PC of NO_2 at the worst-affected human health receptors and NO_x at the worst-affected statutory designated ecological receptor associated with the variable input parameters, are presented in Table C1 as the percentage of maximum reported values in Table 7-1 and Table 7-2 above.

Table C-1: Point Source Dispersion Model Sensitivity Analysis

Model Input Variable	Human Health Receptor		Ecological Receptor	
	Short-term	Long-term	Short-term	Long-term
Reported Results (µg/m^3)	**5.3**	**0.3**	**9.3**	**0.3**
Meteorological data (5-year min-max)	98%	70%	38%	51%
Surface roughness representation (0.5m)	102%	77%	95%	116%
Surface roughness representation (0.2m)	100%	66%	101%	90%
No buildings	98%	60%	44%	70%

The main uncertainty associated with the model is considered to be the meteorological data, with the lowest NO_2 process contribution resulting in a PC that is 70% of the annual mean NO_2 result at the max offsite location; this is equivalent to an overall uncertainty at the worst-affected receptor of -0.14 µg/m^3 (or -0.3% of the relevant AQS objective).

The lowest hourly average NO_2 process contribution was 98% of the value reported in Table 7-1, equivalent to an overall uncertainty at the worst-affected receptor of -0.11µg/m^3 (or -0.1% of the relevant AQS objective).

The surface roughness representation in the main model has been assessed at 0.3m, representative of the maximum surface roughness associated with agricultural land. This is consistent with modelling carried out for the original Environmental Permit application. The surface roughness has been varied and it was found that a higher surface roughness (0.5m), resulted in higher long-term impacts at the worst-case ecological receptor, with the lower surface roughness (0.2m) resulting in lower long-term impacts.

The model has also been run without the inclusion of buildings which results in lower PCs than those presented in the main assessment.

Sensitivity to Amine Model Inputs

The sensitivity of the N-amines model to various input parameters has also been tested. The parameters that have been varied in the model input include:

- sensitivity to the meteorological data and background data used in the model, comparing the maximum results presented to the results for the meteorological year returning the lowest results;
- the main model assumed a percentage of NO_2 within the NO_x emission of 10%. Sensitivity of the model has been tested at 5%; and
- the main model was run with dilution and entrainment turned on. Sensitivity of the model has been tested with no dilution and entrainment.

The results of the sensitivity testing are shown in Table C2 and represent the PCs of nitrosamine and nitramine combined as a percentage against the EAL.

Table C2: N-amines Dispersion Model Sensitivity Analysis

Model Input Varied	AQAL (ng/m^3)	N-amine 1 PC (ng/m^3)	N-amine 2 PC (ng/m^3)	Combined PC (ng/m^3)	Combined PC/AQAL %
Reported Results (ng/m^3)	0.2	**0.093**	**0.046**	**0.14**	**69.6%**
Meteorological data (lowest year)		0.063	0.036	0.10	49.5%
NOx to NO_2 Ratio 5%		0.091	0.046	0.14	68.5%
No dilution and entrainment		0.059	0.042	0.10	50.5%