Scottish Environment Protection Agency
Buidheann Dìon Àrainneachd na h-Alba

Air Quality Monitoring

Mossmorran

January – April 2019

2 October 2019

Updated 29 September 2020

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Updated 29 September 2020 to correct an error in the information provided with respect to details of flaring events during the monitoring period.

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Executive Summary

A three month monitoring study of the air quality in the vicinity of the Mossmorran complex was undertaken between January and April 2019. Four monitoring locations were chosen. A trailer containing continuous air quality monitoring analysers was located at Little Raith Farm to the northeast of the complex; diffusion tubes were located at Little Raith Farm and at three other community locations around the complex, in Cowdenbeath, Donibristle and Lochgelly.

Over the period of the study the monitoring trailer measured the pollutants nitrogen dioxide, sulphur dioxide, carbon monoxide, particulate matter (PM_{10} and $PM_{2.5}$); diffusion tubes were used to determine levels of benzene, toluene, ethylbenzene, xylene, 1,3 butadiene, nitrogen dioxide and total hydrocarbons (C_4 to C_{10}). The particulate matter (PM_{10} and $PM_{2.5}$) results are summarised in Figure 1 and Figure 2.

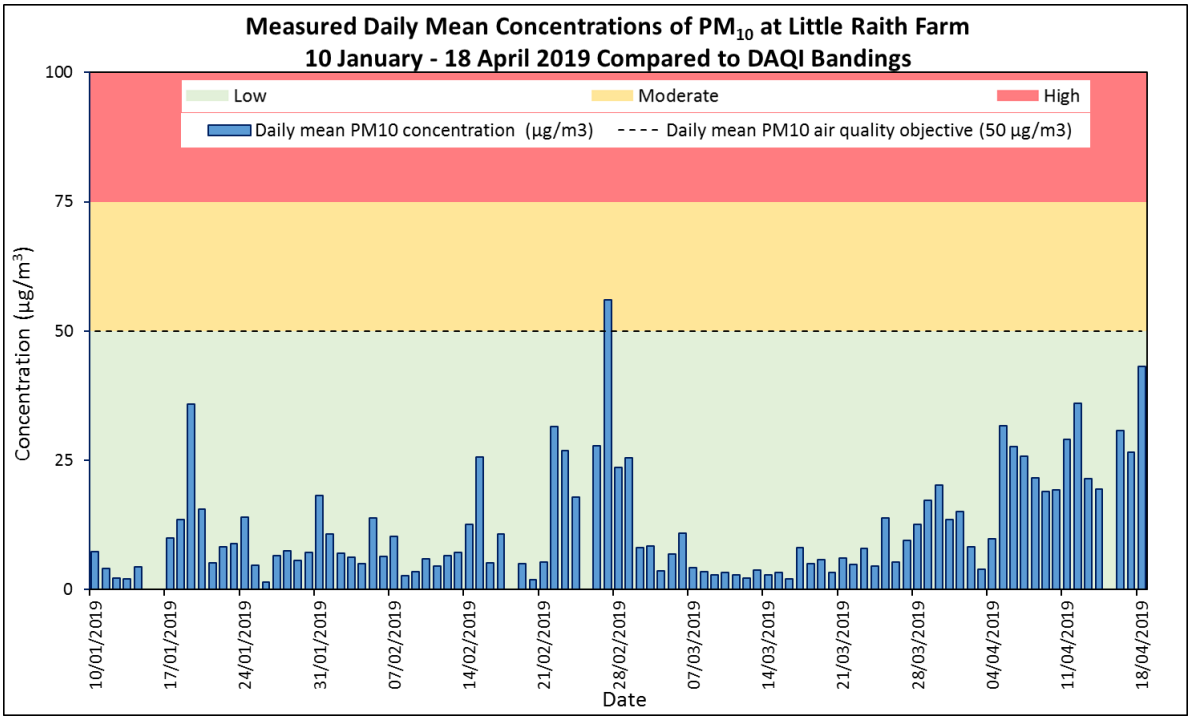

Figure 1: Measured Daily Mean Concentrations of PM_{10}

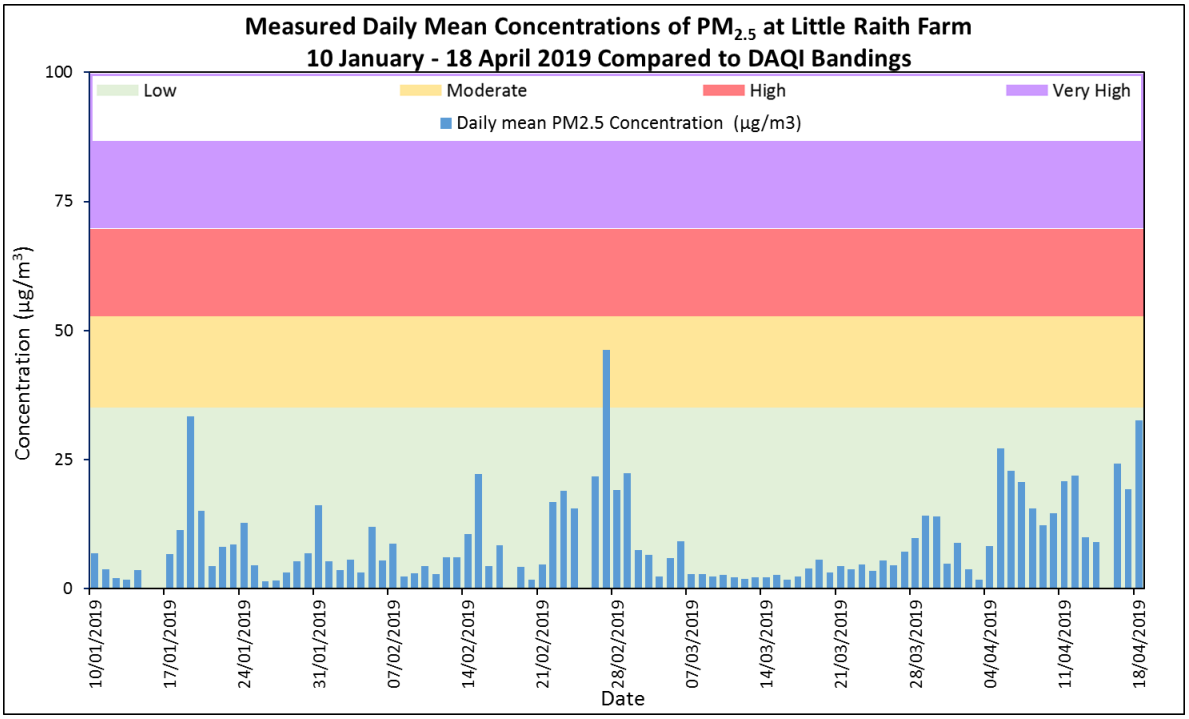

Figure 2: Measured Dally Mean Concentrations of $PM_{2.5}$

There were no breaches of any of the air quality objectives. The air quality objectives relate to air quality monitored over the period of a year, partly to account for the seasonal variation in winds. This study was limited to a period of three months and therefore relies on the period being representative to compare to the objectives. We have demonstrated that the wind conditions during the monitoring period were representative of the general wind patterns in the area. This strengthens the comparison between the measured data and the objectives, giving a useful indication of the air quality over the longer term.

All measurements were in the low band of Defra's daily air quality index (DAQI) for all applicable pollutants, with the exception of particulate matter (PM_{10} and $PM_{2.5}$) which were in the moderate DAQI band on one day (27 February 2019). This coincides with a period of elevated particulate matter across Scotland, probably caused by long range transport of pollution.

Where there are no air quality standards or DAQI for the remaining pollutants measured, we report the results for historical or future comparisons.

Introduction

SEPA does not routinely monitor ambient air around any regulated premises. Our emphasis is on emissions made at the site and requiring monitoring by the operators that demonstrates they are within legal limits. However, in response to community concerns, SEPA offered to carry out a three month programme of enhanced air quality monitoring to inform relevant public agencies.

The monitoring programme was designed to provide up-to-date data and add to the body of evidence that exists from previous reports and data reviews carried out by a number of organisations, including independent consultants.

A monitoring trailer and diffusion tubes were located in four community locations for three months. Locations were discussed and agreed with community representatives, the Mossmorran and Braefoot Bay Independent Air Quality Review Group and the Mossmorran Safety Liaison Group.

This report provides detail about the monitoring SEPA carried out. It will be shared with the Independent Air Quality Review Group (including community representatives), Fife Council, NHS Fife and Health Protection Scotland (HPS).

Due to the technical audience for this report additional information on equipment, methodologies, results and quality control is contained within the appendices.

Equipment focussed on the measurement of combustion-related air pollutants and a range of volatile organic compounds (VOCs).

Several of these compounds have associated health-related air quality standards and objectives against which we compared our monitoring results. Similarly, we have compared our results, where appropriate, against the UK's Department for Environment, Food and Rural Affairs (Defra) Daily Air Quality Index (DAQI).

Monitoring Method

SEPA measured concentrations of pollutants in the ambient air using the SEPA long term air monitoring trailer and diffusion tubes over the period 10 January 2019 to 18 April 2019. Details of the measurement equipment and methodologies are presented in Appendix A.

At Little Raith Farm and in Lochgelly, Donibristle and Cowdenbeath there were:

- Diffusion tubes for nitrogen dioxide;
- Diffusion tubes for a range of volatile organic compounds, namely benzene, toluene, ethyl benzene, xylene, total hydrocarbons (C_4 to C_{10}) and 1,3-butadiene

At Little Raith Farm there was also a trailer and weather station monitoring continuously for:

- Carbon monoxide (CO);
- Nitrogen dioxide (NO_2);
- Sulphur dioxide (SO_2);
- Particulate Matter PM_{10};
- Particulate Matter $PM_{2.5}$;
- Wind speed;
- Wind direction

Prior to commencing monitoring, the details of the environmental monitoring proposal were discussed with NHS Fife and Health Protection Scotland.

The monitoring locations selected by SEPA are summarised in Table 1, and mapped in Figure 3. A photographic record of each monitoring location is presented in Appendix B.

Table 1: Monitoring location summary detailing national grid reference (NGR) and distance and orientation with respect to the Mossmorran site.

Location	NGR	Description	Orientation from Mossmorran Site
Little Raith Farm	NT 20429 91545	Rural	2000m NE
Watters Crescent, Lochgelly	NT 18624 92832	Urban	2500m N
Watson Street, Cowdenbeath	NT 17042 91267	Urban	2000m NNW
Donibristle	NT 16739 88794	Rural	2000m WSW

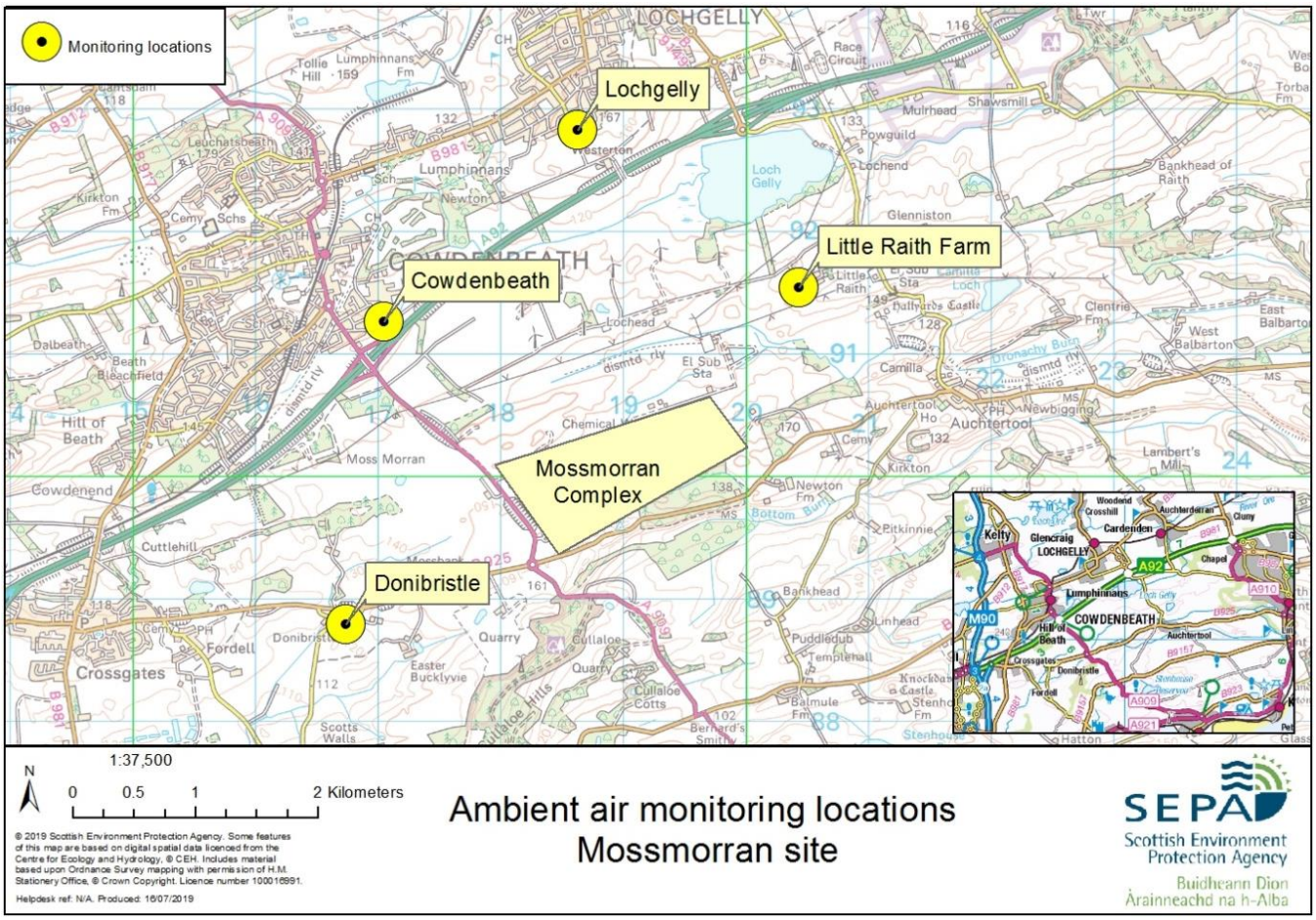

Figure 3: Map of the air quality monitoring locations near Mossmorran

The monitoring investigation was limited to a continuous period of three months. In order to establish how representative the wind patterns were during the deployment, we compared the measured wind speeds and directions with those of a typical calendar year at a nearby official Met Office meteorological station.

A wind rose shows the frequency and speed of wind blowing from particular directions over a set time period. The length of each section shows how often the wind blows from that direction. The coloured bands show wind speed ranges.

The wind rose measured for the 10 January to 18 April 2019 monitoring period is presented in Figure 4, with comparison to wind roses for Gogarbank (proximate to Edinburgh Airport) over the 2014-2018 period, which show the general wind conditions in this region. The Gogarbank weather station (which lies approximately 17km south of Mossmorran) is the nearest official Met Office meteorological station providing representative weather data for the region. The similarity between the wind roses demonstrates that the wind speeds and wind directions during the monitoring period at Little Raith Farm are representative of the general wind profile in this region.

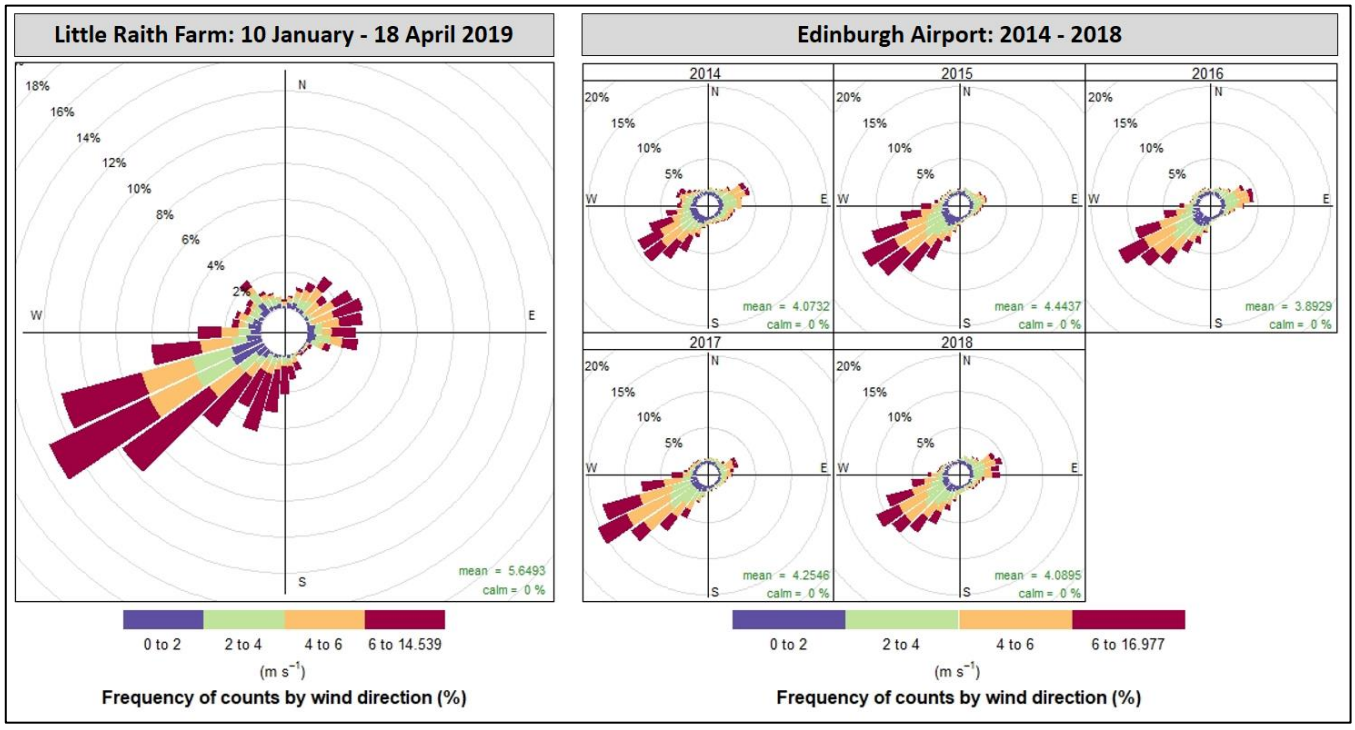

Figure 4: Wind rose for the 10 January to 18 April 2019 monitoring period as measured at Little Raith Farm, alongside comparison wind roses for the 2014 - 2018 period at Gogarbank, near Edinburgh Airport. The Gogarbank wind roses were generated from data supplied by the UK Met Office.

Main Local Sources of Air Pollution

The Mossmorran Complex

The Mossmorran complex comprises of Shell UK Limited's Fife Natural Gas Liquids (NGL) Plant and ExxonMobil Chemical Limited's Fife Ethylene Plant (FEP).

The NGL separates natural gas liquids, received via pipeline from the Shell St Fergus Plant near Peterhead, into its ethane, propane, butane and natural gasoline components.

The ethane is piped to the neighbouring FEP site where it is 'cracked' to produce ethylene. The complex can operate 24 hours a day, 365 days a year.

The facilities at Mossmorran are regulated under Pollution Prevention and Control permits issued by SEPA. These permits specify the conditions for protection of the environment under which the facilities must operate.

The Mossmorran complex has the potential to emit a range of combustion gases and volatile organic compounds (VOC) into the ambient air, during normal operation and during any flaring activities.

During this monitoring period there were three unplanned elevated flaring events (reported by ExxonMobil Chemical Limited):

- 26 Jan 2019 – resulting in 1 hr 37 minutes ground flaring with two concurrent periods of elevated flaring of 10 minutes and 17 minutes respectively.
- 19 Mar 2019 – resulting in 42 minutes ground flaring with a concurrent period of 16 minutes elevated flaring
- 20 Mar 2019 –resulting in 51 minutes ground flaring with two concurrent periods of elevated flaring each of 10 minutes.

Traffic

The A92 road runs approximately southwest-to-northeast, passing between the Mossmorran site to the south and the town of Lochgelly to the north. This is a busy A-road with continuous traffic during daytime and for much of the nighttime.

Traffic on local roads, especially in the larger towns of Lochgelly and Cowdenbeath, will also contribute air pollutants.

The main air pollutants associated with traffic are particulate matter and nitrogen dioxide. Typical daytime traffic patterns can result in peak emissions during normal rush-hour times.

Other local sources of air pollutants

Domestic and commercial combustion – Mainly related to fossil fuel or wood-burning heating systems, and can include bonfires.

Farming and agriculture – For example farm machinery, livestock movements and feeding activities, and manure or fertiliser spreading.

Regional and national pollution events

Under some meteorological conditions, air polluted with particulate matter (PM_{10} and $PM_{2.5}$) from the continent may circulate over the UK – a condition known as the long range transportation of air pollution. Long range transport can result in short term episodes of high pollution[1].

Air Quality Standards and Objectives

A set of air quality standards and objectives has been developed for air pollutants of concern with respect to human health. The objectives adopted in Scotland for the purpose of Local Air Quality Management are set out in the Air Quality (Scotland) Regulations 2000, the Air Quality (Scotland) Amendment Regulations 2002 and the Air Quality (Scotland) Amendment Regulations 2016.

Similar targets are set at EU level, where they are called limit or target values. These are set out in the European 2008 Ambient Air Quality Directive (2008/50/EC) and transposed into Scottish legislation by the Air Quality Standards (Scotland) Regulations 2010[2].

A summary of the current UK and Scottish air quality objectives, restricted to the pollutants monitored in this study, is provided in Table 2.

Table 2: Summary of relevant Scottish and UK air quality objectives (adapted from *www.scottishairquality.scot/air-quality/standards*[2])

Pollutant	Applies to	Air Quality Objective Concentration	Measured as
Benzene	UK	16.25µg m^{-3}	Running annual mean
	Scotland	3.25µg m^{-3}	Running annual mean
1,3-Butadiene	UK	2.25µg m^{-3}	Running annual mean
CO	Scotland	10.0mg m^{-3}	Running 8 hour mean
NO_2	UK	200µg m^{-3} not to be exceeded more than 18 times a year	1 hour mean
	UK	40µg m^{-3}	Annual mean
PM_{10}	UK	50µg m^{-3}, not to be exceeded more than 35 times a year	24 hour mean
	UK	40µg m^{-3}	Annual mean
	Scotland	50µg m^{-3}, not to be exceeded more than 7 times a year	24 hour mean
	Scotland	18µg m^{-3}	Annual mean
$PM_{2.5}$	UK	25µg m^{-3} (target)	Annual mean
	Scotland	10µg m^{-3} (limit)	Annual mean
SO_2	UK	350µg m^{-3}, not to be exceeded more than 24 times a year	1 hour mean
	UK	125µg m^{-3}, not to be exceeded more than 3 times a year	24 hour mean
	UK	266µg m^{-3}, not to be exceeded more than 35 times a year	15 minute mean

The air quality objectives summarised in Table 2 are applicable to air quality monitoring undertaken over the period of a year, partly to account for the seasonal variation in winds. This study was limited to a period of three months. However, we have demonstrated that the wind conditions during the monitoring period were representative of the general wind patterns in the

area. This strengthens the comparison between the measured data and the objectives, giving a useful indication of the air quality over the longer term.

Daily Air Quality Index

Defra has developed a Daily Air Quality Index (DAQI) which is available at the UK AIR (Air Information Resource) website[3]. The website states that the DAQI '*tells you about levels of air pollution and provides recommended actions and health advice. The index is numbered 1-10 and divided into four bands, low (1) to very high (10), to provide detail about air pollution levels in a simple way'[3].* A summary of the relevant indices (i.e. $PM_{2.5}$, PM_{10}, NO_2 and SO_2) is presented in Table 3.

Table 3: Summary of relevant daily air quality indices (adapted from *https://uk-air.defra.gov.uk/air-pollution/daqi*[3])

Band:	Low	Low	Low	Moderate	Moderate	Moderate	High	High	High	Very High	
Pollutant Index:	1	2	3	4	5	6	7	8	9	10	Units
$PM_{2.5}$ (24 hour mean)	0 - 11	12 - 23	24 - 35	36 - 41	42 - 47	48 – 53	54 – 58	59 – 64	65 – 70	≥ 71	µg m^{-3}
PM_{10} (24 hour mean)	0 - 16	17 - 33	34 - 50	51 - 58	59 - 66	67 – 75	76 – 83	84 – 91	92 – 100	≥ 101	µg m^{-3}
NO_2 (1 hour mean)	0 - 67	68 - 134	135 - 200	201 - 267	268 - 334	335 – 400	401 – 467	468 – 534	535 – 600	≥ 601	µg m^{-3}
SO_2 (15 min mean)	0 - 88	89 - 177	178 - 266	267 - 354	355 - 443	444 - 532	533 - 710	711 - 887	888 - 1064	≥ 1065	µg m^{-3}

Results

Carbon monoxide, nitrogen dioxide, particulate matter and sulphur dioxide – measured at Little Raith Farm, near Auchtertool

The continuous analysers at Little Raith Farm give an indication of the air pollutant levels in this area, which is downwind of the Mossmorran site during prevailing winds, blowing from a south westerly direction. A summary of results is presented in Table 4. Details of the quality controls applied to these results are available in Appendix C.

Table 4: Continuous analyser-measured air pollutant concentrations at Little Raith Farm over the period 10 January to 18 April 2019

Pollutant Units	Carbon Monoxide CO (mg m^{-3})	Nitrogen Dioxide NO_2 (µg m^{-3})	Particulate Matter $PM_{2.5}$ (µg m^{-3})	Particulate Matter PM_{10} (µg m^{-3})	Sulphur Dioxide SO_2 (µg m^{-3})
Averaging Period	15 minutes				
% Data Capture	96	88	91	91	93
Maximum	1.1	106.7	174.3	614.6	36.7
Average	0.0	9.5	8.9	11.8	1.0
Averaging Period	8 hours (running)	1 hour	24 hours	24 hours	1 hour
Maximum	0.2	59.1	46.2	56.0	31.3
Average	0.0	9.5	9.2	12.2	1.0

Due to the position of the air monitoring equipment within the boundaries of a working farm, air pollutants from farming operations will have contributed to the measured pollutant levels, most significantly nitrogen dioxide and particulate matter. The site was also likely to receive pollutants associated with passing traffic from the A92, during westerly and northerly winds, again most significantly nitrogen dioxide and particulate matter.

These activities are likely to be responsible for the highest 15 minute totals recorded, but it is important to note that these peaks were transient in nature. The short term air quality objectives and DAQI for particulate matter are based on 24 hour averages; whilst for nitrogen dioxide they are based on hourly averages.

Carbon monoxide (CO): The highest 8 hour mean CO concentration measured over the monitoring period was 0.2mg m^{-3}, which is considerably below the running 8 hour mean air quality objective concentration of less than or equal to 10.0mg m^{-3}. There is no daily air quality index for carbon monoxide.

Nitrogen dioxide (NO_2): The average NO_2 concentration measured by continuous analyser over the three month monitoring period was 9.5µg m^{-3}, which is considerably below the annual mean air quality objective concentration of less than or equal to 40µg m^{-3}.

The highest measured 1 hour mean NO_2 concentration was 59.1µg m^{-3} This is considerably below the 1 hour mean air quality objective concentration of less than or equal to 200µg m^{-3}.

All measured 1 hour mean NO_2 concentrations were within the lowest DAQI band (0-67µg m^{-3}) throughout the monitoring period.

Particulate matter PM_{10}: The average PM_{10} concentration measured by continuous analyser over the monitoring period was 11.8µg m^{-3}, which is below the annual mean air quality objective concentration of less than or equal to 18µg m^{-3}.

93 of the 94 measured 24 hour mean PM_{10} concentrations were within the lowest DAQI band (0-50 µg m^{-3}) and meet the 24 hour mean air quality objective concentration of less than or equal to 50 µg m^{-3}.

The highest 24 hour mean concentration of PM_{10} over the monitoring period was measured on the 27 February 2019 at 56.0µg m^{-3}, which exceeds the 24 hour mean air quality objective concentration of less than or equal to 50µg m^{-3}. This day is classed in the lowest moderate (4) DAQI band (51-58µg m^{-3}). However up to seven exceedances of the 24 hour mean are allowed as part of the Scottish air quality objective (see Table 2).

It should be noted that this measurement was recorded during a period when elevated PM_{10} concentrations were recorded across Scotland. As an illustration, on 27 February 2019 the rural background site at Auchencorth Moss (which is situated in a remote area) measured a 24 hour mean PM_{10} concentration of 37µg m^{-3}. This is considerably higher than the 2018 annual mean PM_{10} concentration of 7µg m^{-3} (based on data downloaded from the *Measurement and Annual Statistics* webpage of the Air Quality in Scotland website[4]). It is likely this was caused by long range transport of pollution.

Particulate matter $PM_{2.5}$: The average $PM_{2.5}$ concentration measured by continuous analyser over the monitoring period was 8.9µg m^{-3}, which is below the annual mean air quality objective concentration of less than or equal to 10µg m^{-3}.

93 of the 94 measured 24 hour mean $PM_{2.5}$ concentrations were within the low DAQI band (0-35µg m^{-3}), with only the 27 February 2019 classed in the mid-moderate DAQI band (42-47µg m^{-3}). As mentioned above, this coincides with a period of elevated particulate levels across Scotland.

Sulphur dioxide (SO_2): The highest 15 minute mean SO_2 concentration measured over the monitoring period was 36.7µg m^{-3}, which is considerably below the 15 minute mean air quality objective concentration of less than or equal to 266µg m^{-3}.

All measured 15 minute mean SO_2 concentrations were within the lowest DAQI band (0-88µg m^{-3}) throughout the monitoring period.

Benzene, toluene, ethylbenzene, xylene, 1,3 butadiene, nitrogen dioxide and total hydrocarbons – measured at Donibristle, Cowdenbeath, Lochgelly and Little Raith Farm.

Diffusion tube results give an indication of the air pollutant levels in the area they are positioned. The diffusion tube results presented in Table 5 are the mean values of data collected over the three month monitoring period. The individual two week average diffusion tube results are presented in Appendix D. Diffusion tube monitoring does not show how pollutants vary over the short term (e.g. hourly or daily averages).

- **Donibristle** - downwind during wind from a northeasterly direction. A combination of domestic combustion, farming activities and traffic sources are likely to be the main non-site related sources of air pollutants.
- **Lochgelly** - downwind during wind from a southerly direction. Domestic and commercial combustion and traffic are likely to be the main non-site related sources of air pollutants.
- **Cowdenbeath** - downwind during wind from a southeasterly direction. Domestic and commercial combustion and traffic are likely to be the main non-site related sources of air pollutants.

Table 5: Mean diffusion tube-measured air pollutant concentrations at Donibristle, Cowdenbeath, Lochgelly and Little Raith Farm over the period 10 January to 18 April 2019

Pollutant measured by diffusion tube	Donibristle	Cowdenbeath	Lochgelly	Little Raith Farm
	Average Measured Concentration (µg m^{-3})			
Benzene	0.5	0.8	0.6	0.7
Toluene	<1.2	1.2	<1.2	<1.2
Ethylbenzene	<1.3	<1.3	<1.3	<1.3
Xylene	1.4	1.4	1.6	1.4
1,3-Butadiene	<0.2	0.2	<0.2	<0.2
Nitrogen Dioxide	13.9	23.0	14.1	17.4
	Average Measured Concentration (ppb)			
Total Hydrocarbons	7.1	7.0	7.6	6.7

Nitrogen dioxide (NO_2) The average indicative NO_2 concentration measured by diffusion tubes over the three month monitoring period at all sites is considerably below the annual mean air quality objective concentration of less than or equal to 40µg m^{-3}.

- **Cowdenbeath** - The higher value measured here is likely to be due to the proximity of the A92 and other local traffic sources.
- **Little Raith Farm -** The average nitrogen dioxide concentration measured by diffusion tube is higher than the concentration measured by the continuous analyser but is considerably below the annual mean air quality objective concentration. The continuous analyser is a more accurate methodology than the diffusion tube monitoring, and therefore we have greater confidence in the data collected by this means.

Benzene: The average diffusion tube-measured benzene concentrations over the monitoring period were all considerably below the Scottish running annual mean air quality objective concentration of less than or equal to 3.25µg m^{-3}.

1,3-Butadiene: The average diffusion tube-measured 1,3-butadiene concentrations over the monitoring period were all considerably below the UK running annual mean air quality objective concentration of less than or equal to 2.25µg m^{-3}.

There are no short term national air quality objectives or daily air quality indices for benzene or 1,3-butadiene.

Toluene, Ethylbenzene, Xylene, Total Hydrocarbons: There are no short or long term national air quality objectives or daily air quality indices for these parameters. These pollutants were measured to allow comparison against data collected in previous studies, and to aid any future comparisons.

Conclusions

A three month monitoring study of the air quality in the vicinity of the Mossmorran complex was undertaken to determine whether there were any significant impacts on local air quality from the complex. Four monitoring locations were chosen. A trailer containing continuous air quality monitoring analysers was located at Little Raith Farm to the northeast of the complex; diffusion tubes were located at Little Raith Farm and three other locations around the complex. A weather station was located at Little Raith Farm.

The wind direction and speed measured over the three month monitoring period was comparable to that measured at Gogarbank Met Office weather station over the preceding five year period and was deemed to be representative of a normal weather pattern.

Over the period of the study a monitoring trailer was used to measure the pollutants nitrogen dioxide, sulphur dioxide, carbon monoxide, particulate matter (PM_{10} and $PM_{2.5}$); diffusion tubes were used to determine levels of benzene, toluene, ethylbenzene, xylene, 1,3 butadiene, nitrogen dioxide and total hydrocarbons (C_4 to C_{10}).

There were no breaches of any of the air quality objectives. The air quality objectives relate to air quality monitored over the period of a year, partly to account for the seasonal variation in winds. This study was limited to a period of three months and therefore relies on the period being representative to compare to the objectives. We have demonstrated that the wind conditions during the monitoring period were representative of the general wind patterns in the area. This strengthens the comparison between the measured data and the objectives, giving a useful indication of the air quality over the longer term.

All measurements were in the low band of Defra's daily air quality index (DAQI) for all applicable pollutants, with the exception of particulate matter (PM_{10} and $PM_{2.5}$) which were in the moderate DAQI band on one day (27 February 2019). This coincides with a period of elevated particulate matter across Scotland, probably caused by long range transport of pollution.

Where there are no air quality standards or DAQI for the remaining pollutants measured, the results are presented for historical or future comparisons.

References

1 *Air Quality: Public Health Impacts and Local Actions*, Department for Environment Food & Rural Affairs (Defra) website, https://laqm.defra.gov.uk/documents/air_quality_note_v7a-(3).pdf, accessed on 14 August 2019

2 *Standards*, Air Quality in Scotland website: http://www.scottishairquality.scot/air-quality/standards, hosted and maintained by Ricardo Energy & Environment on behalf of the Scottish Government, accessed on 16 July 2019

3 *Daily Air Quality Index*, UK AIR website: https://uk-air.defra.gov.uk/air-pollution/daqi, Department for Environment Food & Rural Affairs (Defra), accessed on 16 July 2019

4 *Measurement and Annual Statistics,* Air Quality in Scotland website: http://www.scottishairquality.scot/data/data-selector, hosted and maintained by Ricardo Energy & Environment on behalf of the Scottish Government, accessed on 18 July 2019

5 *Unit Conversion*, Air Pollution Information System (APIS) website: http://www.apis.ac.uk/unit-conversion, hosted and maintained by the Centre for Ecology & Hydrology (CEH), accessed on 17 July 2019

6 *Conversion Factors Between ppb and µg m^{-3} and ppm and mgm^{-3},* UK AIR website: https://uk-air.defra.gov.uk/assets/documents/reports/cat06/0502160851_Conversion_Factors_Between_ppb_and.pdf (Ricardo-aea, August 2014), Department for Environment Food & Rural Affairs (Defra), accessed on 16 July 2019

7 SEPA Procedure ES-NFC-WP-019, *Construction, configuration and use of the Campbell Scientific weather station with the CR10/CR10X data logger,* Issue no.4

8 BS EN 14211:2012 *Ambient air. Standard method for the measurement of the concentration of nitrogen dioxide and nitrogen monoxide by chemiluminescence,* BSI Standards Publication, The British Standards Institution 2012

9 SEPA Procedure ES-NFC-WP-013A, *Measurement of ambient NO-NO2-NOX from the AHER long term monitoring trailer using a Teledyne T200 nitrogen oxide analyser, Issue no. 2*

10 BS EN 14212:2012 *Ambient air - Standard method for the measurement of the concentration of sulphur dioxide by ultraviolet fluorescence,* incorporating corrigendum April 2014, BSI Standards Publication, The British Standards Institution 2014

11 SEPA Procedure ES-NFC-WP-014, *Measurement of ambient sulphur dioxide using a TEI 43C or Teledyne T100 pulsed fluorescence analyser, Issue no.11*

12 British Standard, BS EN14626:2012 *Ambient air - Standard method for the measurement of the concentration of carbon monoxide by non – dispersive infrared spectroscopy*, BSI Standards Publication, The British Standards Institution 2012

13 SEPA Procedure ES-NFC-WP-062, *Measurement of ambient carbon monoxide using a Teledyne T300 non-dispersive infrared analyser*, Issue no. 1

14 SEPA Procedure ES-NFC-WP-020, *Measurement of ambient particulate matter from the AHER Long Term Monitoring Trailer*, Issue no. 3

15 *Monitoring Ambient Air*, Technical Guidance Note (Monitoring) M8, Environment Agency, Version 2, 2011

Appendix A: Equipment Details and Methodologies

Diffusion tubes

NO_2 diffusion tube monitoring was completed using Palmes-type diffusion tubes. These were deployed at 4 locations for 7 consecutive 14 day-periods from 10 January 2019 to 18 April 2019. VOC diffusion tube monitoring was carried out using ATD type diffusion tubes. These were deployed concurrently with the NO_2 tubes. The tubes and analysis were supplied by the National Physical Laboratory (NPL). Quality assurance of the diffusion tube data analysis was carried out by NPL. All sample tubes passed the quality control checks. Analysis of 'travel blank' tubes submitted along with the monitoring location sample tubes measured concentrations below detection limits for all tubes and determinands.

The results from NPL were reported to SEPA in parts per billion (ppb), these results have been converted into mass concentrations measured in micrograms per cubic metre (µg m^{-3}). A ppb to µg m^{-3} conversion factor has been applied for each measured parameter. These conversion factors have been calculated using the unit conversion tool on the Air Pollution Information System (APIS) website[5]. A summary of the conversion factors is provided in Table A1.

The results for total hydrocarbons are reported in ppb as conversion to a mass concentration is not possible when analysing for multiple compounds with different molecular weights.

Table A1: Conversion factors for each diffusion tube measured parameter at 20°C and 1013mb.

Compound	Molecular Weight (g/mol)	Conversion Factor 1 ppb =
Nitrogen dioxide	46.006	1.9125 µg m^{-3} *
Benzene	78.11	3.2430 µg m^{-3} *
Toluene	92.14	3.831 µg m^{-3}
Ethylbenzene	106.17	4.414 µg m^{-3}
Xylene	106.17	4.414 µg m^{-3}
1,3-Butadiene	54.092	2.2452 µg m^{-3} *
Total Hydrocarbons (C4-C10)	Not applicable	Not applicable

*from *Conversion Factors Between ppb and µg m^{-3} and ppm and mg m^{-3},* UK AIR website[6]

Weather Station

A Campbell Scientific CR200 weather station was set up and operated according to SEPA in-house procedure ES-NFC-WP-019[7].

Continuous Analysers

The automatic real-time analysers produce high resolution measurements averaged over 15 minute periods. Once deployed, the analysers underwent fortnightly calibration checks, using certified check gas cylinders. The analysers were calibrated, and checked for precision, before being deployed in the field.

NO_2 monitoring was completed using a calibrated Teledyne API Model T200 NO_x analyser, working to the principles of British Standard BS EN 14211:2012[8] following SEPA procedure ES-NFC-WP-013A[9]. The Teledyne T200 is a chemiluminescent analyser which is certified (Sira MC050068/11 issued 08 March 2016) to measure NO_2 in the range 0 to 500ppb and NO in the range 0 to 1000ppb. Initially the NO_2 concentrations were measured in parts per billion (ppb). The ppb results have subsequently been converted into mass concentrations with units of micrograms per cubic metre (µg m^{-3}) by applying a conversion factor of 1.9125 based on Defra's (20°C and 1013mb) conversion factor for reporting data to the European Commission[6].

SO_2 monitoring was completed using a calibrated Teledyne API Model T100 SO_2 analyser, working to the principles of British Standard BS EN 14212:2012[10] following SEPA procedure ES-NFC-WP-014[11]. The Teledyne T100 is a UV fluorescence analyser which is certified (Sira MC050067/07 issued 23 February 2016) to measure SO_2 in the range 0 to 500ppb. The ppb results have subsequently been converted into mass concentrations with units of micrograms per cubic metre (µg m^{-3}) by applying a conversion factor of 2.6609 based on Defra's (20°C and 1013mb) conversion factor for reporting data to the European Commission[6].

CO monitoring was completed using a calibrated Teledyne API Model T300 CO analyser, working to the principles of British Standard BS EN 14626:2012[12] following SEPA procedure ES-NFC-WP-062[13]. The Teledyne T300 is a gas filter correlation analyser which is certified (Sira MC050069/07 issued 23 February 2016) to measure CO in the range 0 to 50ppm (0 to 50 000ppb). The measured ppb results have subsequently been converted into mass concentrations with units of milligrams per cubic metre (mg m^{-3}) by applying a conversion factor of 0.0011642 based on Defra's (20°C and 1013mb) conversion factor for reporting data to the European Commission[6].

PM_{10} and $PM_{2.5}$ monitoring was completed using a calibrated GRIMM Aerosol Technik Ainring GmbH & Co. Model EDM180 PM analyser, following SEPA procedure ES-NFC-WP-020[14]. The GRIMM EDM180 is a light scattering-type analyser which is certified (Sira MC120198/04 issued 08 February 2018) to measure PM_{10} in the range 0 to 10,000µg m^{-3} and $PM_{2.5}$ in the range 0 to 6,000µg m^{-3}. *This certificate applies to all PM_{10} and $PM_{2.5}$ instruments EDM 180 fitted with firmware version 7.80 onwards (serial number 18A12020 onwards).*

Appendix B: Photographic Record of Monitoring Sites

Figure B1: Photographic record of the monitoring sites in the vicinity of Mossmorran between 10 January 2019 and 18 April 2019

Appendix C: Quality Control – Continuous Analysers

The continuous analysers used in this investigation were calibrated in-line with the procedures documented in Appendix A. Once deployed the analysers were calibration checked *in situ* on a fortnightly basis, using certified 'span' gas cylinders and zero air (generated by passing the ambient air through a series of air scrubbers containing silica gel, Purafil and activated charcoal). Tables C1 to C5 present a summary of the quality control data for each analyser and parameter. The associated tolerances for zero and span checks are drawn from the relevant British Standards, documented in Appendix A, and are stated in the notes section of each table.

Carbon monoxide (CO)

Table C1 : Quality control data for the CO analyser

Carbon Monoxide (CO)				
Instrument:	Teledyne T300			
Calibration date:	16/11/2018			
Deployment date:	07/01/2019			
Collection date:	18/04/2019			
Date	Instrument serial no.	Zero check* (ppb)	Span check** (ppb)	% Span drift
09/01/2019	SN76	152.3	40393.0	
17/01/2019	SN76	-20.0	39625.0	-1.9
31/01/2019	SN76	151.0	40759.0	0.9
07/02/2019	SN76	174.1	40784.8	1.0
21/02/2019	SN76	230.0	40792.0	1.0
07/03/2019	SN76	247.1	41034.0	1.6
15/03/2019	SN76	278.3	41215.9	2.0
21/03/2019	SN76	261.0	41081.0	1.7
28/03/2019	SN76	280.0	41137.0	1.8
11/04/2019	SN76	314.0	41009.0	1.5
18/04/2019	SN76	415.0	41089.0	1.7

Notes:
** Zero check: Air drawn through silica gel, Purafil and activated carbon; zero check action criteria ≥ 0.5 ppm (500 ppb)*
*** Span check: Span check gas - initial span at 40393 ppb CO (SEPA ref: GAS 080.1); span check action criteria ≥ 5 % of initial span value*

All manual zero and span checks were within the zero and span check action criteria values for CO throughout the period of monitoring.

Nitrogen dioxide (NO_2)

Table C2 : Quality control data for the NO_2 analyser

Oxides of Nitrogen (NOx)				
Instrument:	Teledyne T200			
Calibration date:	15/11/2018			
Deployment date:	07/01/2019			
Collection date:	18/04/2019			
Date	Instrument serial no.	Zero check* (ppb)	Span check**(ppb)	% Span drift
09/01/2019	SN81	0.4	476.2	
17/01/2019	SN81	0.1	470.4	-1.2
31/01/2019	SN81	0.4	476.2	0.0
07/02/2019	SN81	0.1	464.3	-2.5
21/02/2019	SN81	0.4	461.8	-3.0
07/03/2019	SN81	0.4	462.3	-2.9
15/03/2019	SN81	0.3	452.4	-5.0
21/03/2019	SN81	0.0	458.0	-3.8
28/03/2019	SN81	0.8	460.0	-3.4
11/04/2019	SN81	2.0	456.2	-4.2
18/04/2019	SN81	0.6	454.9	-4.5

Notes:
** Zero check: Air drawn through silica gel, Purafil and activated carbon; zero check action criteria ≥ 4 ppb*
*** Span check: Span check gas - initial span at 476.2 ppb NO (SEPA ref: GAS 068.1); span check action criteria ≥ 5 % of initial span value*

The analyser converts the incoming nitrogen dioxide (NO_2) gas to nitrogen monoxide (NO) and therefore the span check gas used is NO. All manual zero and span checks were within the zero and span check action criteria values for nitrogen dioxide throughout the period of monitoring, with the exception of the manual span check on 15/03/2019 which was at the span check action criteria value. The data between 07/03/2019 and 21/03/2019 should be treated as indicative only.

Sulphur dioxide (SO_2)

Table C3 : Quality control data for the SO_2 analyser

Sulphur Dioxide (SO_2)				
Instrument:	Teledyne T100			
Calibration date:	14/11/2018			
Deployment date:	07/01/2019			
Collection date:	21/03/2019			
Date	Instrument serial no.	Zero check* (ppb)	Span check**(ppb)	% Span drift
09/01/2019	SN102	2.2	550.0	
17/01/2019	SN102	3.9	559.4	1.7
31/01/2019	SN102	3.7	551.9	0.3
07/02/2019	SN102	4.2	550.6	0.1
21/02/2019	SN102	1.6	540.0	-1.8
07/03/2019	SN102	4.8	554.9	0.9
15/03/2019	SN102	3.8	557.2	1.3
20/03/2019	SN102	4.0	557.2	1.3

Notes:
** Zero check: Air drawn through silica gel, Purafil and activated carbon; zero check action criteria ≥ 4 ppb*
*** Span check: Span check gas - initial span at 550.0 ppb SO2 (SEPA ref: GAS 075.3); span check action criteria ≥ 5 % of initial span value*

Table C4 : Quality control data for the replacement SO_2 analyser

Sulphur Dioxide (SO_2)				
Instrument:	Teledyne T100			
Calibration date:	20/03/2019			
Deployment date:	21/03/2019			
Collection date:	18/04/2019			
Date	Instrument serial no.	Zero check* (ppb)	Span check**(ppb)	% Span drift
21/03/2019	SN82	0.3	542.0	
28/03/2019	SN82	0.2	544.0	0.4
11/04/2019	SN82	2.5	543.6	0.3
18/04/2019	SN82	2.8	533.4	-1.6

Notes:
** Zero check: Air drawn through silica gel, Purafil and activated carbon; zero check action criteria ≥ 4 ppb*
*** Span check: Span check gas - initial span at 542.0 ppb SO2 (SEPA ref: GAS 075.3); span check action criteria ≥ 5 % of initial span value*

Due to the zero checks being >4.0ppb for T100 serial number 102, a second T100 analyser (serial number 82) was calibrated and installed for the period 21/03/2019 to 18/04/2019. The zero checks undertaken on 07/02/2019, 07/03/2019 and 20/03/2019 were above the zero check action criteria of 4ppb, however a replacement analyser was unavailable. Therefore data over the period 31/01/2019 to 21/03/2019 are reported, but should be treated as indicative only.

Particulate matter ($PM_{2.5}$ & PM_{10})

Table C5 : Quality control data for the particulate matter analyser

Suspended Particulate Matter (PM_{10} & $PM_{2.5}$)	
Instrument:	GRIMM EDM180
Calibration date:	02/05/2018*
Deployment date:	07/01/2019
Collection date:	18/04/2019
* *Calibrated externally by manufacturer (GRIMM)*	

Uncertainty of continuous analysers

The continuous analyser results presented in Table 4 have been ratified, following SEPA quality control procedures. However all measurement results have an associated 'degree of uncertainty' which defines the limits within which the true value lies to a specified level of confidence. The quality control procedures are designed to reduce uncertainties to a minimum and to quantify the overall uncertainties that remain.

The expanded uncertainty for the PM_{10} and $PM_{2.5}$ measurements is expected to be ≤25% as reported in the GRIMM EDM180 Sira MCERTS certification stated in Appendix A. The expanded uncertainties for the CO, NO_2 and SO_2 measurements are expected to be ≤15% as reported in the Sira MCERTS certification for each gas analyser detailed in Appendix A. The SO_2 and NO_2 data collected during the periods highlighted above, when the analysers operated slightly outwith the acceptable quality control parameters (i.e. exceedance of zero and/or span action criteria values), may have a greater associated uncertainty. Similarly, the averaged data for periods of less than 75% data capture have a higher level of uncertainty associated, and should be treated as indicative values.

Appendix D: Diffusion Tube Results

The diffusion tubes were prepared and analysed by the National Physical Laboratory (NPL), and deployed and collected by SEPA. The analysis results were received from NPL quoted in units of parts per billion (ppb). The diffusion tube analysis results for each 14 day deployment period between 10 January and 18 April 2018, and the calculated overall 98 day average, are presented adjusted from the originally reported ppb values to mass concentration values as micrograms per cubic metre (µg m^{-3}) at 20°C and 1013 mbar (based on the conversion factors stated in Appendix A).

Table D1 (continued on following pages): Combined summary of diffusion tube results from Donibristle, Cowdenbeath, Lochgelly and Little Raith Farm over the period 10 January 2019 to 18 April 2019, adjusted from original NPL-reported ppb results to provide mass concentration values, where possible

Period			**Average Benzene Concentration (µg m^{-3})**			
Start Date	End Date	Exposure time (days)	Donibristle	Cowdenbeath	Lochgelly	Little Raith Farm
10/01/2019	24/01/2019	14	0.6	0.6	0.3	0.6
24/01/2019	07/02/2019	14	0.6	1.0	0.6	<0.3
07/02/2019	21/02/2019	14	0.3	0.6	1.0	<0.3
21/02/2019	07/03/2019	14	1.0	1.3	0.6	1.0
07/03/2019	21/03/2019	14	0.3	1.0	1.0	1.3
21/03/2019	04/04/2019	14	0.6	0.6	0.6	0.6
04/04/2019	18/04/2019	14	0.3	0.6	0.3	0.6
10/01/2019	**18/04/2019**	**98**	**0.5**	**0.8**	**0.6**	**0.7**

Period			**Average Toluene Concentration (µg m^{-3})**			
Start Date	End Date	Exposure time (days)	Donibristle	Cowdenbeath	Lochgelly	Little Raith Farm
10/01/2019	24/01/2019	14	<1.2	<1.2	<1.2	<1.2
24/01/2019	07/02/2019	14	<1.2	1.2	<1.2	<1.2
07/02/2019	21/02/2019	14	<1.2	<1.2	<1.2	<1.2
21/02/2019	07/03/2019	14	<1.2	1.5	<1.2	<1.2
07/03/2019	21/03/2019	14	<1.2	<1.2	<1.2	<1.2
21/03/2019	04/04/2019	14	<1.2	<1.2	<1.2	<1.2
04/04/2019	18/04/2019	14	<1.2	<1.2	<1.2	<1.2
10/01/2019	**18/04/2019**	**98**	**<1.2**	**1.2**	**<1.2**	**<1.2**

Period			Average Ethylbenzene Concentration (µg m^{-3})			
Start Date	End Date	Exposure time (days)	Donibristle	Cowdenbeath	Lochgelly	Little Raith Farm
10/01/2019	24/01/2019	14	<1.3	<1.3	<1.3	<1.3
24/01/2019	07/02/2019	14	<1.3	<1.3	<1.3	<1.3
07/02/2019	21/02/2019	14	<1.3	<1.3	<1.3	<1.3
21/02/2019	07/03/2019	14	<1.3	<1.3	<1.3	<1.3
07/03/2019	21/03/2019	14	<1.3	<1.3	<1.3	<1.3
21/03/2019	04/04/2019	14	<1.3	<1.3	<1.3	<1.3
04/04/2019	18/04/2019	14	<1.3	<1.3	<1.3	<1.3
10/01/2019	**18/04/2019**	**98**	**<1.3**	**<1.3**	**<1.3**	**<1.3**

Period			Average Xylene Concentration (µg m^{-3})			
Start Date	End Date	Exposure time (days)	Donibristle	Cowdenbeath	Lochgelly	Little Raith Farm
10/01/2019	24/01/2019	14	1.8	1.3	<1.3	<1.3
24/01/2019	07/02/2019	14	<1.3	1.3	<1.3	<1.3
07/02/2019	21/02/2019	14	<1.3	<1.3	1.3	<1.3
21/02/2019	07/03/2019	14	<1.3	1.8	<1.3	1.8
07/03/2019	21/03/2019	14	<1.3	1.3	3.1	<1.3
21/03/2019	04/04/2019	14	<1.3	<1.3	<1.3	<1.3
04/04/2019	18/04/2019	14	<1.3	<1.3	<1.3	<1.3
10/01/2019	**18/04/2019**	**98**	**1.4**	**1.4**	**1.6**	**1.4**

Period			Average Total Hydrocarbons Concentration (ppb)			
Start Date	End Date	Exposure time (days)	Donibristle	Cowdenbeath	Lochgelly	Little Raith Farm
10/01/2019	24/01/2019	14	15.0	8.0	<5.0	5.0
24/01/2019	07/02/2019	14	5.0	9.0	7.0	7.0
07/02/2019	21/02/2019	14	<5.0	5.0	7.0	<5.0
21/02/2019	07/03/2019	14	10.0	12.0	8.0	15.0
07/03/2019	21/03/2019	14	<5.0	<5.0	14.0	5.0
21/03/2019	04/04/2019	14	<5.0	<5.0	7.0	<5.0
04/04/2019	18/04/2019	14	<5.0	<5.0	<5.0	<5.0
10/01/2019	**18/04/2019**	**98**	**7.1**	**7.0**	**7.6**	**6.7**

Period			Average 1,3-Butadiene Concentration (µg m^{-3})			
Start Date	End Date	Exposure time (days)	Donibristle	Cowdenbeath	Lochgelly	Little Raith Farm
10/01/2019	24/01/2019	14	<0.2	<0.2	<0.2	<0.2
24/01/2019	07/02/2019	14	<0.2	0.4	<0.2	<0.2
07/02/2019	21/02/2019	14	<0.2	<0.2	<0.2	<0.2
21/02/2019	07/03/2019	14	<0.2	<0.2	<0.2	<0.2
07/03/2019	21/03/2019	14	<0.2	<0.2	<0.2	<0.2
21/03/2019	04/04/2019	14	<0.2	<0.2	<0.2	<0.2
04/04/2019	18/04/2019	14	<0.2	<0.2	<0.2	<0.2
10/01/2019	**18/04/2019**	**98**	**<0.2**	**0.2**	**<0.2**	**<0.2**

Period			Average Nitrogen Dioxide Concentration (µg m^{-3})			
Start Date	End Date	Exposure time (days)	Donibristle	Cowdenbeath	Lochgelly	Little Raith Farm
10/01/2019	24/01/2019	14	22.2	26.4	19.3	23.9
24/01/2019	07/02/2019	14	22.5	33.0	20.1	22.9
07/02/2019	21/02/2019	14	11.5	23.5	14.9	23.5
21/02/2019	07/03/2019	14	16.6	29.6	18.3	20.1
07/03/2019	21/03/2019	14	8.6	15.1	8.8	13.0
21/03/2019	04/04/2019	14	9.4	15.9	9.6	12.4
04/04/2019	18/04/2019	14	6.3	17.6	8.0	6.3
10/01/2019	**18/04/2019**	**98**	**13.9**	**23.0**	**14.1**	**17.4**

Notes:

The 14 day average concentrations for each parameter below the detection limit for the analysis technique have been reported as less than (<) the detection limit, but for the purposes of calculating the monitoring period average have been included as equal to the detection limit.

The diffusion tube results presented in Table 5 (which have been summarised from the results tabulated here in Table D1) have been reported directly from the original NPL certificates of analysis, with a mass concentration conversion factor applied. No bias correction factor has been applied to the overall NO_2 result.

Statement received from NPL: The uncertainty associated with the benzene, toluene, ethylbenzene, xylene & 1,3-butadiene results is ±30%, taking into account sampling and analysis. The uncertainty for NO_2 is ±25%. The total hydrocarbon values do not have a quoted uncertainty and are for indication only.

Appendix E: Measured Pollutant Concentrations – Charts

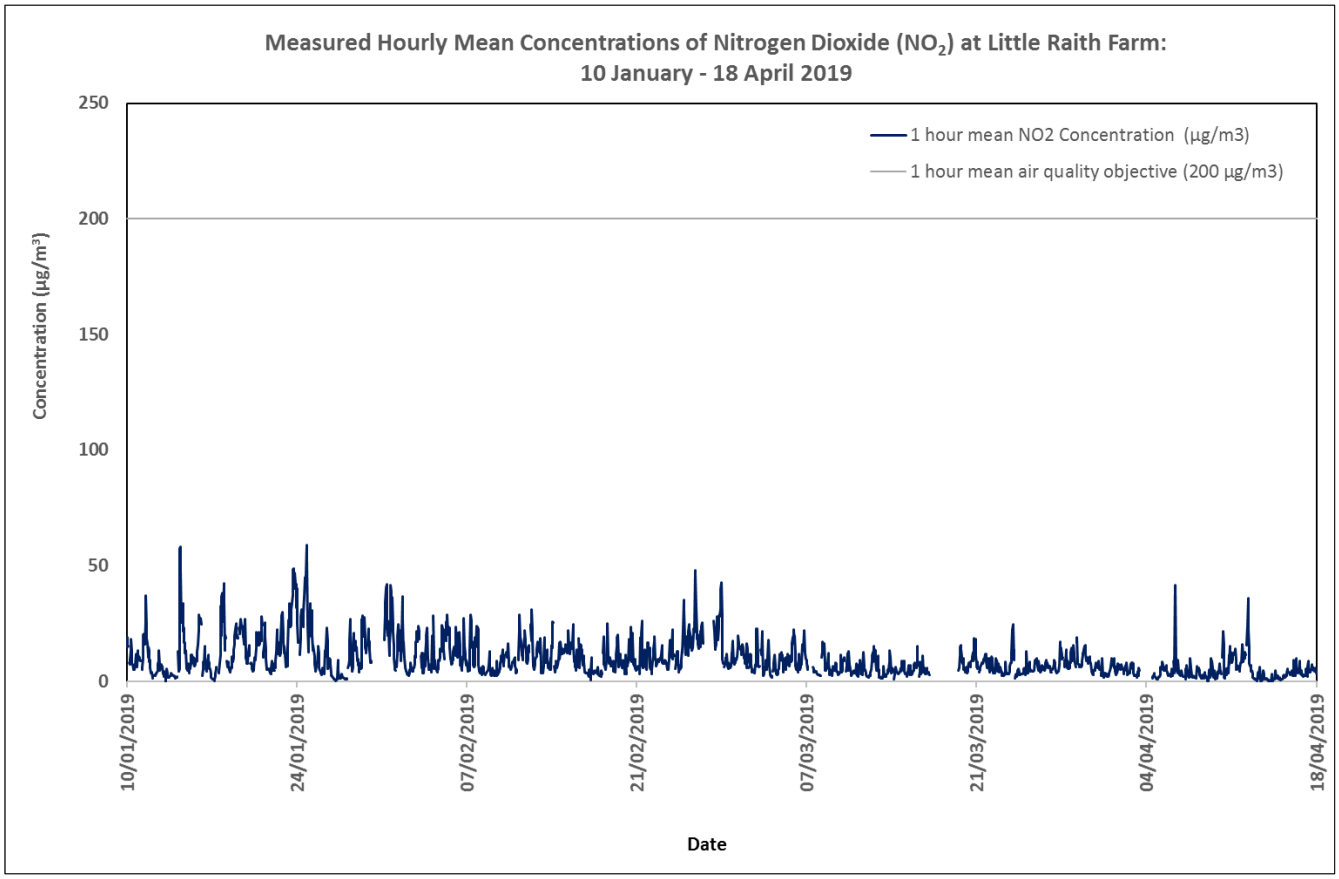

Figure E1: Hourly mean NO_2 concentrations measured at Little Raith Farm between 10 January 2019 and 18 April 2019

Notes:

The 1 hour mean UK and Scottish air quality objective for NO_2 is 200µg m^{-3} (not to be exceeded more than 18 times in a year). The annual mean UK and Scottish air quality objective for NO_2 is 40µg m^{-3}.

The continuous nitrogen dioxide monitoring data has been collected as 15 minute-average data. However it has been reported in the form of 1 hour mean values to allow comparison with the air quality objective 1 hour mean value and the daily air quality index. As stipulated in the Environment Agency's Technical Guidance Note M8[15], each new data point must be the average of at least 75% data, therefore a 1 hour mean requires 45 minutes of data within the preceding hour to achieve 75%. It should be noted that in order to maximise the data capture in this investigation, hourly mean periods of less than 75% data capture have also been reported.

The overall percentage data capture for nitrogen dioxide over the monitoring period (based on the 15 minute-average data) is 88% (as reported in Table 4).

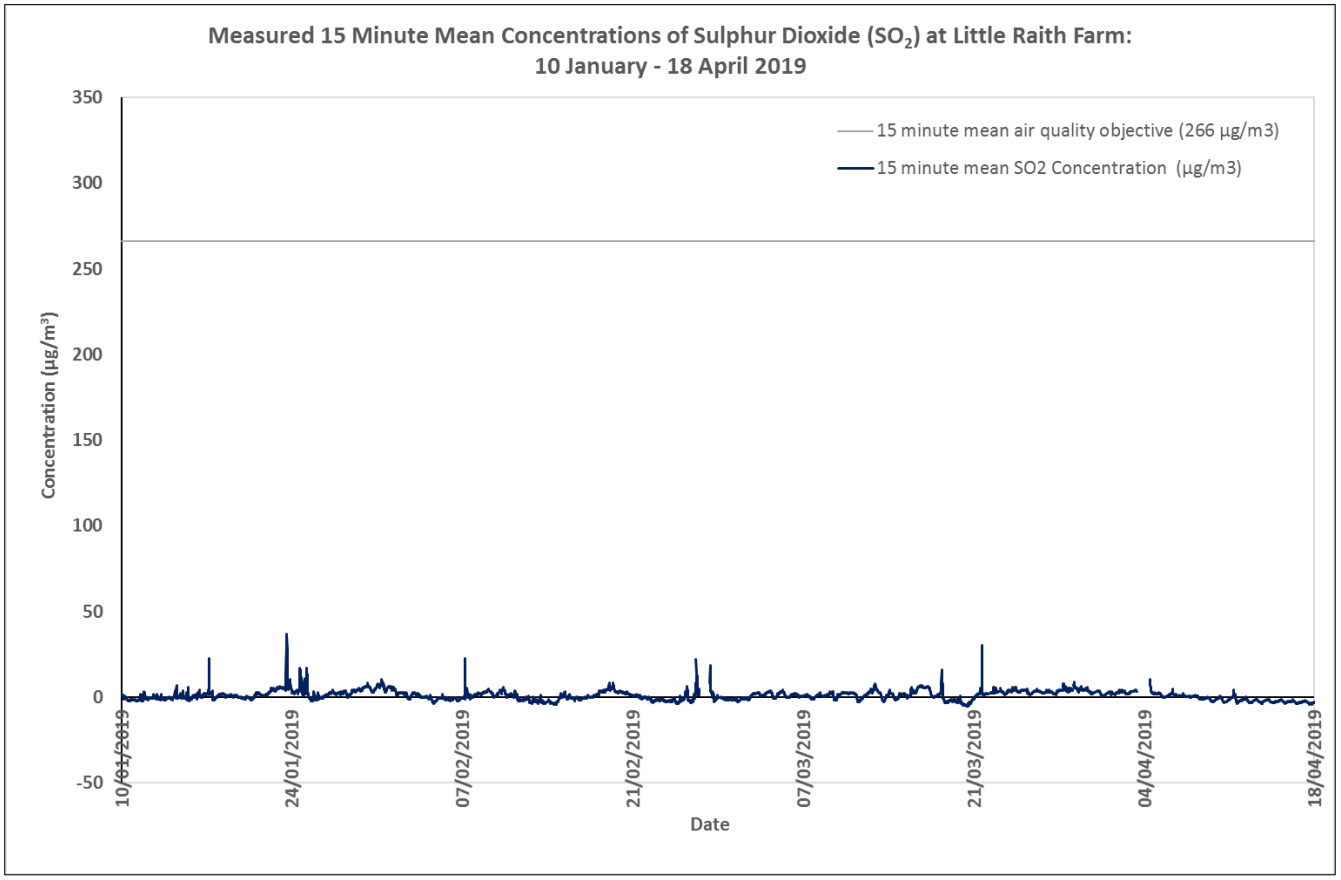

Figure E2: 15 minute mean SO_2 concentrations measured at Little Raith Farm between 10 January 2019 and 18 April 2019

Notes:

The 15 minute mean UK and Scottish air quality objective for SO_2 is 266µg m^{-3} (not to be exceeded more than 35 times in a year). The 1 hour mean UK and Scottish air quality objective for SO_2 is 350µg m^{-3} (not to be exceeded more than 24 times in a year). The daily mean UK and Scottish air quality objective for SO_2 is 125µg m^{-3} (not to be exceeded more than 3 times in a year).

The continuous sulphur dioxide monitoring data has been collected as 15 minute-average data. It has been reported in the form of 15 minute mean values to allow comparison with the air quality objective 15 minute mean value and the daily air quality index. It has also been reported as 1 hour mean values to allow comparison with the air quality objective 1 hour mean value. It should be noted that in order to maximise the data capture in this investigation, hourly mean periods of less than 75% data capture have also been reported.

The overall percentage data capture for sulphur dioxide over the monitoring period (based on the 15 minute-average data) is 93% (as reported in Table 4).

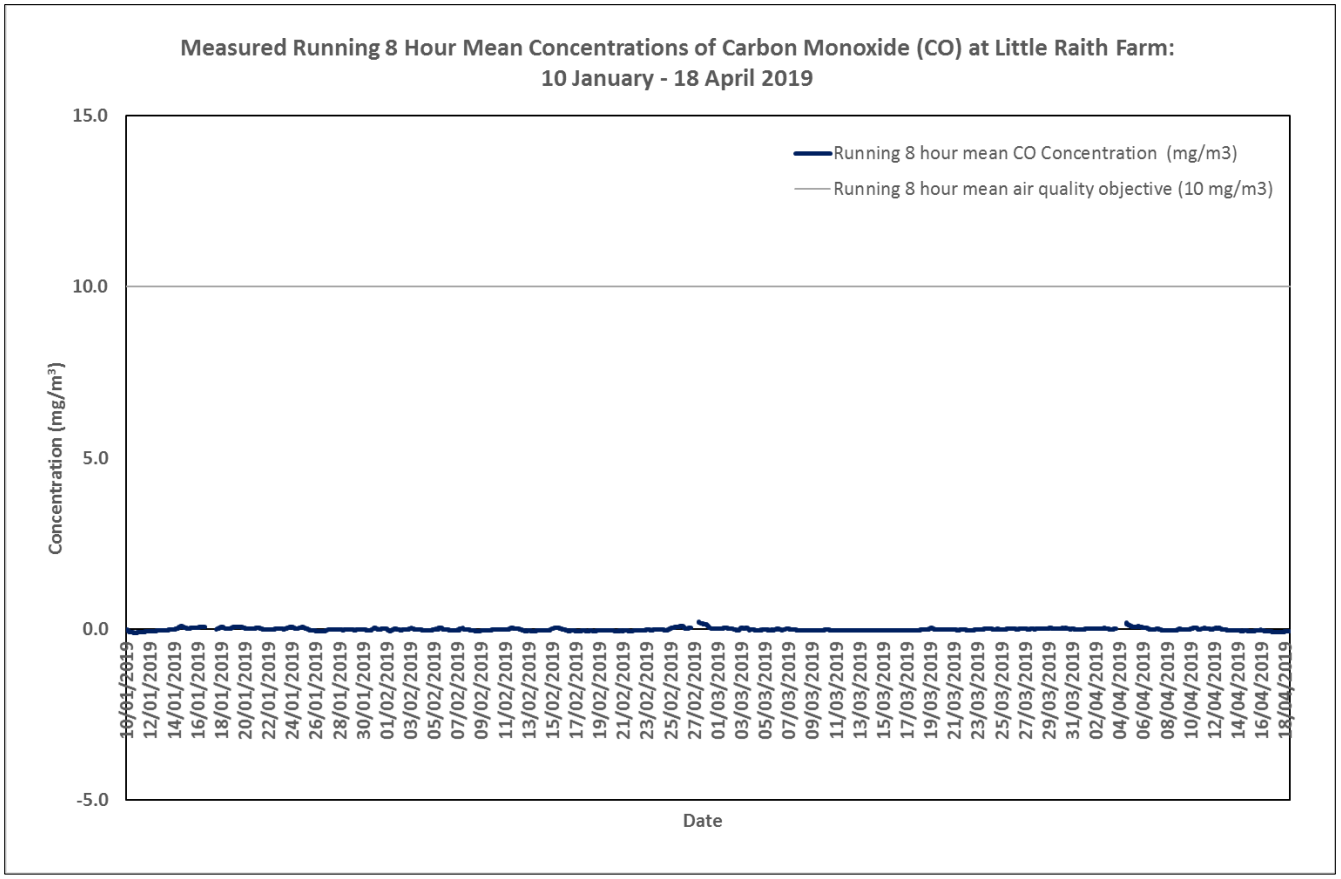

Figure E3: 8-hour running mean CO concentrations measured at Little Raith Farm between 10 January 2019 and 18 April 2019

Notes:
The running 8 hour mean Scottish air quality objective for CO is 10mg m^{-3}.

The continuous carbon monoxide monitoring data has been collected as 15 minute-average data. However it has been reported in the form of 8 hour running mean values to allow comparison with the air quality objective value. It should be noted that in order to maximise the data capture in this investigation, 8 hour running mean periods of less than 75% data capture have also been reported.

The overall percentage data capture for carbon monoxide over the monitoring period (based on the 15 minute-average data) is 96% (as reported in Table 4).

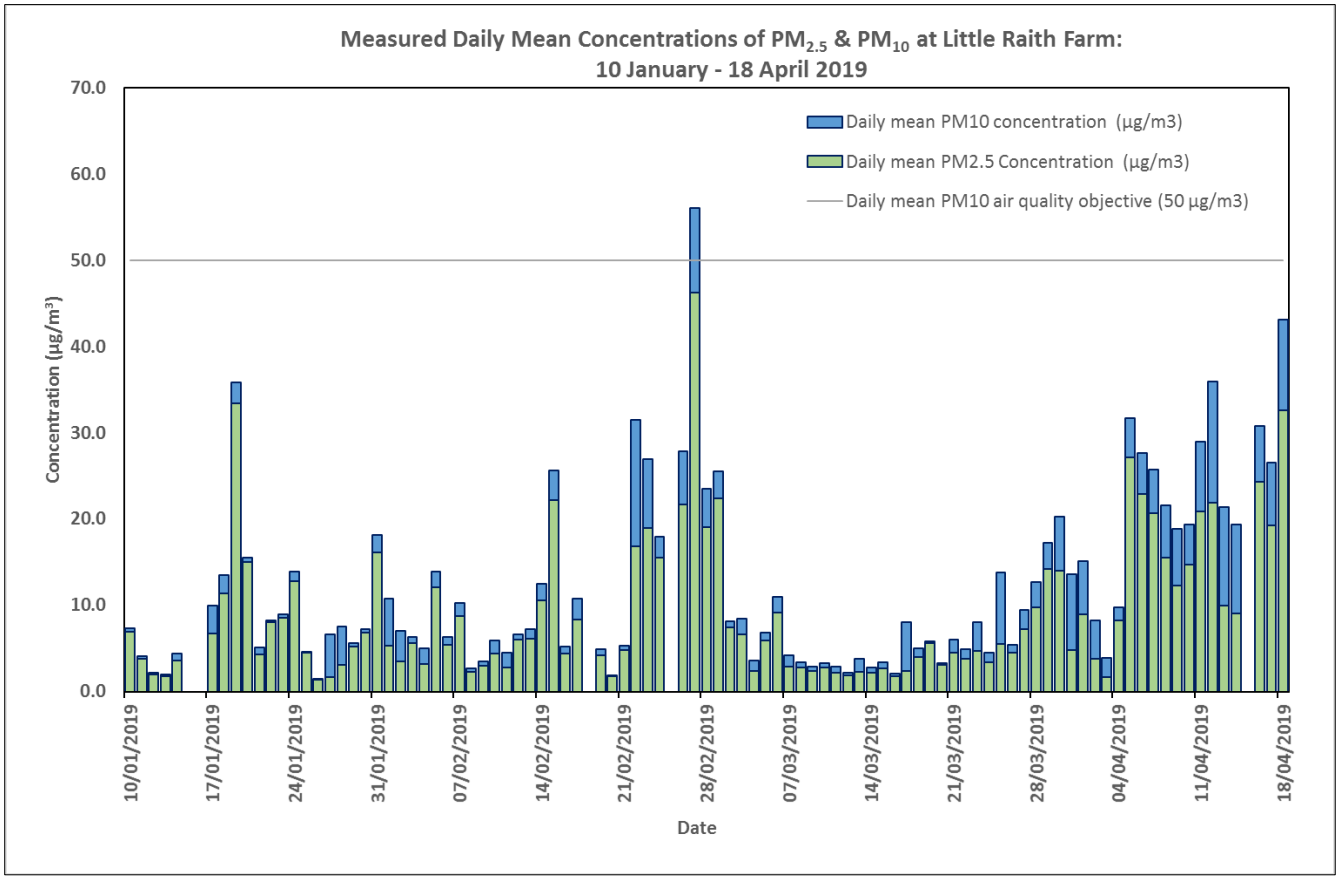

Figure E4: Daily mean $PM_{2.5}$ and PM_{10} concentrations measured at Little Raith Farm between 10 January 2019 and 18 April 2019

Notes:
The 24 hour mean Scottish air quality objective for PM_{10} is 50µg m^{-3} (not to be exceeded more than 7 times in a year). The annual mean Scottish air quality objective for PM_{10} is 18µg m^{-3}. The annual mean Scottish air quality objective for $PM_{2.5}$ is 10µg m^{-3}.

The continuous PM_{10} and $PM_{2.5}$ monitoring data collected as 15 minute-average data has been reported in the form of 24 hour (daily) mean values to allow comparison with the air quality objective 24 hour (daily) mean value and the daily air quality index. It should be noted that in order to maximise the data capture in this investigation, 24 hour mean periods of less than 75% data capture (i.e. days with less than 18 hours of captured data) have also been reported. No daily mean values have been reported for 15/01/2019, 16/01/2019, 18/02/2019, 25/02/2019 and 15/04/2019 as no data was captured on these 5 days due to instrument error.

The overall percentage data capture for PM_{10} and $PM_{2.5}$ over the monitoring period (based on the 15 minute-average data) is 91% (as reported in Table 4).