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Unconventional Gas Exploration and Extraction (UGEE) Joint Research Programme

Summary Report 3: Baseline Characterisation of Air Quality

Authors: Dawn Keating and Rob Saikaly

Ambient air quality monitoring sampling intake

CDM Smith
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On the 23rd of July 2016, the Department of Communications, Energy and Natural Resources (DCENR) became the DCCAE. Along with a name change, the new Department incorporates functions that were formerly held within the Environment Division of the DECLG. The Department retains responsibility for the Telecommunications, Broadcasting and Energy sectors. It regulates, protects, develops and advises on the Natural Resources of Ireland. Of particular relevance is the role of the Petroleum Affairs Division (PAD) to maximise the benefits to the State from exploration for and production of indigenous oil and gas resources, while ensuring that activities are conducted safely and with due regard to their impact on the environment and other land/sea users. The Geological Survey of Ireland (GSI) is also within DCCAE and provides advice and guidance in all areas of geology including geohazards and groundwater and maintains strong connections to geoscience expertise in Ireland.

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UGEE Joint Research Programme

Environmental Impacts of Unconventional Gas Exploration and Extraction

(2014-W-UGEE-1)

Summary Report 3:

Baseline Characterisation of Air Quality

by

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DISCLAIMER

References to government departments (DCENR and DCELG) throughout the report use the names of these departments prior to July 2016. References to the Department for the Economy (DfE) throughout the report use the name of its predecessor, the Department of Enterprise Trade and Investment (DETI), the department responsible for petroleum licensing in Northern Ireland until May 2016.

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1 More details available at:
http://www.epa.ie/pubs/reports/research/ugeejointresearchprogramme/ugeejrptasksorganisations.html

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Executive Summary

Unconventional gas exploration and extraction (UGEE) involves hydraulic fracturing ("fracking") of low-permeability rock to permit the extraction of natural gas on a commercial scale from unconventional sources such as shale gas deposits, coal seams and tight sandstone. The Environmental Protection Agency (EPA), the Department of Communications, Energy and Natural Resources (DCENR) and the Northern Ireland Environment Agency (NIEA) awarded a contract in August 2014 to a consortium led by CDM Smith Ireland Limited, to carry out a 24-month research programme looking at the potential impacts on the environment and human health of UGEE projects and operations (including construction, operation and aftercare).

The UGEE Joint Research Programme (JRP)[1] is composed of five interlinked projects and involves field studies (baseline monitoring of water and seismicity), as well as an extensive desk-based literature review of UGEE practices and regulations worldwide. The UGEE JRP was designed to provide the scientific basis to assist regulators – in both Northern Ireland and Ireland – in making an informed decision about whether or not it is environmentally safe to allow fracking. As well as research in Ireland, the UGEE JRP is looking at and collating evidence from other countries.

1 www.ugeeresearch.ie

Project A3 (Air Quality) deals with the requirements and needs for additional air baseline monitoring (in terms of the frequency, location and type of pollutants to be covered) in the context of Environmental Impact Statements (EISs), the output of which is in *Final Report 3: Baseline Characterisation of Air Quality*, of which this document is a summary.

A full baseline characterisation of air quality was not carried out before the commencement of operations in any of the assessed jurisdictions in which commercial UGEE operations are ongoing. In many cases, this lack of baseline characterisation prior to the commencement of UGEE activities has been highlighted as an important information gap. However, extensive studies into air quality and other environmental impacts are being carried out across almost all jurisdictions. Many studies across all jurisdictions have made recommendations for baseline studies and extensive investigations to be conducted on potential air quality impacts. Ireland finds itself well placed to comply with these international recommendations for baseline studies to be carried out and for potential impacts to be thoroughly assessed before UGEE operations, exploratory or otherwise, are carried out.

This report presents and describes recommendations for additional ambient air quality monitoring for oxides of nitrogen, ozone precursors, particulate matter, benzene and non-methane volatile organic compounds, benzo[*a*]pyrene and radon.

1 Introduction

1.1 Overall Project

Unconventional gas exploration and extraction (UGEE) involves hydraulic fracturing ("fracking") of low-permeability rock to permit the extraction of natural gas on a commercial scale from unconventional sources such as shale gas deposits, coal seams and tight sandstone. The Environmental Protection Agency (EPA), the Department of Communications, Energy and Natural Resources (DCENR) and the Northern Ireland Environment Agency (NIEA) awarded a contract in August 2014 to a consortium led by CDM Smith Ireland Limited, to carry out a 24-month research programme looking at the potential impacts on the environment and human health of UGEE projects and operations (including construction, operation and aftercare).

The UGEE Joint Research Programme (JRP)[2] is composed of five interlinked projects, outlined below, and involves field studies (baseline monitoring of water and seismicity), as well as an extensive desk-based literature review of UGEE practices and regulations worldwide.

- Project A1 (Groundwater, Surface Water and Associated Ecosystems) dealt with the baseline characterisation of groundwater, surface water and associated ecosystems, which is required for potential impacts to be assessed.
- Project A2 (Seismicity) dealt with the baseline characterisation of seismicity, which is required for potential impacts to be assessed.
- Project A3 (Air Quality) dealt with the requirements and needs for additional air baseline monitoring (in terms of the frequency, location and type of pollutants to be covered) in the context of Environmental Impact Statements (EISs).
- Project B (UGEE Projects/Operations: Impacts and Mitigation Measures) involved the identification and a detailed examination of the potential impacts on the environment and human health, and of successful mitigation measures to counteract these impacts, associated with UGEE projects/operations that have come to the fore worldwide, using published reports and other sources.
- Project C (Regulatory Framework for Environmental Protection) aimed to identify all of the regulatory requirements, including gaps in the existing regulations, and the best operational practices associated with the establishment and operation of UGEE projects/operations in the context of the island of Ireland.

The UGEE JRP was designed to provide the scientific basis to assist regulators – in both Northern Ireland and Ireland – in making an informed decision about whether or not it is environmentally safe to allow fracking. As well as research in Ireland, the UGEE JRP is looking at and collating evidence from other countries.

1.2 Objective and Aim of Project A3

Project A3 (Air Quality) dealt with the requirements and needs for additional air baseline monitoring (in terms of the frequency, location and type of pollutants to be covered) in the context of EISs.

This report is a brief summary of *Final Report 3: Baseline Characterisation of Air Quality*, which specifically described the work carried out under Tasks 1, 2 and 3 (see "Terms of Reference"[3]) and addressed the following three key objectives (as shown in Figure 1.1):

- Task 1: to review existing air monitoring data, including data on naturally occurring radioactive materials (NORM);
- Task 2: to review the requirements and experience of air baseline characterisation in countries in which UGEE projects/operations have taken or are taking place; and
- Task 3: to identify and make recommendations for guidelines on the extent of the air baseline monitoring (in terms of the frequency, location and type of pollutants to be covered) that needs to be carried out for an EIS (i.e. on a project basis).

2 www.ugeeresearch.ie

3 http://www.epa.ie/pubs/reports/research/ugeejointresearchprogramme/ugeeresearchrevisedtermsofreference.html

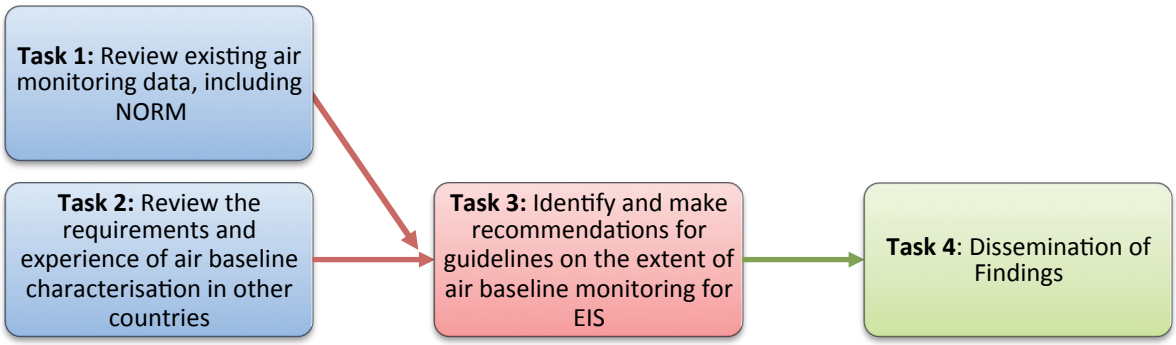

Figure 1.1. Tasks of Project A3 of the UGEE JRP.

1.3 Methodology and Information Sources

The preparation of *Final Report 3: Baseline Characterisation of Air Quality* (and, by extension, this summary report) involved desk-study work, including reviews of:

- available data and information on existing air quality monitoring programmes in Ireland;
- baseline characterisation practices in other countries, notably those in which UGEE has taken place or is planned, with an emphasis on reviewing lessons-learned documentation; and
- data gaps and recommendations for air baseline monitoring (in terms of the frequency, location and type of pollutants to be covered).

2 Background

Chapter 3 of *Final Report 3: Baseline Characterisation of Air Quality* set out the background to the project, key elements of which are summarised within this section.

Shale gas is a natural gas found in shale (a fine-grained sedimentary rock). With conventional gas extraction, gas is extracted from reservoirs or traps where it has migrated to; with unconventional gas, the gas is extracted from the rock itself. Hydraulic fracturing, or "fracking", is a method used by drilling engineers to stimulate or improve the flow of oil or gas from rocks in the subsurface.

The exploration and extraction of unconventional gas must comply with all relevant requirements of EU legislation, as confirmed by a guidance note issued in 2011; this includes the Environmental Impact Assessment (EIA) Directive (2014/52/EU), which entered into force on 15 May 2014.

UGEE operations and their associated potential impacts are currently undergoing assessment in various jurisdictions; for example, the US Department of Energy has, relatively recently, ordered a comprehensive assessment of challenges, including the environmental challenges, of extended shale gas development (Secretary of Energy Advisory Board, 2011). An initial European Commission assessment of hydraulic fracturing practices in the context of shale gas developments has identified a number of environmental areas that are potentially at risk from these practices, including impacts on air quality (EC, 2012). Potential impacts of unconventional gas extraction have also been subject to a number of independent reviews, all of which concluded that there are potential environmental impacts related to air quality associated with shale gas extraction, and stressed the importance of monitoring potential impacts. In addition, a special report by the International Energy Agency (IEA) stresses the need for robust and coherent measures, including "full transparency, measuring and monitoring of environmental impacts" (IEA, 2012), and has recently concluded that "governments, industry and other stakeholders must work together to address legitimate public concerns about the associated environmental and social impacts" of unconventional fossil fuel projects.

In nearly all countries with operational UGEE activities, shale gas extraction has proceeded without extensive baseline investigations being carried out. This lack of baseline monitoring has complicated the task of determining the range and magnitude of environmental impacts, including impacts on air quality and incremental air pollution, of shale gas activities. Unlike many countries, the island of Ireland is now in a position in which full baseline studies and investigations can be completed in the absence of ongoing UGEE works, and before any decisions are made on whether UGEE operations should be permitted or not.

3 UGEE and Air Pollution

This section summarises the content of Chapter 4 of *Final Report 3: Baseline Characterisation of Air Quality*, in which the assessed literature and available information on air quality and emissions relating to UGEE operations is presented.

3.1 Background

Air contaminants can adversely affect humans in different ways (as shown in Figure 3.1). UGEE projects and operations can result in the emission of some pollutants that, if present in high enough concentrations, are associated with possible health effects through direct external contact or inhalation (Atherton *et al.*, 2014). In addition, pollutants can be created by the processes used during UGEE operations, increased traffic and the use of diesel-fuelled machinery. Leaking equipment can also result in fugitive emissions.

Emissions from multiple developments of wells in an small area or larger region could have potentially significant impacts on air quality. However, on a site-by-site basis, these emissions are typically intermittent and are not unique to UGEE activities (Public Health England, 2013). Many pollutants associated with UGEE projects and operations are also produced in significant quantities by other activities, including industry, transport and domestic fuel consumption, as well as secondary pollutants from atmospheric processes. These sources contribute to background levels of pollution and it is, therefore, important that any UGEE emissions are considered in that context. Background levels vary geographically at local, regional and national scales.

3.2 Emissions to Ambient Air and the UGEE Process

In terms of the life cycle of UGEE operations, unconventional gas differs from conventional natural gas in three main ways:

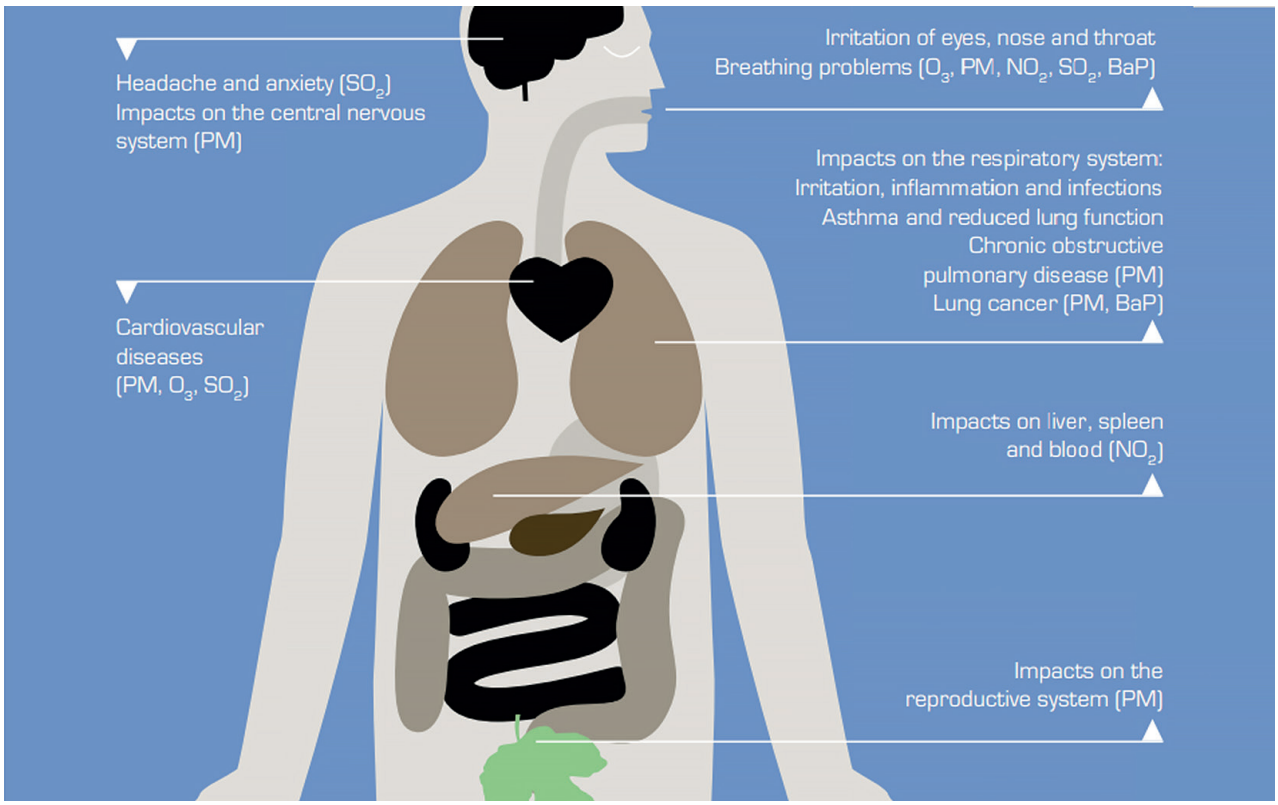

Figure 3.1. Health impacts of air pollution (source: EEA, 2013). See list of abbreviations for definitions.

- it often requires directional or horizontal drilling at much greater depths;
- fracturing procedures are more expensive than conventional gas recovery; and
- it typically has a sharper decline in production.

However, once out of the ground, unconventional gas is subject to the same fate (processing, transport and end use) as natural gas.

Research indicates that there is potentially a wide variety of sources of air pollution from shale gas and related activities depending on the phase of the activity (preproduction, production, transmission/storage/distribution, end use and end of life of the well) (Colorado School of Public Health, 2011; Adgate *et al*., 2014). It should be noted that much of the primary data originate in the USA, and the European regulatory framework would result in variations to American operational practices (holding ponds for flowback fluids would not be permitted, for example). There would, therefore, be reductions or variations in associated overall emissions associated with any UGEE operations within Europe.

The main compounds that can affect air quality during the various phases of UGEE projects and operations are shown in Figure 3.2 and more information on the sources is provided in Table 3.1.

Preproduction	Production	Transmission, Storage and Distribution	Well Production, End of Life
Methane	Methane	Methane	Methane
BTEX	BTEX		
NMVOCs	NMVOCs		
NO_2	Radon		
$PM_{2.5}$	NO_2		
Silica			
Radon			

Figure 3.2. Key species emitted to the atmosphere during specific stages of the natural gas life cycle. See list of abbreviations for definitions.

Table 3.1. Emissions by UGEE operational phase[a]

Phase	Sources	Commentary
Preproduction	Exploration, site clearing, road construction, drilling, fracturing and well completion	Sources of emissions include large diesel engine equipment, particulate matter from transport and raw materials (including silica) and pockets of methane. Drilling fluids can contain chemicals that, when returned to the surface, may emit volatile components. Venting and flaring may release hydrocarbons, although recent technology advances now limit these. (No complete emissions inventory has been defined.) (Moore *et al*., 2014; Werner *et al*., 2015)
Production	Diesel compressors and pumps, equipment bleeding and leaks, emergency flaring and maintenance emissions	There is little consensus on the magnitude of the impact of these emissions, because of variations in the composition of the gas and differences in emission controls and requirements
Transmission, storage and distribution	Transmission, storage and distribution (including, for example, tank breathing losses and compressor stations)	Much less information exists on these phases. The production well is plugged but, in some cases, these can leak; however, there is no reliable information on the magnitude of the emissions. (This is discussed in more detail in *Final Report 4: Impacts and Mitigation Measures*, Chapter 7)
End use	Dependent on end use	This will be the same as that for other sources of gas and will be off site and thus not relevant for baseline monitoring requirements

[a]More details on the information contained in this summary table and further supporting information is available in *Final Report 3: Baseline Characterisation of Air Quality,* section 4.2.

3.3 Other Pollutants

The term naturally occurring radioactive materials (NORM) includes all radioactive materials found in the natural environment, but is used to describe those for which human activities have increased the potential for exposure. UGEE projects and operations can, in certain geological conditions, release NORM in drill cuttings and water. NORM can also form a layer on the interior surfaces of UGEE equipment. The levels in drilling fluids and muds are typically similar to the ground beneath and are not of concern, but flowback waters can contain elevated levels, which need to be addressed in the wastewater process. (This is discussed in *Final Report 4: Impacts and Mitigation Measures*, Chapter 10.)

In the gaseous phase (i.e. relating to air quality), **radon** is the gas of primary concern, although there is evidence that both radon-222 and radium-226 have been detected at UGEE wellheads (Burkhart *et al.*, 2013). These could be released in the production stage due to leakage and during the flowback period, when returning water degasses under reduced pressure. Although there are few available data, the literature indicates that there is little danger to the public because of radon's short half-life and the diffusion and dilution in the atmosphere (Anspaugh, 2012; Brown, 2014, Pennsylvania Department of Environmental Protection, 2015).

Methane is the primary component of shale gas and is a powerful greenhouse gas (28–34 times greater than carbon dioxide over a 100-year period). It is the second largest contributor to direct radiative forcing due to greenhouse gases (O'Hare *et al.*, 2014). Internationally, the most effort has concentrated on addressing the life-cycle emissions of methane, rather than just the UGEE projects and operations. Emissions reporting is required under the Kyoto Protocol, but maximum concentration requirements in legislation are related to protecting worker safety (i.e. there is a significant explosion risk should methane build up in a confined space).

Most methane emissions occur during well completion when the "frack fluids" flow back to the surface; however, these emissions can now be controlled by using equipment to collect and separate the gas. After completion, emissions are released from diesel equipment, chemical processing and leaks.

4 Air Quality Legislation and Guidelines

4.1 Overview

Existing air quality legislation and guidelines are addressed in more detail in Chapter 5 of *Final Report 3: Baseline Characterisation of Air Quality*. For the sake of brevity, the tables specifying concentrations on a compound-by-compound basis are not reproduced in this summary report, but are available for reference in Chapter 5, *Final Report 3: Baseline Characterisation of Air Quality*.

There are three main elements to the specification of air quality in EU legislation:

- limit values, which are legally binding concentration thresholds that must not be exceeded;
- target values, which are to be attained where possible (not legally binding); and
- exposure reduction obligations.

Air quality limits and target values across the island of Ireland are defined in EU legislation, the Clean Air for Europe (CAFE) Directive (EP and CEU, 2008) and the Fourth Daughter Directive (EP and CEU, 2004). The CAFE Directive is an amalgamation of the Air Quality Framework Directive and its subsequent First, Second and Third Daughter Directives. The provisions of the directives were transposed into national legislation as follows:

- in Ireland by the Air Quality Standards Regulations 2011 (S.I. No 180 of 2011) and the Arsenic, Cadmium, Mercury, Nickel and Polycyclic Aromatic Hydrocarbons in Ambient Air Regulations 2009 (S.I. No 58 of 2009); and
- in Northern Ireland by the Air Quality Standards Regulations (Northern Ireland) 2010.

In addition, the Air Quality Strategy for England, Scotland, Wales and Northern Ireland, first published in 1997 and updated in 2007, provides a comprehensive framework for tackling air pollution in Northern Ireland.

The time periods over which average concentrations are calculated relate to the nature of the potential impacts. Some pollutants have limits expressed as annual averages because of the chronic nature of their impacts on human health or the environment, that is, their effects occur after a prolonged period of exposure to elevated concentrations. Other compounds have limits expressed as short-term averages (i.e. 15-minute, 1-hour or 24-hour averages); this is because of the acute way in which they can affect human health or the environment. Some compounds have both short- and long-term average periods to prevent both chronic and acute impacts.

4.1.1 World Health Organization standards

Supplementary to national and European legislation (which aims to protect public health and forms an important component of national risk management and environmental policies) are the guidelines published by the World Health Organization (WHO). WHO guidelines are designed to offer guidance in reducing the health impacts of air pollution and are based on the now extensive body of scientific evidence relating to air pollution and its health consequences. WHO guidelines can often be more stringent than national air quality standards.

Table 4.1 summarises some of the main characteristics of the key pollutants addressed by the foregoing legislation (and these are addressed in more detail in *Final Report 3: Baseline Characterisation of Air Quality*, sections 5.2 to 5.10).

Table 4.1. Summary of key pollutants with respect to ambient air quality

Pollutant	Mechanisms	Local context and sources
NO_x	Produced during combustion at high temperatures	The main sources of NO_x emissions across the island of Ireland are vehicles and power stations. The industrial sector is also a significant contributor to NO_x levels in the island of Ireland
SO_2	Formed when sulfur-containing fuels (mainly coal and oil) are burned in power stations, both domestically and elsewhere	Levels of SO_2 are low across the island of Ireland and much of the European Union
CO	Formed as a result of incomplete oxidation during combustion of fuel	The main source of CO in the island of Ireland is from automobiles, although tobacco smoke and poorly adjusted and maintained combustion devices, such as boilers, also contribute. Concentrations tend to be higher in areas with heavy traffic congestion
O_3	Secondary pollutant formed at ground level by the reaction of a mixture of other chemicals (O_3 precursors) (NO_x, CO and VOCs) in the presence of sunlight	Levels are higher in remote regions and tend to be highest along the western seaboard and lower in the east of the island of Ireland
PM_{10}	Direct emissions such as dust, emissions from combustion engines and burning of solid fuels, or from natural sources such as windblown salt, plant spores and pollens. Indirect emissions through the formation of aerosols as a result of reactions of other pollutants such as NO_x and SO_2	The main sources are solid fuel burning and vehicular traffic
$PM_{2.5}$	Various sources, including nitrates and sulfates, VOCs, metals and soil or dust particles. $PM_{2.5}$ can be emitted directly or formed secondarily	$PM_{2.5}$ is associated with the transport, industrial and residential sectors
VOCs	Benzene and VOCs can be released to the air from vehicular emissions (unleaded petrol may contain up to 1% benzene), petroleum refining, fuel storage/filling stations, industrial emissions, chemical usage and tobacco smoke	The major source of benzene and VOCs in the island of Ireland is automobile exhaust emissions. Urban areas can have measurable quantities of benzene in the air
PAHs	PAHs are chemical compounds that consist of two or more fused aromatic rings made entirely from carbon and hydrogen and can be formed during combustion. (Typically benzo[*a*] pyrene is the most significant PAH and is used as a marker for all PAHs)	PAHs are emitted domestically from the combustion of solid fuels, such as peat, wood and coal, or incomplete combustion of fuel in automobiles. Waste burning or “backyard burning” and bonfires are also a source of PAHs, as is cigarette smoke
Radon	Some industries that process natural resources may concentrate radionuclides to a degree that they may pose a risk to both humans and the environment if they are not controlled	Of all human radiation exposure, 90% arises from natural sources such as cosmic radiation, exposure to radon gas and terrestrial radiation

See list of abbreviations for definitions.

5 Review of Existing Air Monitoring Network

5.1 Introduction

Ambient air quality networks are designed to meet a variety of purposes, and individual stations in the network may serve different purposes. Ireland and Northern Ireland have separate environmental agencies and their ambient air quality networks are independent. Up-to-date air quality information is available on www.epa.ie and www.airqualityni.co.uk for Ireland and Northern Ireland, respectively.

5.1.1 Ireland

The Ireland network consists of 32 monitoring stations (see Figure 5.1). The EPA is the designated competent authority in relation to air quality and the monitoring network; it monitors compliance with legislation and allows the calculation of air quality indices on a regional basis. There are four designated zones as shown in Figure 5.2. Ambient air quality in Zone D (non-urban areas) is likely to be the most representative of potential UGEE project and operations areas.

5.1.2 Northern Ireland

The Northern Ireland administration is responsible for the jurisdiction's air quality policy and legislation. The overall UK Air Quality Strategy sets outs standards and objectives, which are implemented by the local authorities. The monitoring stations in Northern Ireland are shown in Figure 5.1 and the two reporting zones are shown in Figure 5.2. The monitoring programme is supplemented by regional air quality modelling of several parameters to assist the local authorities in their assessment of air quality.

5.2 Naturally Occurring Radioactive Material

Both Ireland and Northern Ireland assess:

- ambient radioactivity from natural and man-made sources;
- radioactivity in foods and drinking water; and
- radioactivity in the marine environment.

There are 20 permanent radiation monitoring stations across the island of Ireland (15 in Ireland and five in Northern Ireland). Maps of radon in 10-km grids can be found on gis.epa.ie for Ireland and on www.ukradon.org for Northern Ireland.

5.2.1 Tellus and Tellus Border projects

Tellus is a regional mapping project that includes measurements of uranium, thoron and radioactive potassium. The results show a strong correlation with local geology.

5.3 Monitored Compounds

Both Ireland and Northern Ireland monitor a variety of air pollutants and details of these can be found in section 6.4 of *Final Report 3: Baseline Characterisation of Air Quality*.

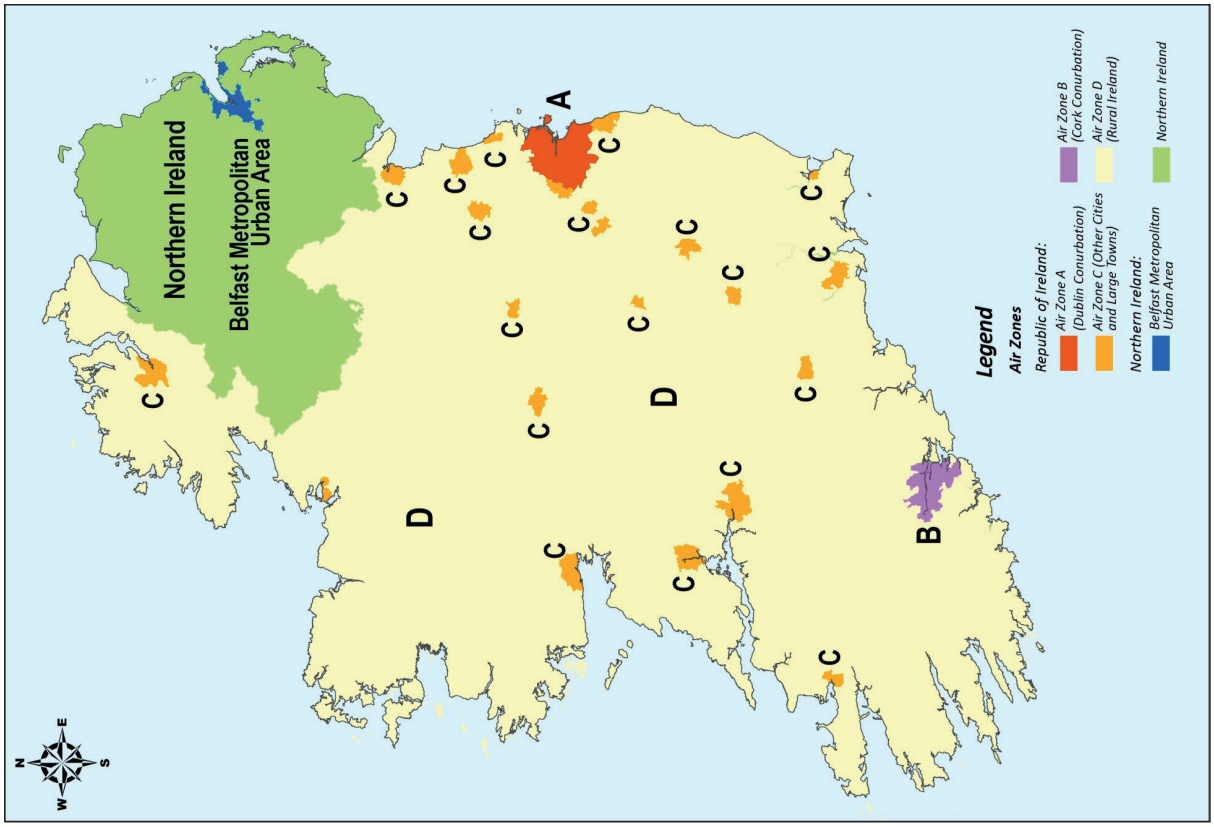

Figure 5.2. Air quality zones in Ireland and Northern Ireland.

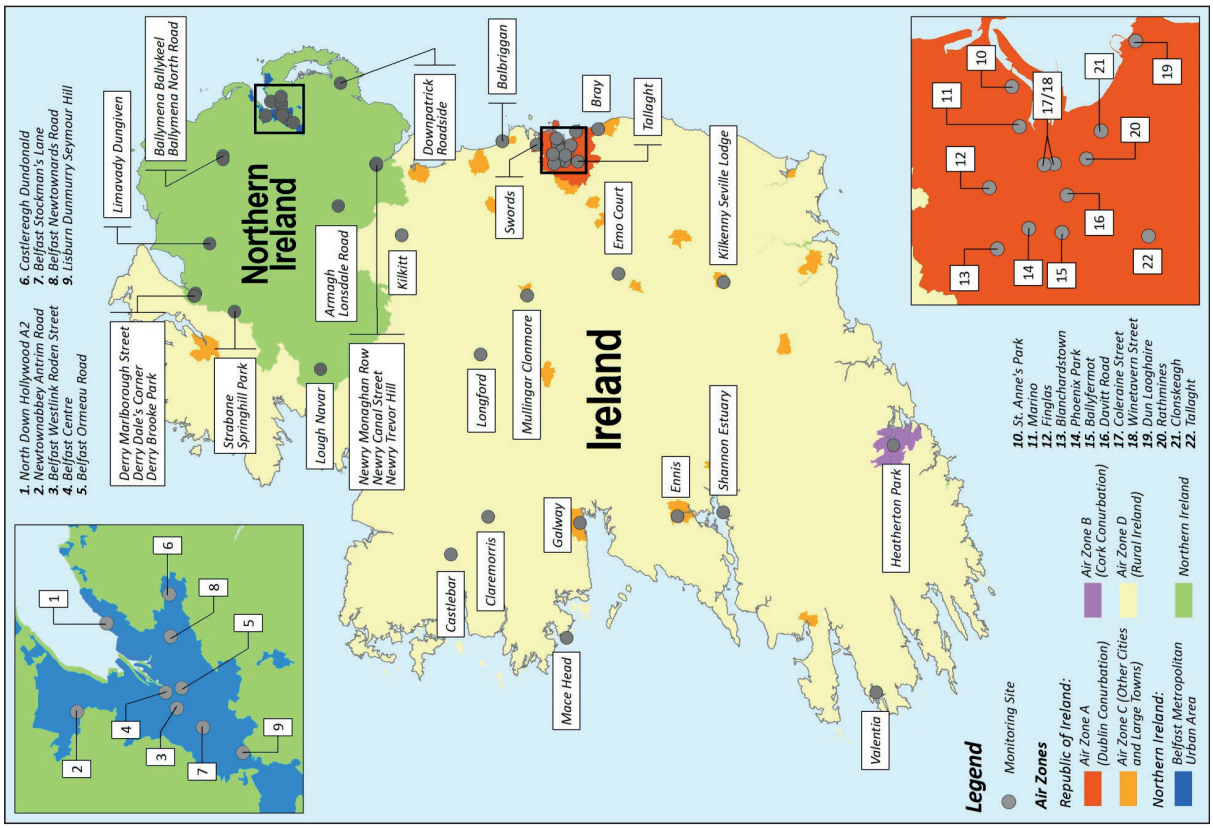

Figure 5.1. Ambient air quality monitoring networks in Ireland and Northern Ireland.

6 Review of International Requirements and Baseline Characterisation

Section 7 of *Final Report 3: Baseline Characterisation of Air Quality* considers the requirements of the following jurisdictions with respect to baseline monitoring of air quality:

- Europe;
  - UK;
  - Poland;
  - Germany;
  - France;
- South Africa;
- USA; and
- Canada.

It was found that a full baseline characterisation of air quality was not carried out before the commencement of operations in any of the jurisdictions considered in Project A3 in which commercial UGEE operations are ongoing. In many cases, this lack of baseline characterisation prior to the commencement of UGEE activities has been highlighted as an important information gap. As described in *Final Report 3: Baseline Characterisation of Air Quality*, section 4.2.3, published studies report that air quality impacts vary from significantly detrimental to having little or no impact and so no clear consensus on the range of pollutants required for monitoring has emerged.

It should be noted that current recommendations in Germany require that a comprehensive initial state report be undertaken before any new UGEE operations; however, no guidance on monitoring programme specifics has been published.

Many studies across all jurisdictions have made recommendations for baseline studies and extensive investigations to be conducted on potential air quality impacts. Ireland finds itself well placed to comply with these international recommendations for baseline studies to be carried out and for potential impacts to be thoroughly assessed before UGEE operations, exploratory or otherwise, are carried out.

7 Conclusions

Chapter 8 of *Final Report 3: Baseline Characterisation of Air Quality* presents the conclusions of the work summarised in this document and presented in more detail in the final report. While an extensive ambient air monitoring network is in operation across the island of Ireland, *Final Report 3: Baseline Characterisation of Air Quality* identified that supplementary air quality baseline monitoring on a project-by-project basis would be needed for impact assessments. Chapter 8 of the final report presents details (the frequency, location and type) of potential supplementary baseline air quality monitoring to be undertaken in the context of EIA. This is summarised briefly in the following text.

7.1 The Rationale Underpinning Monitoring Recommendations

Despite a lack of clear agreement on the magnitude of the air quality impacts caused by UGEE activities, the available literature (including Groundwater Protection Council, 2009; Colorado School of Public Health, 2011; Walther, 2011; McKenzie *et al*., 2012; AMEC, 2013; NETL, 2013; Public Health England, 2013; Adgate *et al*., 2014; Maryland Department of the Environment and Maryland Department of Natural Resources, 2014; Moore *et al.*, 2014; Werner *et al.*, 2015) appears to broadly agree on the compounds or families of compounds associated with UGEE activities, even if estimations of the quantity of emissions vary significantly (Research Triangle Environmental Health Collaborative, 2013).

Werner *et al.* (2015), after reviewing available health-related studies, reported that very few, if any, methodologically rigorous studies have examined the potential cause-and-effect relationship between UGEE activities and air emissions. In many cases, adverse health impacts were attributed to these activities as a precaution. The evidence currently available is not sufficient to identify or rule out health impacts (whether these are significant or specific, future or cumulative) of UGEE activities. Therefore, a risk assessment approach was applied to determine the primary air quality pollutants to be addressed in this study and that ought to be covered in the recommendations. Pollutants not regarded as resulting from UGEE activities were not considered in detail in this study, including pollutants for which ambient air quality standards have been established in the CAFE Directive or Fourth Daughter Directive. Furthermore, it should also be borne in mind that, as the available scientific knowledge grows, any environmental assessment should take account of the latest scientific information available.

7.2 Key Recommendations Regarding General Monitoring Requirements

While details on the potential scope of additional air quality baseline monitoring to be undertaken are presented in Chapter 8 of *Final Report 3: Baseline Characterisation of Air Quality*, key overarching considerations are set out below.

To ensure that the monitored data are of a satisfactory quality, monitoring should be carried out in line with the relevant principles set out in S.I. No 180/2011, Air Quality Standards Regulations 2011. In particular, monitoring should be carried out in accordance with:

- Schedule 1, Part A, Data quality objectives; and
- Schedule 3, Assessment of ambient air quality and location of sampling points for the measurement of sulfur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter (PM_{10} and $PM_{2.5}$), lead, benzene and carbon monoxide in ambient air, including:
  - Part A (General);
  - Part B (Macroscale siting of sampling points);
  - Part C (Microscale siting of sampling points).

If the proponent of a project wishes to place a station strategically to characterise the air quality baseline to represent multiple well pads, they must prove to the relevant authorities that it is in fact representative of those sites. Short-term monitoring may be needed to do this.

Project A3 did not set out to be prescriptive in terms of the specifications of air monitoring equipment, manufacturers or models; however, equipment selection should be guided by the requirements for the following comparisons:

- meaningful comparison with averaging periods set out in the ambient standards (hourly, daily, etc.);
- meaningful comparison with threshold values in terms of detection limits and accuracy of monitoring equipment (e.g. the limit of detection should be below the relevant standards); and
- meaningful comparison with the existing ambient air monitoring network.

7.3 Key Recommendations Regarding Pollutants to be Monitored

Details of the potential monitoring scope, together with supporting rationale are set out on a pollutant-by-pollutant basis, together with the rationale supporting each recommendation, in more detail in section 8.7 of *Final Report 3: Baseline Characterisation of Air Quality*. The rationale for inclusion in or exclusion from a baseline monitoring programme of each pollutant is summarised in Table 7.1, with the monitoring specifications set out in Table 7.2.

Table 7.1. Rationale for proposed supplementary baseline monitoring recommendations

Pollutant	Rationale	Recommendation for inclusion or exclusion
NO_x	Emissions of NO_x are generated primarily from fuel combustion processes and have been linked to UGEE activities through on-site activities and the increase in HGV movements associated with operations. NO_2 (and other NO_x) is also a precursor for a number of harmful secondary air pollutants, including nitric acid, the nitrate part of secondary inorganic aerosols and ozone (WHO, 2013)	Monitoring of NO_x and NO_2 is recommended to facilitate the assessment of ambient levels both on site and at the roadside, where, for the latter, increases in levels may be caused by increases in traffic movements
SO_2	SO_2 is typically not regarded as a critical compound in terms of UGEE-related emissions, particularly when flaring is routinely practised	Under the precautionary principle, it is nonetheless recommended that monitoring be carried out to support impact assessment
CO	CO is not regarded as a critical compound in terms of UGEE-related emissions. Levels at all stations across the island of Ireland are currently well within objectives and have been for many years, and are expected to stay low for the foreseeable future (DOENT, 2014; EPA, 2014)	No supplementary baseline monitoring is recommended
O_3	O_3 is not directly released through UGEE processes; Irish O_3 levels are instead highly influenced by transboundary sources and will therefore require a European, and possibly a global, effort to reduce levels. In addition, ambient O_3 levels are not consistent with changes in emission levels of ozone precursors (the compounds that react to form O_3) on a local or regional scale	No supplementary baseline monitoring is recommended
Particulate matter	Emissions of particulate matter have been linked to UGEE activities through on-site activities and the increase in HGV movements associated with the operations	Monitoring is recommended to support the assessment of impacts of on-site activities and roadside impacts relating to the increase in HGV movements
Benzene and NMVOCs	UGEE processes are associated with potential emissions of both benzene and a range of VOCs on site, from preproduction to production processes	Baseline monitoring is recommended to characterise baseline levels and support any air quality assessments
Benzo[*a*]pyrene and PAHs	UGEE processes have been associated with elevated levels of PAHs, which, dependent on ambient concentration levels, can have an impact on human health	Typically, benzo[*a*]pyrene is used as a marker for all PAHs and baseline monitoring of benzo[*a*]pyrene is, therefore, recommended
Radon	UGEE processes may result in emissions of radon, in particular at the well head and its vicinity, during the flowback and production periods. While outdoor levels of radon quickly dissipate to harmless levels, radon can accumulate indoors	Monitoring of radon is recommended on site and at a selection of representative receptors in the vicinity of any proposed works
Methane	Fugitive emissions of methane, both pre- and post-closure, matter significantly in the context of climate change	It is advised that background concentrations of methane be characterised to support life-cycle emission calculations and leakage monitoring

See list of abbreviations for definitions.

Table 7.2. Details of potential supplementary baseline ambient air quality monitoring

Pollutant	Monitoring location(s)	Duration of monitoring	Temporal resolution (not less than)
NO_2	Within the curtilage of the well pad	1 year[a]	Hourly
NO_2	Roadside background[b]	Not less than 1 month	Hourly
NO_x	Within the curtilage of the well pad	1 year[a]	None specified
SO_2	Within the curtilage of the well pad	1 month	Hourly
CO	None specified	None specified	None specified
O_3	None specified	None specified	None specified
PM_{10}	Within the curtilage of the well pad	1 year[a]	Daily
PM_{10}	Roadside background	Not less than 1 month	Daily
$PM_{2.5}$	Within the curtilage of the well pad	1 year[a]	Daily
$PM_{2.5}$	Roadside background[b]	Not less than 1 month	Daily
Benzene and NMVOCs	Within the curtilage of the well pad	1 year[a]	Hourly
Benzo[*a*]pyrene	Within the curtilage of the well pad	1 year[a]	None specified
Radon (outdoor)	Within the curtilage of the well pad	1 year[a]	At regular intervals defined by the monitoring method or equipment
Radon (indoor)	Representative receptors in the vicinity of the proposed development	3 months	None specified
Methane	Within the curtilage of the well pad	Not less than 1 month	To be defined by the monitoring method or equipment

See list of abbreviations for definitions.

[a]It is acknowledged that, in the case of NO_2, NO_x, PM_{10}, $PM_{2.5}$, benzene and NMVOCs, benzo[*a*]pyrene and radon, the monitored data may indicate that background concentrations are consistent from month to month or that the existing network adequately represents ambient concentrations. In this case, it is recommended that the possibility of curtailing the monitoring period be addressed with the relevant agencies, that is, the EPA or the NIEA.

[b]In Northern Ireland, use may be made of the modelled background concentrations for the purposes of calculations of traffic-related impacts.

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Abbreviations

BaP	Benzo[*a*]pyrene
BTEX	Benzene, toluene, ethylbenzene and xylenes
CAFE	Clean Air for Europe
CO	Carbon monoxide
DCCAE	Department of Communications, Climate Action and Environment
DCENR	Department of Communications, Energy and Natural Resources
DfE	Department for the Economy
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
HGV	Heavy goods vehicle
IEA	International Energy Agency
JRP	Joint Research Programme
NIEA	Northern Ireland Environment Agency
NMVOC	Non-methane volatile organic compound
NORM	Naturally occurring radioactive materials
NO_x	Oxides of nitrogen
O_3	Ozone
PAH	Polycyclic aromatic hydrocarbon
PM	Particulate matter
PM_{10}	Particles with diameters of 10 µm or less
$PM_{2.5}$	Particles with diameters of 2.5 µm or less
SO_2	Sulfur dioxide
UGEE	Unconventional gas exploration and extraction
VOC	Volatile organic compound
WHO	World Health Organization

Summary Report 3: Baseline Characterisation of Air Quality

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Unconventional gas exploration and extraction (UGEE) involves hydraulic fracturing ("fracking") of low permeability rock to permit the extraction of natural gas on a commercial scale from unconventional sources, such as shale gas deposits, coal seams and tight sandstone.

The UGEE Joint Research Programme (JRP) (**www.ugeeresearch.ie**) is composed of five interlinked projects and involves field studies (baseline monitoring of water and seismicity), as well as an extensive desk-based literature review of UGEE practices and regulations worldwide. The UGEE JRP was designed to provide the scientific basis that will assist regulators - in both Northern Ireland and Ireland - to make informed decisions about whether or not it is environmentally safe to permit UGEE projects/operations involving fracking. As well as research in Ireland, the UGEE URP looks at and collates evidence from other countries.

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List of Outputs:

- Final Report 1: Baseline Characterisation of Groundwater, Surface Water and Aquatic Ecosystems
- Summary Report 1: Baseline Characterisation of Groundwater, Surface Water and Aquatic Ecosystems
- Final Report 2: Baseline Characterisation of Seismicity
- Summary Report 2: Baseline Characterisation of Seismicity
- Final Report 3: Baseline Characterisation of Air Quality
- Summary Report 3: Baseline Characterisation of Air Quality
- Final Report 4: Impacts & Mitigation Measures
- Summary Report 4: Impacts & Mitigation Measures
- Final Report 5: Regulatory Framework for Environmental Protection
- Summary Report 5: Regulatory Framework for Environmental Protection
- UGEE Joint Research Programme Integrated Synthesis Report

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