SEPA
Scottish Environment Protection Agency
Buidheann Dìon Àrainneachd na h-Alba

# Air Quality Monitoring

# Mossmorran

# August 2019 – March 2020

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## 1.1 Executive Summary

Following the temporary shutdown of the Fife Ethylene Plant a study was commissioned to monitor air quality in the vicinity of the Mossmorran Complex during the plant shutdown and subsequent start up. The study ran between August 2019 and March 2020 with monitoring undertaken at multiple locations. The continuous measurement of particulate matter ($PM_{10}$ and $PM_{2.5}$) at Auchtertool, Donibristle and Lochgelly was established immediately. Subsequent expansion of the study added continuous air quality monitoring for a wider suite of pollutants at Little Raith, and diffusion tube sampling at Cowdenbeath, Donibristle, Little Raith and Lochgelly.

Particulate monitoring was undertaken at Auchtertool, Donibristle and Lochgelly from the onset of the plant shut-down. Diffusion tubes, used to determine levels of benzene, toluene, ethylbenzene, xylene, 1,3 butadiene, nitrogen dioxide and total hydrocarbons ($C_4$ to $C_{10}$), were subsequently deployed at Cowdenbeath, Donibristle, Little Raith and Lochgelly in anticipation of the plant restarting. The monitoring trailer containing continuous air quality monitoring analysers, which measure the pollutants nitrogen dioxide, sulphur dioxide, carbon monoxide and particulate matter ($PM_{10}$ and $PM_{2.5}$), was installed at Little Raith. The trailer was intended to expand upon existing monitoring capabilities prior to the rescheduled restart. A weather station was located at Lochgelly throughout the shutdown and restart.

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 seven months and therefore relies on the wind during the period being representative to allow comparison against 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 applicable pollutants. The data collected was compared to other air quality monitoring sites in the region and it was found to largely follow trends observed across those sites.

The data produced during this study would indicate no measurable impact on airborne pollutant levels as a result of the shutdown and start up activities, including flaring.

## 1.2 Contents

## Appendices



## Figures

## Tables

# 1 Introduction

Unplanned elevated flaring at ExxonMobil Chemical Limited's Fife Ethylene Plant (FEP) began on 12 August 2019 and continued until 15 August 2019 at which point the FEP shutdown. In late January 2020 the FEP entered the start-up process with ground flaring and intermittent elevated flaring taking place. Throughout the shutdown/start-up period the ground flares located at Shell U.K. Limited's Natural Gas Liquids (NGL) Plant were utilised to flare excess gas.

On 21 February 2020 ExxonMobil Chemical Limited announced that the start-up was complete and the plant had returned to normal production.

In response to community concerns surrounding air quality a monitoring programme was established to record conditions throughout the FEP shutdown and start up. Its goal was to determine if the interim use of ground flaring and the anticipated use of elevated flaring had any measurable impact on air quality.

The equipment utilised focussed on the measurement of combustion-related airborne pollutants and a range of volatile organic compounds (VOCs). Several of these compounds have associated air quality standards and objectives against which monitoring data were compared. Where appropriate, results were also compared against the UK's Department for Environment, Food and Rural Affairs (Defra) Daily Air Quality Index (DAQI).

Particulate monitoring was deployed first, positioned at three locations best placed to capture any potential impact within the local communities. Selected sites were distributed to provide measurements upwind and downwind of the Mossmorran Complex based upon prevailing winds (see wind data in Results section). Further air quality monitoring was established with the addition of continuous analysers and diffusion tubes. SEPA undertook monitoring between Jan-April 2019 (SEPA, 2019), that was developed in consultation with both the Mossmorran and Braefoot Bay Independent Air Quality Monitoring Review Group (MBBIAQMRG) and the Community Safety Liaison Group, which contains air quality experts from the council and academia, local community members and health professionals from NHS Fife. The shutdown/ start up monitoring over October 2019 – February 2020 monitoring replicated this to allow us to produce comparable results, however additional particulate monitoring equipment was included during the shutdown/ start up monitoring campaign.

This report provides detail about the monitoring SEPA carried out and the data collected. It will be shared with the MMBBIAQMRG, 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.

# 2 Monitoring Operations

## 2.1 Monitoring Locations

SEPA determined a scientifically robust monitoring plan to assess the impact of the shudown/ start up of the Mossmorran FEP site on the long-term air quality conditions. Monitoring locations were chosen based upon suitable site conditions, (i.e. security, access to power, lack of obstructions) and their position with respect to community receptors and prevailing wind conditions.

Monitoring commenced with the deployment of particulate matter analysers in three locations, at Auchtertool, Donibristle and Lochgelly. Positioning of the equipment meant there were analysers downwind of the Mossmorran Complex whilst comparable data was collected from a location upwind (based upon prevailing wind conditions). A previously monitored (SEPA, 2019) fourth location, at Little Raith to the northeast of the Mossmorran Complex, was added to host the SEPA air quality monitoring trailer.

Further air quality monitoring was undertaken utilising diffusion tubes located in Cowdenbeath, Donibristle, Little Raith and Lochgelly.

The monitoring locations selected are summarised in Table 2.1, and mapped in Figure 2.1. A photographic record of each monitoring location is presented in Appendix C.

**Table 2.1: Monitoring Locations Around the Mossmorran Complex**

| Location | NGR | Description | Orientation from FEP |
|---|---|---|---|
| **Particulate Monitors** | | | |
| Auchtertool | NT 22280 90907 | Rural | 3500 m E |
| Donibristle | NT 16654 89374 | Rural | 2000 m WSW |
| Lochgelly | NT 18811 92903 | Urban | 2500 m N |
| **Diffusion Tubes** | | | |
| Cowdenbeath | NT 17042 91267 | Urban | 2000 m NNW |
| Donibristle | NT 16739 88794 | Rural | 2000 m WSW |
| Little Raith | NT 20429 91545 | Rural | 2000 m NE |
| Lochgelly | NT 18624 92832 | Urban | 2500 m N |
| **Air Quality Trailer** | | | |
| Little Raith | NT 20429 91545 | Rural | 2000 m NE |

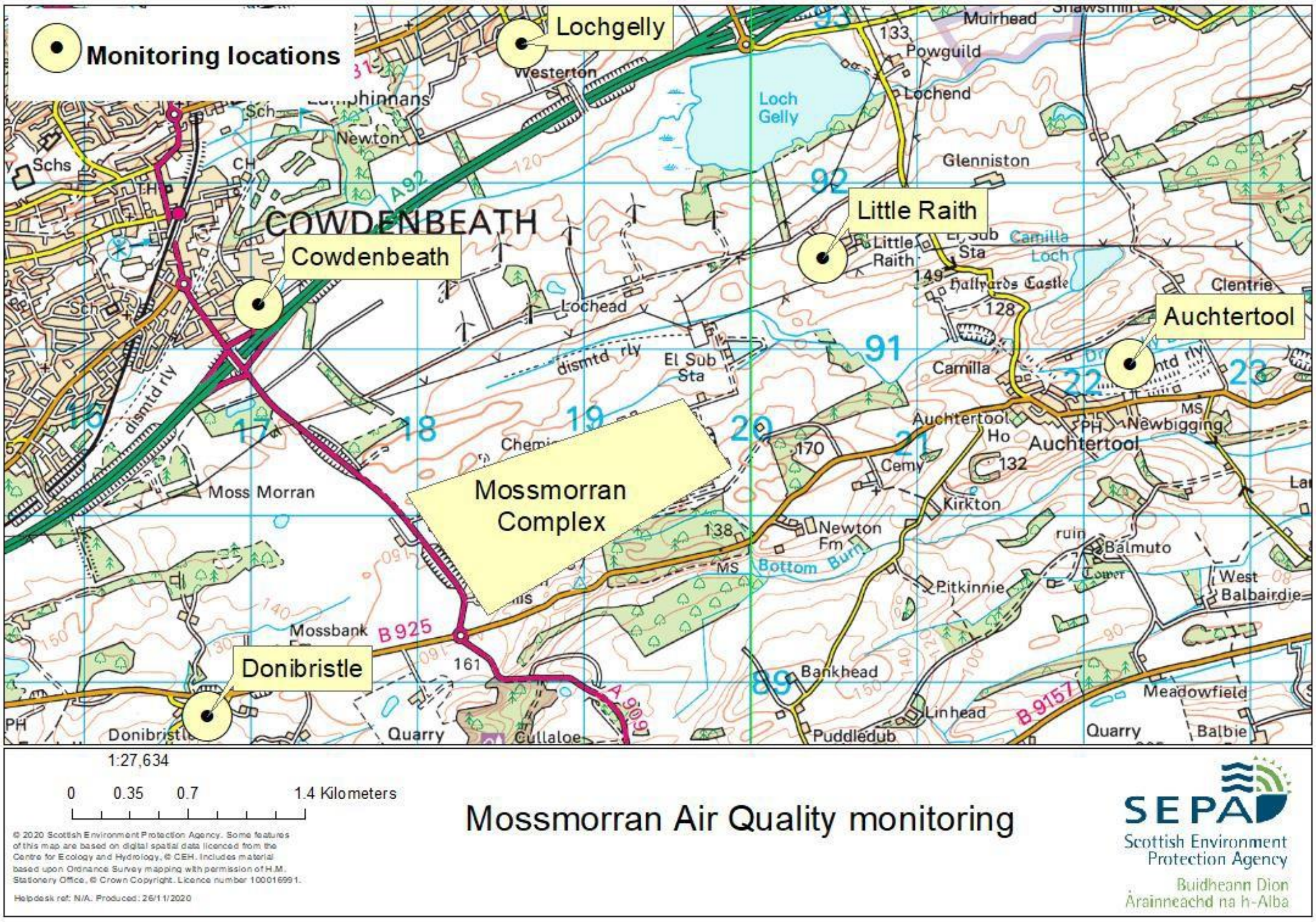



**Figure 2.1: Map of the air quality monitoring locations around Mossmorran Complex**



## 2.2 Monitoring Parameters and Equipment

A summary of the monitoring equipment deployed, duration and location of sampling is provided in Table 2.2.

Particulate matter ($PM_{10}$ and $PM_{2.5}$) monitoring was undertaken at three locations around the Mossmorran Complex between 14 August 2019 and 11 March 2020 (Auchtertool, Donibristle and Lochgelly). A further particulate analyser was deployed on 04 December 2019 (Little Raith) in anticipation of the site start up and use of the elevated flaring. The analyser at Little Raith was part of a broader air quality monitoring package which included carbon monoxide (CO), nitrogen dioxide ($NO_2$) and sulphur dioxide ($SO_2$).

Passive monitoring of selected air quality parameters ($NO_2$ and VOCs) commenced on 23 October 2019 with the deployment of diffusion tubes at four locations around the Mossmorran Complex (Cowdenbeath, Donibristle, Little Raith and Lochgelly). Passive monitoring continued until

20 February 2020 with a short break between 20 December 2019 and 23 January 2020.

Diffusion tube results give an indication of the air pollutant levels in the area they are positioned for the overall duration of deployment. Diffusion tubes cannot show how pollutants vary over the short term (e.g. hourly or daily averages).

Meteorological conditions in the area were recorded throughout the period (14 August 2019 to 11 March 2020) using a weather station positioned at Lochgelly.

Full technical details of the measurement equipment and methodologies used are provided in Appendix A.

**Table 2.2: Air Quality Monitoring Parameters**

| Location | Monitoring Parameter | Sampler/Analyser | Monitoring Period* |
|---|---|---|---|
| Auchtertool | $PM_{10}$, $PM_{2.5}$ | Turnkey Osiris | 14/08/2019 to 11/03/2020 |
| Cowdenbeath | $NO_2$, VOCs[#] | Diffusion tube | 23/10/2019 to 20/02/2020[‡] |
| Donibristle | $PM_{10}$, $PM_{2.5}$ | Turnkey Osiris | 14/08/2019 to 11/03/2020 |
| | $NO_2$, VOCs[#] | Diffusion tube | 23/10/2019 to 20/02/2020[‡] |
| Little Raith | $PM_{10}$, $PM_{2.5}$ | GRIMM EDM180 | 04/12/2019 to 11/03/2020 |
| | CO | Teledyne T300 | |
| | $NO_2$ | Teledyne T200 | |
| | $SO_2$ | Teledyne T100 | |
| | $NO_2$, VOCs[#] | Diffusion tube | 23/10/2019 to 20/02/2020[‡] |
| Lochgelly | $PM_{10}$, $PM_{2.5}$ | Fidas 200S | 14/08/2019 to 11/03/2020 |
| | $NO_2$, VOCs[#] | Diffusion tube | 23/10/2019 to 20/02/2020[‡] |
| | Wind speed/direction | Campbell Scientific Met Station CR200 | 14/08/2019 to 11/03/2020 |

**Notes:**

* The monitoring period only includes dates from the plant shut down to restart, selected monitoring had commenced prior to shut down and continued beyond restart

[#] VOC – Analytical suite including benzene, toluene, ethyl benzene, xylene, 1,3-butadiene and total hydrocarbons ($C_4$ to $C_{10}$)

[‡] Monitoring period by diffusion tube included a break in sampling between 20/12/2019 and 23/01/2020

# 3 Results

The equipment used to collect the monitoring data reported is mentioned briefly in this section then expanded upon in Appendix A.

Information relating to the quality control checks applied to these results is given in Appendix B.

## 3.1 Wind Speed/Direction

Meteorological conditions (wind speed and direction, air temperature, humidity and rainfall) were monitored using a Campbell Scientific CR200 weather station positioned in Lochgelly.

Wind speed and direction at Lochgelly were recorded in 15-minute intervals continuously over the monitoring period. A wind rose showing the frequency and speed of wind blowing from particular directions was generated from the dataset (Figure 3.1).

The length of each section shows how often the wind blows from that direction while the coloured bands show wind speed ranges. It can be seen from the wind rose in Figure 3.1 that the prevailing wind direction measured at Lochgelly is from the west-south-west, which indicates that the prevailing wind from Mossmorran will blow towards Auchtertool and Little Raith.

The wind rose generated from the data gathered at Lochgelly was compared with those for the calendar years 2015 to 2019 at the nearest official Met Office meteorological station (17 km south of FEP at Gogarbank, close to Edinburgh Airport) (Figure 3.1). The similarity between the wind rose for Lochgelly and those for Gogarbank (generated from data supplied by the UK Met Office), demonstrates that the wind speeds and directions recorded at Lochgelly were representative of the general wind profile in this region.

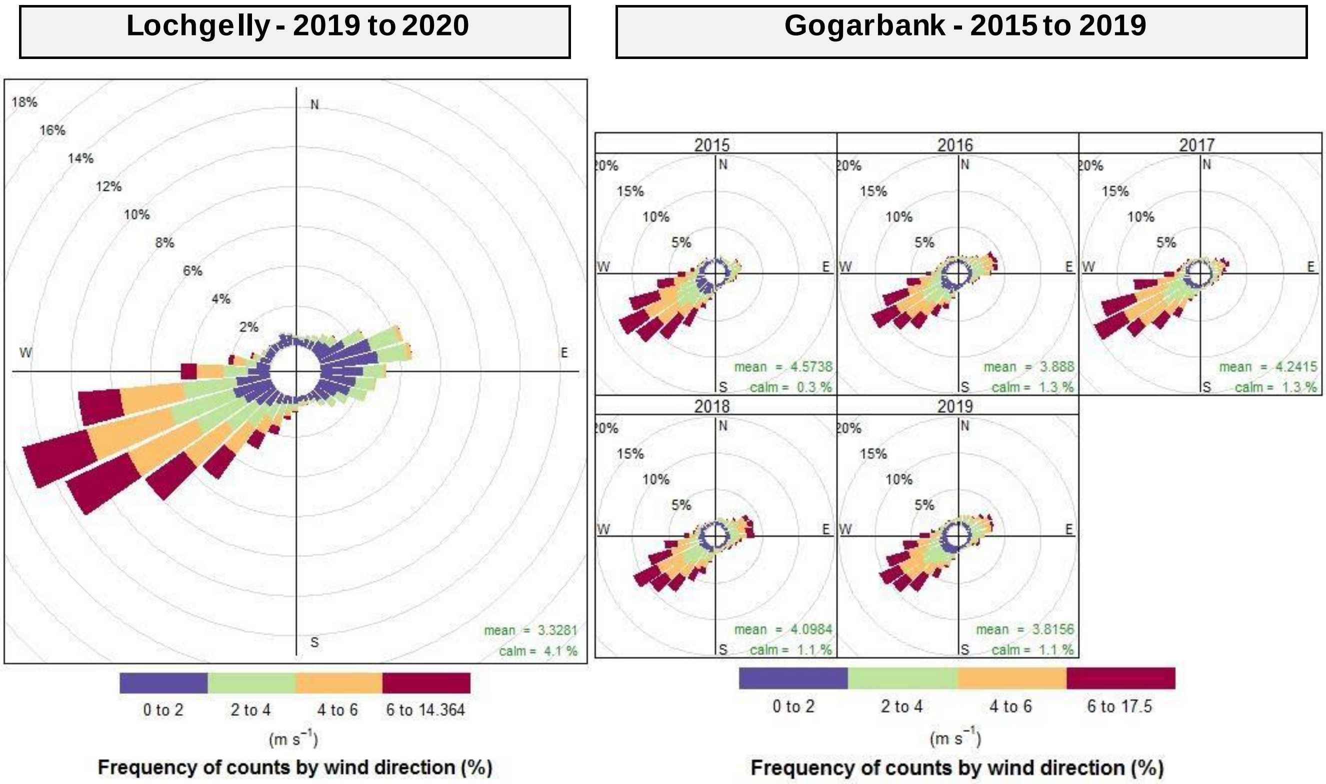



**Figure 3.1: Wind rose for the conditions measured at Lochgelly, alongside comparative wind roses for the 2015 - 2019 period at Gogarbank (Edinburgh Airport).**

## 3.2 Particulate Matter

Particulate matter was monitored at four different locations around Mossmorran using three different analyser models (Table 2.2). The analysers selected measure particulates using light scattering technology and return values for both $PM_{10}$ and $PM_{2.5}$ concentration.

The $PM_{10}$ and $PM_{2.5}$ data were collected as a 15-minute average and have been reported in the form of 24-hour (daily) mean values to allow comparison with the air quality objective and the daily air quality index (DAQI). In order to maximise the data capture, daily mean periods of less than 75 % data capture (i.e. days with less than 18 hours of captured data) have also been reported when this lower level of data capture within a 24 hour period would normally be excluded when reporting against national Air Quality Standards.

No daily mean values were reported for Auchtertool on 07/11/2019; 14/01/2020 to 16/01/2020; 31/01/2020 to 03/02/2020; and 06/02/2020 due to various instrument failures. No daily mean values were reported for Donibristle on 09/11/2019 to 13/11/2019; 06/02/2020; and 07/02/2020 due to power failures. No daily mean values were reported for Little Raith on 26/02/2020 and 28/02/2020 due to a power failure.

Particulate data obtained from local authority air quality monitoring stations have been provided for comparison. These data demonstrate the range of particulate values measured across Fife throughout the FEP shutdown and restart.

Summary statistical results for $PM_{10}$ and $PM_{2.5}$ are provided below in Table 3.1 and Table 3.2 respectively with all daily mean values tabulated and plotted in Appendix E.

**Table 3.1: Daily mean particulate matter ($PM_{10}$) concentrations between 14 August 2019 and 11 March 2020**

| | Particulate matter ($PM_{10}$) concentrations expressed as µg/m³ | | | | | |
|---|---|---|---|---|---|---|
| | SEPA Monitoring Sites | | | | Fife Council Sites* | |
| | Auchtertool | Donibristle | Little Raith** | Lochgelly | Dunfermline | Kirkcaldy |
| **Range** | 1.0 – 16.9 | 1.2 – 18.2 | 1.2 – 25.9 | 2.1 – 23.1 | 2.3 – 21.6 | 2.1 – 51.7 |
| **Mean** | 6.5 | 6.6 | 5.4 | 7.0 | 8.5 | 10.0 |
| **Median** | 6.1 | 6.2 | 4.1 | 6.5 | 8.0 | 8.8 |
| **Std. Deviation** | 3.2 | 3.0 | 4.0 | 3.2 | 3.4 | 6.3 |
| **RSD*** ** | 50 % | 45 % | 75 % | 45 % | 40 % | 63 % |
| **Data Capture** | 96 % | 97 % | 98 % | 100 % | 100 % | 100 % |
| **Air Quality Objective******** | 50.0 (40 / 18) | | | | | |

**Notes:**

Averaging period of $PM_{10}$ data collection from SEPA analysers was 15 minutes
* Local authority monitoring locations (provided as comparative regional data)
** Monitoring started on 04 December 2019
*** RSD – Relative standard deviation
**** Air Quality Objective for $PM_{10}$ – 24-hour Mean UK 50 µg/m³ (35x per year) / Scotland 50 µg/m³ (7x per year)
- Annual Mean UK 40 µg/m³ / Scotland 18 µg/m³

**Table 3.2: Daily mean particulate matter ($PM_{2.5}$) concentrations between 14 August 2019 to 11 March 2020**

| | Particulate matter ($PM_{2.5}$) concentrations expressed as $\mu g/m^3$ | | | | | |
|---|---|---|---|---|---|---|
| | SEPA Monitoring Sites | | | | Fife Council Sites* | |
| | Auchtertool | Donibristle | Little Raith** | Lochgelly | Dunfermline | Kirkcaldy |
| **Range** | 0.5 – 14.1 | 1.0 – 15.0 | 1.1 – 19.1 | 1.1 – 16.8 | 1.4 – 15.2 | 1.1 – 22.9 |
| **Mean** | 4.8 | 5.1 | 4.5 | 4.4 | 5.0 | 5.5 |
| **Median** | 4.5 | 4.8 | 3.5 | 3.8 | 4.4 | 4.7 |
| **Std. Deviation** | 2.6 | 2.5 | 3.1 | 2.5 | 2.5 | 3.3 |
| **RSD*** ** | 53 % | 49 % | 69 % | 56 % | 50 % | 60 % |
| **Data Capture** | 96 % | 97 % | 98 % | 100 % | 100 % | 100 % |
| **Air Quality Objective****** | 25.0 / 10.0 | | | | | |

**Notes:**

Averaging period of $PM_{2.5}$ data collection from SEPA analysers was 15 minutes
* Local authority monitoring locations (provided as comparative regional data)
** Monitoring started on 04 December 2019
*** RSD – Relative standard deviation
**** Air Quality Objective for $PM_{2.5}$ – Annual Mean UK 25 $\mu g/m^3$ (target) / Scotland 10 $\mu g/m^3$ (limit)

## 3.3 Nitrogen Dioxide (NO2)

Nitrogen dioxide ($NO_2$) was monitored at four different locations around Mossmorran using a combination of active continuous analysis (Teledyne T200) and passive sampling (diffusion tubes), see Table 2.2 for details. The continuous analyser measures $NO_2$ by chemiluminescence while diffusion tubes absorb $NO_2$ from the atmosphere onto a sample media with subsequent analysis by UV-Vis spectroscopy.

### 3.3.1 Nitrogen dioxide (NO2) by continuous analyser

The continuous $NO_2$ monitoring data were collected as 15-minute average data and have been reported in the form of 1-hour mean values to allow comparison with the air quality objective and DAQI. In order to maximise the data capture, hourly mean periods of less than 75 % data capture have also been reported (i.e. hours with less than 45 minutes of captured data).

No 1-hour mean values were reported on 26/02/2020 due to a power failure.

Nitrogen dioxide data obtained from local authority air quality monitoring stations have been provided for comparison. These data demonstrate the range of nitrogen dioxide values measured across Fife throughout the FEP shutdown and restart.

Summary statistical results for $NO_2$ concentrations are provided below in Table 3.3. Maximum daily 1-hour mean and measured 1-hour mean values are tabulated and plotted respectively in Appendix E.

**Table 3.3: Nitrogen dioxide concentrations measured by continuous analyser between 10 December 2019 and 11 March 2020**

| | $NO_2$ concentrations expressed as µg/m³ | | | |
|---|---|---|---|---|
| | SEPA Monitoring Site | | Fife Council Sites* | |
| | Little Raith | | Dunfermline | Kirkcaldy |
| **Averaging Period** | 15 minutes | 1 hour | 1 hour | 1 hour |
| **Range** | 0.0 – 121 | 0.5 – 70.6 | 0.8 - 84.4 | 0.1 – 92.4 |
| **Mean** | 10.9 | 10.9 | 21.9 | 14.7 |
| **Median** | 8.4 | 9.0 | 18.2 | 11.2 |
| **Std. Deviation** | 8.0 | 7.3 | 15.8 | 12.6 |
| **RSD**** | 95 % | 67 % | 87 % | 113 % |
| **Data Capture** | 94 % | 96 % | 100 % | 99 % |
| **Air Quality Objective***** | N/A | 200 (40) | | |

**Notes:**

Averaging period of $NO_2$ data collection was 15 minutes
* Local authority monitoring locations (provided as comparative regional data)
** RSD – Relative standard deviation
**** Air Quality Objective for $NO_2$ – 1-hour Mean UK 200 µg/m³ (18x per year), Annual Mean UK 40 µg/m³

## 3.3.2 Nitrogen dioxide ($NO_2$) by diffusion tube

The results presented in Table 3.4 (summarised from the results tabulated in Appendix E) have been reported directly from the original NPL certificates of analysis, with a mass concentration conversion factor applied (see Table A.1 for conversion factors). No bias correction factor has been applied to the overall $NO_2$ result.

Results from the fifth and sixth deployment periods 23 January 2020 to 20 February 2020 have been excluded due to abnormally low values for $NO_2$, approximately an order of magnitude lower than earlier deployments.

Two sample tubes from the fifth deployment were found to have unexpectedly passed their expiry date upon receipt at NPL/Gradko. That could account for the low $NO_2$ recovery involving those specific tubes. All tubes were sourced as single batch, it is therefore unclear how these two tubes could have exceeded their expiry date.

There is a possibility that operator error resulted in tubes being installed incorrectly during the final two deployments which subsequently led to lower than expected $NO_2$ recovery.

**Table 3.4: Nitrogen dioxide concentrations measured by diffusion tubes between 23 October 2019 and 20 February 2020**

| Period | Exposure time (days) | $NO_2$ concentration expressed as µg/m$^3$ | | | |
|---|---|---|---|---|---|
| | | Donibristle | Cowdenbeath | Lochgelly | Little Raith |
| 23/10/2019 – 06/11/2019 | 14 | 14.7 | 21.9 | 13.9 | 10.7 |
| 06/11/2019 – 22/11/2019 | 16 | 17.0 | 22.8 | 16.9 | 13.7 |
| 22/11/2019 – 06/12/2019 | 14 | 17.2 | 24.8 | 17.7 | 15.7 |
| 06/12/2019 – 20/12/2019 | 14 | 13.2 | 23.4 | 14.4 | 12.7 |
| 23/01/2020 – 06/02/2020 | FS* | FS* | FS* | FS* | FS* |
| 06/02/2020 – 20/02/2020 | FS* | FS* | FS* | FS* | FS* |
| **Mean** | **58** | **15.5** | **23.2** | **15.7** | **13.2** |
| **Std. Deviation** | | **1.7** | **1.1** | **1.6** | **1.8** |
| **RSD** | | **11 %** | **5 %** | **10 %** | **14 %** |
| **Air Quality Objective**** | | **40** | | | |

**Notes:**

* Failed sample
** Air Quality Objective for $NO_2$ - Annual Mean UK 40 µg/m$^3$

## 3.4 Sulphur Dioxide (SO2)

Sulphur dioxide ($SO_2$) was monitored at Little Raith using a continuous analyser (Teledyne T100), see Table 2.2 for details. The Teledyne T100 measures $SO_2$ by UV-Fluorescence spectroscopy.

The continuous $SO_2$ monitoring data were collected as 15-minute average data and have been reported in the form of both 15-minute and 1-hour mean values to allow comparison with the air quality objective and DAQI (15-minute). In order to maximise the data capture 1-hour mean periods of less than 75 % data capture have also been reported (i.e. hours with less than 45 minutes of captured data).

Sulphur dioxide data obtained from a neighbouring local authority (Falkirk) air quality monitoring station have been provided for comparison. These data are a summary of wider regional ambient conditions throughout the FEP shutdown and start up.

Summary statistical results for $SO_2$ concentrations are provided below in Table 3.5. Maximum daily 15-minute mean and measured 15-minute mean values are tabulated and plotted respectively in Appendix E.

**Table 3.5: Sulphur dioxide concentrations measured by continuous analyser between 10 December 2019 and 11 March 2020**

| | $SO_2$ concentrations expressed as (µg/m$^3$) | | | |
|---|---|---|---|---|
| | Little Raith | | Falkirk (Hope St)* | |
| **Averaging Period** | 15 minutes | 1 hour | 15 minutes | 1 hour |
| **Range** | 0.0 to 21.9 | 0.0 to 14.4 | 0.0 to 23.8 | 0.0 to 18.0 |
| **Mean** | 1.2 | 1.2 | 1.2 | 1.2 |
| **Median** | 1.2 | 1.2 | 0.6 | 0.6 |
| **Std. Deviation** | 1.5 | 1.4 | 1.8 | 1.8 |
| **RSD**** | 121 % | 117 % | 150 % | 147 % |
| **% Data Capture** | 95 % | 96 % | 96 % | 95 % |
| **Air Quality Objective***** | 266 | 350 | 266 | 350 |

**Notes:**

Averaging period of $SO_2$ data collection was 15 minutes
* Local authority monitoring location (provided as comparative urban data)
** RSD – Relative standard deviation
*** Air Quality Objective for $SO_2$ – 15-minute Mean UK 266 µg/m$^3$ (35x per year), 1-hour Mean UK 350 µg/m$^3$ (24x per year), 24-hour Mean UK 125 µg/m$^3$

## 3.5 Carbon Monoxide (CO)

Carbon Monoxide (CO) was monitored at Little Raith using a continuous analyser (Teledyne T300), see Table 2.2 for details. The Teledyne T300 measures CO by infrared spectroscopy.

The continuous CO monitoring data were collected as 15-minute average data. However, they have been reported in the form of 8-hour running mean values to allow comparison with the air quality objective. 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.

Measured 8-hour running mean values have been plotted in Appendix E.

The mean 15-minute CO concentrations were all below the method limit of detection after zero and drift corrections were applied (Table 3.6).

**Table 3.6: Carbon monoxide concentrations measured by continuous analyser between 10 December 2019 and 11 March 2020**

| | CO concentrations at Little Raith expressed as ($mg/m^3$) | |
|---|---|---|
| **Averaging Period** | 15 minutes | 8 hours |
| **Range** | <LOD* | <LOD* |
| **% Data Capture** | 83 | 83 |
| **Air Quality Objective**** | N/A | 10 |

**Notes:**

Averaging period of CO data collection was 15 minutes
* All drift/zero corrected measurements were below the method limit of detection (LOD)
** Air Quality Objective for CO – 8-hour running Mean Scotland 10 $mg/m^3$

## 3.6 VOCs

Usually the term volatile organic compounds (VOCs) refers to a wide range of chemical compounds but for the purpose of this study the compounds of interest are 1,3-butadiene (Table 3.7), benzene (Table 3.8), toluene (Table 3.9), ethylbenzene (Table 3.10), xylene (Table 3.11) and total hydrocarbons ($C_4$ to $C_{10}$) (Table 3.12).

Sampling for VOCs was undertaken using diffusion tubes with subsequent analysis by GC-FID (see Appendix A).

There are annual air quality objectives, but no short-term air quality objectives or daily air quality indices, for benzene or 1,3-butadiene. There are no short or long term national air quality objectives or daily air quality indices for toluene, ethylbenzene, xylene or total hydrocarbons. These pollutants were measured to allow comparison against data collected in previous studies, and to aid any future comparisons.

When results were reported as a less than value, i.e. below the method limit of detection (LOD) these were taken as an absolute value equivalent to the LOD for the purposes of conversion from ppb to $\mu g/m^3$ and statistical calculations.

An unidentified problem occurred during the second deployment at Cowdenbeath and Lochgelly with no measurable VOCs recorded. These samples were classed as failed samples.

**Table 3.7: 1,3-Butadiene concentrations measured by diffusion tubes between 23 October2019 and 20 February 2020**

| Period | Exposure time (days) | 1,3-butadiene concentration expressed as µg/m³ | | | |
|---|---|---|---|---|---|
| | | Donibristle | Cowdenbeath | Lochgelly | Little Raith |
| 23/10/2019 – 06/11/2019 | 14 | <0.2 | <0.2 | <0.2 | <0.2 |
| 06/11/2019 – 22/11/2019 | 16 | <0.2 | FS* | FS* | <0.2 |
| 22/11/2019 – 06/12/2019 | 14 | <0.2 | <0.2 | <0.2 | <0.2 |
| 06/12/2019 – 20/12/2019 | 14 | <0.2 | <0.2 | <0.2 | <0.2 |
| 23/01/2020 – 06/02/2020 | 14 | <0.2 | <0.2 | <0.2 | <0.2 |
| 06/02/2020 – 20/02/2020 | 14 | <0.2 | <0.2 | <0.2 | <0.2 |
| **Mean** | **86** | <0.2 | <0.2 | <0.2 | <0.2 |
| **Air Quality Objective**** | | 2.25 | | | |

**Notes:**

* Failed sample tube
** Air Quality Objective for 1,3-butadiene – running Annual Mean UK 2.25 µg/m³

**Table 3.8: Benzene concentrations measured by diffusion tubes between 23 October 2019 and 20 February 2020**

| Period | Exposure time (days) | Benzene concentration expressed as µg/m³ | | | |
|---|---|---|---|---|---|
| | | Donibristle | Cowdenbeath | Lochgelly | Little Raith |
| 23/10/2019 – 06/11/2019 | 14 | 1.2 | 1.1 | 0.6 | 0.6 |
| 06/11/2019 – 22/11/2019 | 16 | 1.0 | FS* | FS* | 1.4 |
| 22/11/2019 – 06/12/2019 | 14 | 0.9 | 1.2 | 0.6 | 1.0 |
| 06/12/2019 – 20/12/2019 | 14 | 0.6 | 0.9 | 0.4 | 0.7 |
| 23/01/2020 – 06/02/2020 | 14 | 0.6 | 0.7 | 0.7 | <0.3 |
| 06/02/2020 – 20/02/2020 | 14 | 0.4 | 0.4 | <0.3 | 0.4 |
| **Mean** | **86** | **0.8** | **0.9** | **0.5** | **0.7** |
| **Std. Deviation** | | **0.2** | **0.3** | **0.1** | **0.4** |
| **RSD** | | **32 %** | **32 %** | **27 %** | **51 %** |
| **Air Quality Objective**** | | 16.25 / 3.25 | | | |

**Notes:**

* Failed sample tube
** Air Quality Objective for benzene – Annual Mean UK 16.25 µg/m³ / Scotland 3.25 µg/m³
Less than (<) values taken as an absolute for purposes of statistical calculation

**Table 3.9: Toluene concentrations measured by diffusion tubes between 23 October 2019 and 20 February 2020**

| Period | Exposure time (days) | Toluene concentration expressed as µg/m³ | | | |
|---|---|---|---|---|---|
| | | Donibristle | Cowdenbeath | Lochgelly | Little Raith |
| 23/10/2019 – 06/11/2019 | 14 | 2.1 | 1.5 | <1.1 | <1.1 |
| 06/11/2019 – 22/11/2019 | 16 | <1.1 | FS* | FS* | 1.9 |
| 22/11/2019 – 06/12/2019 | 14 | 1.3 | 1.7 | <1.1 | <1.1 |
| 06/12/2019 – 20/12/2019 | 14 | <1.1 | 4.1 | <1.1 | 1.8 |
| 23/01/2020 – 06/02/2020 | 14 | <1.1 | <1.1 | 3.0 | <1.1 |
| 06/02/2020 – 20/02/2020 | 14 | <1.1 | <1.1 | <1.1 | <1.1 |
| **Mean** | **86** | **1.3** | **1.9** | **1.5** | **1.4** |
| **Std. Deviation** | | **0.4** | **1.1** | **-** | **0.3** |
| **RSD** | | **27 %** | **59 %** | **-** | **25 %** |

**Notes:**

* Failed sample tube

Less than (<) values taken as an absolute for purposes of statistical calculation

**Table 3.10: Ethylbenzene concentrations measured by diffusion tubes between 23 October 2019 and 20 February 2020**

| Period | Exposure time (days) | Ethylbenzene concentration expressed as µg/m³ | | | |
|---|---|---|---|---|---|
| | | Donibristle | Cowdenbeath | Lochgelly | Little Raith |
| 23/10/2019 – 06/11/2019 | 14 | <1.3 | <1.3 | <1.3 | <1.3 |
| 06/11/2019 – 22/11/2019 | 16 | <1.3 | FS* | FS* | <1.3 |
| 22/11/2019 – 06/12/2019 | 14 | <1.3 | <1.3 | <1.3 | <1.3 |
| 06/12/2019 – 20/12/2019 | 14 | <1.3 | <1.3 | <1.3 | <1.3 |
| 23/01/2020 – 06/02/2020 | 14 | <1.3 | <1.3 | <1.3 | <1.3 |
| 06/02/2020 – 20/02/2020 | 14 | <1.3 | <1.3 | <1.3 | <1.3 |
| **Mean** | **68** | <1.3 | <1.3 | <1.3 | <1.3 |

**Notes:**

* Failed sample tube

**Table 3.11: Xylene concentrations measured by diffusion tubes between 23 October 2019 and 20 February 2020**

| Period | Exposure time (days) | Xylene concentration expressed as µg/m³ | | | |
|---|---|---|---|---|---|
| | | Donibristle | Cowdenbeath | Lochgelly | Little Raith |
| 23/10/2019 – 06/11/2019 | 14 | 4.9 | 1.9 | <1.3 | <1.3 |
| 06/11/2019 – 22/11/2019 | 16 | 1.5 | FS* | FS* | 2.1 |
| 22/11/2019 – 06/12/2019 | 14 | <1.3 | 2.2 | <1.3 | 2.2 |
| 06/12/2019 – 20/12/2019 | 14 | 1.7 | 1.5 | <1.3 | <1.3 |
| 23/01/2020 – 06/02/2020 | 14 | <1.3 | <1.3 | <1.3 | <1.3 |
| 06/02/2020 – 20/02/2020 | 14 | <1.3 | <1.3 | <1.3 | <1.3 |
| **Mean** | **86** | **2.0** | **1.6** | **-** | **1.6** |
| **Std. Deviation** | | **1.3** | **0.3** | **-** | **0.4** |
| **RSD** | | **64 %** | **20 %** | **-** | **24 %** |

**Notes:**

* Failed sample tube
Less than (<) values taken as an absolute for purposes of statistical calculation

**Table 3.12: Total Hydrocarbons ($C_4$-$C_{10}$) concentrations measured by diffusion tubes between 23 October 2019 and 20 February 2020**

| Period | Exposure time (days) | Total hydrocarbon* concentration expressed as ppb (v/v) | | | |
|---|---|---|---|---|---|
| | | Donibristle | Cowdenbeath | Lochgelly | Little Raith |
| 23/10/2019 – 06/11/2019 | 14 | 26 | 8 | <5 | 5 |
| 06/11/2019 – 22/11/2019 | 16 | 6 | FS** | FS** | 10 |
| 22/11/2019 – 06/12/2019 | 14 | 5 | 10 | <5 | 8 |
| 06/12/2019 – 20/12/2019 | 14 | 9 | 16 | 6 | 14 |
| 23/01/2020 – 06/02/2020 | 14 | <5 | 7 | 12 | <5 |
| 06/02/2020 – 20/02/2020 | 14 | <5 | <5 | <5 | 5 |
| **Mean** | **86** | **9** | **9** | **7** | **8** |
| **Std. Deviation** | | **8** | **4** | **3** | **3** |
| **RSD** | | **81 %** | **41 %** | **41 %** | **43 %** |

**Notes:**

* Total hydrocarbon concentration calculated between $C_4$ and $C_{10}$ following removal of two peaks related to suspected contamination and unrelated to flaring activities. See Discussion section for further details.
** Failed sample tube
Less than (<) values taken as an absolute for purposes of statistical calculation

# 4 Discussion

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 plant 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 Mossmorran complex is 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.

During the monitoring period 14 August 2019 to 11 March 2020, activities at the FEP were mostly suspended with unused gases being burnt off using the NGL ground flares. As operations were slowly brought back online and stabilised, a period of elevated flaring was undertaken. Towards the end of the monitoring a period of routine operation at FEP was also included.

## 4.1 Potential airborne pollutants associated with Mossmorran flaring operations

The Mossmorran complex has the potential to emit a range of airborne pollutants into the ambient air, during normal operation and during any flaring activities.

The gas flared at the FEP predominately consists of ethane and/or ethylene which, when burnt in the flare under ideal conditions, is converted mainly to carbon dioxide and water vapour. Other materials such as nitrogen dioxide and carbon monoxide may be created. If insufficient steam is provided to the flare incomplete combustion occurs. During incomplete combustion additional pollutants may be emitted such as particulate matter and volatile organic compounds such as 1,3-butadiene, benzene, toluene, ethyl benzene and xylene.

### 4.1.1 Particulate matter

Particulate matter is made up of many components, including chemical substances, soot, soil and dust particles and comes from both anthropogenic and natural sources. It consists of substances which are released directly from the source into the atmosphere, and secondary components which are formed in the atmosphere by chemical reactions.

Particulate matter is not made up of one type of substance; it is a classification of particles by size. It is measured in micrometres (µm). A human hair is approximately 100 µm wide.

Larger particles are generally filtered in the nose and throat, but particulate matter smaller than about 10 µm can be inhaled, which is why these are measured for air quality assessment due to the potential health impacts.

- $PM_{10}$ describes all particles that are 10 µm or smaller. The measurement of this figure includes $PM_{2.5}$;
- $PM_{2.5}$ describes all particles that are 2.5 µm or smaller.

The finer particles, such as 2.5 µm are becoming of increasing interest with regard to health effects. They can be carried deep into the lungs where they can cause inflammation and may lead to a worsening of existing heart and lung conditions.

### 4.1.2 Nitrogen dioxide

When nitrogen is released during combustion it combines with oxygen to create nitric oxide (NO) which further combines with oxygen to create nitrogen dioxide ($NO_2$). Nitric oxide is not considered hazardous to health at typical ambient concentrations, unlike $NO_2$ which can be.

Nitrogen dioxide mainly affects the respiratory system and can cause inflammation of the airways at high concentrations. Long term exposure may decrease lung function and increase the risk of respiratory conditions. Nitrogen dioxide can also contribute to the formation of particulate matter and ground level ozone, both associated with adverse health effects.

### 4.1.3 Sulphur dioxide

Sulphur dioxide ($SO_2$) is produced when a material, or fuel, containing sulphur is burned. It affects human health when it is breathed in by irritating the nose, throat, and airways to cause coughing, wheezing, shortness of breath, or a tight feeling around the chest. The effects are felt very quickly, and most people would feel symptoms in under 15 minutes. Those most at risk are people with asthma, heart or lung disease.

Long term exposure to $SO_2$ may cause changes in lung function, and increased mortality has been observed when combined with increased particulate levels. Sulphur dioxide, like $NO_2$, can contribute to particulate formation with the associated health risks detailed previously.

### 4.1.4 Carbon monoxide

Carbon monoxide (CO) is a colourless, odourless gas that can be harmful when inhaled in large amounts. It is released during combustion with major anthropogenic sources to air being from vehicles, domestic heating and industry. Breathing air with a high concentration of CO reduces the amount of oxygen that can be transported in the blood stream to critical organs like the heart and brain.

At very high concentrations, which are possible indoors or in other enclosed environments, CO can cause dizziness, confusion, unconsciousness and death. Although very high concentrations of CO are not likely to occur outdoors, moderately elevated levels can be of concern for people with certain types of heart disease. They are especially vulnerable to the effects of CO when exercising or under increased physical stress.

### 4.1.5 Volatile organic compounds (VOCs)

The European Union describes a VOC as any organic compound having an initial boiling point less than or equal to 250°C measured at a standard atmospheric pressure of 101.3 kPa[16]. Volatile organic compounds are ubiquitous in the environment, ever present in both indoor and outdoor air. They have been measured at concentrations up to parts per billion (ppb) in the upper troposphere and lower stratosphere[18]. Anthropogenic sources account for a significant proportion of global VOCs (ca. 25 %) with combustion of fossil fuels a major contributor[19].

Although many substances are considered VOCs, those associated with petrol and diesel distribution and combustion such as benzene and some of its organic derivatives, like toluene, ethylbenzene and xylene (BTEX), which comprise over 60 % of the VOCs found in urban areas[20]. Exposure to the BTEX compounds may lead to chronic health effects including, respiratory problems, central nervous system disorders, liver and kidney damage, reproductive disorders and birth defects. Similar effects have been noted with exposure to 1,3-butadiene.

Benzene and 1,3-butadiene are classified by the International Agency for Research on Cancer (IARC) in Group 1 as carcinogenic for humans. Both substances are linked with incomplete combustion during flaring and have air quality objectives assigned.

## 4.2 Background inputs to local air pollution

In assessing any impacts to air quality from flaring operations at Mossmorran it is necessary to consider background levels of air pollution and the sources from which it arises.

### 4.2.1 Traffic

The main air pollutants associated with traffic are particulate matter and $NO_2$. Typical traffic patterns will largely result in peak emissions during daily rush-hour times.

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 trunk road with continuous traffic during daytime and for much of the night.

Traffic on minor roads, particularly through the larger towns of Lochgelly and Cowdenbeath, will contribute to local air pollution.

### 4.2.2 Domestic and commercial properties

Homes and businesses in the area contribute to local air pollution through fossil fuel and wood-burning heating systems, kitchen extractors (homes, takeaways, restaurants) and dust generating processes.

Other domestic pollution sources include garden bonfires, patio heaters and barbecues.

### 4.2.3 Farming and agriculture

Nitrogen-containing compounds ($NO_2$, NO, $NH_3$, $N_2O$) are emitted to the atmosphere from agricultural activities. Methane and non-methane VOCs are also emitted by agriculture[17].

Fossil fuel operated farm equipment, generators and heating systems produce combustion by-products as will stubble burning. An impact on airborne particulate matter may also be seen with livestock movements and feeding during periods of dry weather, ploughing and harvesting activities.

### 4.2.4 Regional and national pollution events

Under some meteorological conditions, air polluted with particulate matter ($PM_{10}$ and $PM_{2.5}$) from the continent, or further, 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 levels[1].

## 4.3 Monitoring Data

The data collected during this monitoring programme have been summarised in the previous section. More detailed data is tabulated and plotted in Appendix E.

In the previous section the data were summarised as ranges, mean, median, standard deviation, and relative standard deviation. The level of data capture and any relevant air quality objectives were also presented. The 'average' is presented in both the traditional sense as the mean (values summed then divided by number of data points) but also as the median (the mid-point of the data). In a data set with a normal distribution and no outliers both mean and median values should be close. If the data contain outliers, or is skewed in any way, the median gives an indication of this. However the National Air Quality Objectives are determined using mean calculations, and the medians presented cannot be used to determine compliance against the objectives.

### 4.3.1 Particulate Matter

The daily mean particulate data has been summarised in the previous section alongside data from two local authority monitoring sites. The daily mean $PM_{10}$ and $PM_{2.5}$ concentrations have been tabulated in Table E.1 for comparison with the DAQI bandings. In Figure E.1 to Figure E.4 $PM_{10}$ and $PM_{2.5}$ concentrations have been plotted against the values recorded for both local authority monitoring sites and a rural background site at Auchencorth Moss south of the Pentland Hills.

Data capture across the four SEA monitoring sites ranged from 96 to 100 % (Table 3.1 and Table 3.2). At Auchtertool and Donibristle issues with solar powered communications resulted in the loss of data as did power failures (Donibristle and Little Raith) and an instrument failure (Auchtertool).

#### PM10

The range of $PM_{10}$ concentrations measured at each of the four SEPA locations showed good agreement between the different locations and analyser types. Daily mean concentrations of $PM_{10}$ ranged from 1.0 to 25.9 µg/m$^3$ across the four sites, well below the daily air quality standard of 50 µg/m$^3$ (Table 3.1).

The overall mean concentrations of $PM_{10}$ across the four locations ranged from 5.4 to 7.0 µg/m$^3$ while median values ranged from 4.1 to 6.5 µg/m$^3$. The similarity between mean and median values suggest only minor influences from outliers or skewness. These values are all markedly lower than the United Kingdom and Scottish annual air quality standards of 40 µg/m$^3$ and 18 µg/m$^3$ respectively.

The lowest overall mean and median $PM_{10}$ values were recorded at the rural location of Little Raith; however that location also returned the highest daily mean $PM_{10}$ concentration (25.9 µg/m$^3$) and RSD (75 %). The analyser at Little Raith was deployed in an agricultural environment where the movement of agricultural machinery and livestock may cause occasional elevated levels of $PM1_{10}$

The $PM_{10}$ concentrations measured at the SEPA monitoring locations were broadly comparable to those measured by the local authority monitoring stations in Dunfermline and Kirkcaldy.

Occasional spikes in $PM_{10}$ concentrations, which were observed almost simultaneously at both SEPA and local authority monitoring locations, highlight the impact to local air quality from wider reaching events such as wildfires, Saharan dust storms, volcanic emissions, etc.

The daily mean concentrations of $PM_{10}$ recorded over the monitoring period at each of the SEPA locations tracked mostly at, or below, concentrations recorded at Dunfermline and Kirkcaldy and slightly above concentrations measured at Auchencorth Moss (Figure E.1 to Figure E.4). Given the roadside location of the local authority stations and the remote nature of the Auchencorth Moss site, this observation was to be expected. The data from SEPA's analyser at Lochgelly matched most closely with that from the local authority sites.

All daily mean $PM_{10}$ concentrations recorded at the SEPA monitoring locations were below the daily air quality standard and within the DAQI 'Low' banding.

## Particulate Matter (PM2.5)

As noted for the $PM_{10}$ concentrations the range of daily mean $PM_{2.5}$ concentrations were broadly similar and showed good agreement between the different locations and analyser types. Daily mean concentrations of $PM_{2.5}$ ranged from 0.5 to 19.1 µg/m$^3$ across the four sites, (Table 3.2). The overall mean concentrations of $PM_{2.5}$ across the four locations ranged from 4.4 to 5.1 µg/m$^3$ while median values ranged from 3.5 to 4.8 µg/m$^3$. The similarity between mean and median values suggest only minor influences from outliers or skewness. These values are between *ca.* 20 % and 50 % of the United Kingdom and Scottish annual air quality standards of 25 µg/m$^3$ and10 µg/m$^3$ respectively.

The lowest overall median $PM_{2.5}$ value was recorded at Little Raith but also the highest daily mean $PM_{2.5}$ concentration (19.1 µg/m$^3$) and RSD (69 %). This is similar to the observation made for the $PM_{10}$ concentrations.

The daily mean $PM_{2.5}$ concentrations measured at the SEPA monitoring locations were again broadly comparable to those measured by the local authority monitoring stations in Dunfermline and Kirkcaldy. The concentrations of $PM_{2.5}$ followed a similar trend to the concentrations of $PM_{10}$ (Figure E.1 to Figure E.4). There was greater variability in the daily mean $PM_{2.5}$ concentrations at Auchtertool and Donibristle versus Little Raith, Lochgelly and the local authority sites.

All daily mean $PM_{2.5}$ concentrations recorded at the SEPA monitoring locations were within the DAQI 'Low' banding.

### 4.3.2 Nitrogen Dioxide (NO2)

Nitrogen dioxide was measured by two separate techniques, continuous analyser and diffusion tube, with a degree of overlap in the periods monitored. The $NO_2$ concentrations from the continuous analyser were presented as both 15-minute and 1-hour mean (Table 3.3). The $NO_2$ concentrations measured by diffusion tube were determined as the averages over the 14 day and overall 58 day period of deployment (Table 3.4).

In Figure E.5 all 1-hour mean $NO_2$ concentrations have been plotted against the values recorded for both local authority monitoring sites.

Data capture from the continuous analyser was 94 % and 96 % for 15-minute and 1-hour mean data respectively (Table 3.3). The primary cause of data loss was power failure in the monitoring trailer. Data capture using the diffusion tubes was 100 %; however, following laboratory testing and quality control checks the last two deployments were deemed to have failed and thus the data capture for data reported was ca. 67 % of the overall possible time.

## Nitrogen dioxide (NO2) by continuous analyser

The $NO_2$ concentrations measured by continuous analyser ranged from 0.0 to 121 µg/m$^3$ (15-minute mean) and 0.5 to 70.6 µg/m$^3$ (1-hour mean). All 1-hour mean $NO_2$ concentrations were below the United Kingdom air quality objective of 200 µg/m$^3$ (not to be breached more than 18 times per year) (Table 3.3).

The highest recorded 1-hour mean $NO_2$ concentrations from each day have been tabulated in Table E.2 and compared against the corresponding DAQI Index values. Only one day, 6 March 2020, recorded a 1-hour mean value that exceeded DAQI Index 1 (DAQI Index 2), this was after the FEP restarted and continuous flaring had ceased.

The mean concentration of $NO_2$ was 10.9 µg/m$^3$ for both the 15-minute and 1-hour averaging periods while median values were 8.4 and 9.0 µg/m$^3$ respectively. The difference between the meanand median values and a high RSD (95 %) for the 15-minute averaged data suggests influences from outliers or skewness that were smoothed out by the 1-hour averaging (RSD of 67 %). Both mean and median 1-hour averaged values were markedly lower than the annual United Kingdom air quality objective of 40 µg/m$^3$.

The range of 1-hour mean $NO_2$ concentrations measured by the SEPA continuous analyser was broadly comparable to those measured by the local authority monitoring stations in Dunfermline and Kirkcaldy (Figure E.5). However, the mean and median values calculated for both local authority sites werehigher than those calculated for the SEPA site. This difference reflects the increased frequency of elevated $NO_2$ concentrations above ambient at urban roadside locations (i.e. during rush-hour). As Little Raith has no urban roadside $NO_2$ inputs this observation was to be expected.

All 1-hour mean $NO_2$ concentrations reported from the SEPA monitoring site were below the 1-hour air quality standard and within the DAQI 'Low' banding.

## Nitrogen dioxide (NO2) by diffusion tube

The concentrations of $NO_2$ measured across the monitoring locations were broadly similar at Donibristle, Little Raith and Lochgelly. At these sites the concentrations of $NO_2$ measured ranged from 10.7 to 17.7 µg/m$^3$. The levels recorded at Cowdenbeath were up to twice those measured at the other locations, ranging from 21.9 to 24.8 µg/m$^3$ (Table 3.4). The increased $NO_2$ levels recorded at Cowdenbeath are likely to result from the site's proximity to a busy junction on the A92.

The overall mean concentrations of $NO_2$ across the four locations ranged from 13.2 to 23.2 µg/m$^3$ and variability between deployment periods was low with RSD values between 5 % and 14 %.

Mean $NO_2$ concentrations across the monitoring locations were lower than the United Kingdom annual air quality objective of 40 µg/m$^3$.

### 4.3.3 Sulphur Dioxide (SO2)

The $SO_2$ data has been summarised in the previous section alongside data from a monitoring site in a neighbouring local authority. The highest recorded 15-minute mean $SO_2$ concentrations from each day have been tabulated in Table E.3 and compared to the corresponding DAQI Index values. In Figure E.6 all recorded 15 minute mean $SO_2$ concentrations have been plotted against the values recorded at a local authority monitoring site in Falkirk.

Data capture for the 15-minute mean $SO_2$ concentration was 95 % which increased to 96 % for the 1-hour mean averaging period (Table 3.5). Loss of power in the monitoring trailer was the primary cause for gaps in the data recording.

The $SO_2$ concentrations measured ranged from 0.0 to 21.9 µg/m$^3$ (15-minute mean) and 0.0 to 14.4 µg/m$^3$ (1-hour mean). All 15-minute and 1-hour mean $SO_2$ concentrations were below the United Kingdom air quality objectives of 266 µg/m$^3$ (not to be breached more than 35 times per year) and 350 µg/m$^3$ (not to be breached more than 24 times per year) respectively (Table 3.5).

At no point throughout the monitoring period did any 15-minute mean $SO_2$ concentration exceed

DAQI Index 1.

The mean and median concentrations of $SO_2$ were 1.2 µg/m$^3$ for both the 15-minute and 1-hour averaging periods. The mean and median returning the same value suggests no measurable influence from any outliers or skewness in the data. There is no annual mean air quality objective for $SO_2$.

The ranges of 15-minute and 1-hour averaged $SO_2$ concentrations measured by the SEPA continuous analyser were broadly comparable to those measured by the local authority monitoring station in Falkirk. The mean values for the 15-minute and 1-hour averaged $SO_2$ concentrations were the same for both the SEPA monitoring location and the Falkirk monitoring station. However, the median values calculated for the Falkirk site were half the calculated mean. This would suggest a lower overall ambient concentration of $SO_2$ around the Falkirk site compared to Little Raith but with more frequent spikes in concentrations, most likely traffic related. At the SEPA monitoring location the ambient concentrations were more evenly distributed, influenced in part from local traffic sources and farming activities, i.e. fossil fuel burning and hydrogen sulphide ($H_2S$) converting to $SO_2$ from livestock manure.

The 15-minute mean concentrations of $SO_2$ reported from the SEPA monitoring site tracked close to those measured at Falkirk throughout the monitoring period (Figure E.6). The baseline concentration at Little Raith often drifted higher than that of the Falkirk site; however, significantly fewer spikes were seen in the Little Raith concentrations. This observation supports the previous discussion regarding the mean and median values for Falkirk and Little Raith, it also explains the differences in the calculated RSD values.

All 15-minute and 1-hour mean $SO_2$ concentrations reported from the SEPA monitoring site were below their respective air quality objectives. All 15-minute mean $SO_2$ concentrations were within the DAQI 'Low' banding.

## 4.3.4 Carbon Monoxide (CO)

The CO data has been summarised in the previous section. The running 8-hour mean CO concentrations have been plotted in Figure E.7.

Data capture for the 15-minute and 8-hour mean CO concentrations was 83 % (Table 3.6). Loss of power in the monitoring trailer was the primary cause for gaps in the data recording.

All CO results were determined to be below the method limit of detection following the drift and zero correction.

With no results measured above the detection limit there were no breaches of the 8-hour mean Scottish air quality objective.

## 4.3.5 Volatile Organic Compounds (VOCs)

The VOC data has been summarised in the previous section. The raw data provided by the subcontractor (as ppb v/v) has been tabulated in Table E.4 with the converted data (as µg/m$^3$) tabulated in Table E.5.

Analysis of VOCs was carried out by gas chromatography with flame ionisation detection (GC-FID) and the compounds quantified from a chromatogram as shown in the example below (Figure 4.1). This example is of a typical profile obtained from a VOC diffusion tube located close to an active ground flare.

The concentrations of individual VOCs were determined from the area of their corresponding peak on the chromatogram while the concentration of total hydrocarbons was determined by measuring the entire area of all peaks between butane and decane ($C_4$ to $C_{10}$).

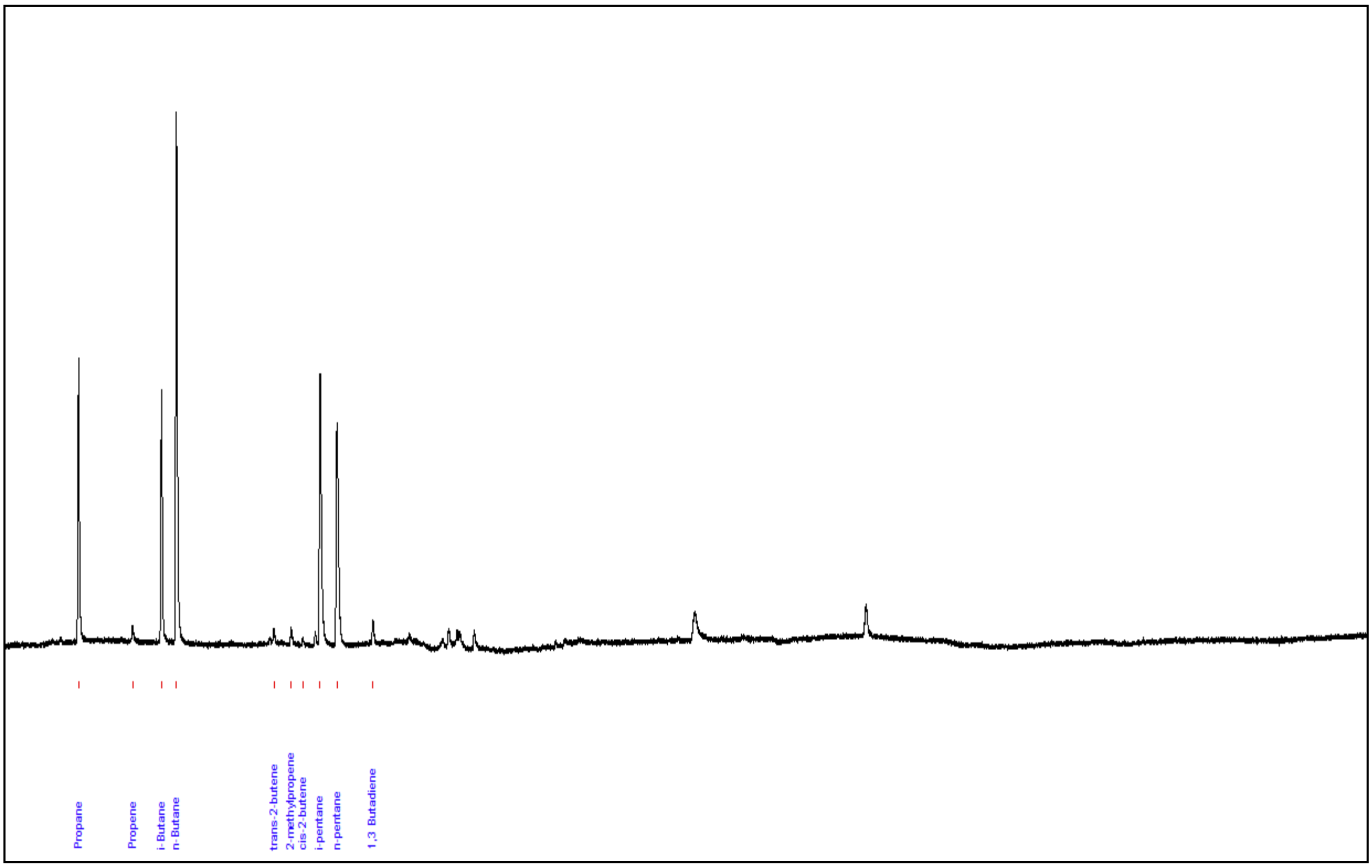



**Figure 4.1: Example chromatogram from a pumped diffusion tube sample near to an active ground flare (supplied by NPL)**

Data capture using the VOC diffusion tubes was 100 %. However, following laboratory testing and quality control checks two tubes from the second deployment (Cowdenbeath and Lochgelly) were deemed not to have been exposed, while the travel blanks had recorded VOC exposure. It is unclear if the travel blanks were installed in error or if loose caps resulted in the observed exposure. Taking the unexposed tubes from the second deployment into account meant overall data capture reported was ca. 92 %.

## 1,3-butadiene

Measured concentrations of 1,3-butadiene were all below the method limit of detection.

Therewere no breaches of the running annual mean United Kingdom air quality objective.

## Benzene

The range of benzene concentrations measured were broadly similar across the monitoring locations with levels from < 0.3 to 1.4 µg/m$^3$. The levels of benzene recorded at Lochgelly were slightly lower than those measured at the other locations, with no values recorded above 0.7 µg/m$^3$. The highest individual result was measured at Little Raith which may be related to farming operations (Table 3.8).

The overall mean concentrations of benzene across the four sites ranged from 0.5 to 0.9 µg/m$^3$ and variability between deployment periods was moderate with RSD values between 27 and 51 % (Table 3.8).

Benzene concentrations were less than half of the annual mean Scottish air quality objective of 3.25 µg/m$^3$ and significantly below the United Kingdom annual mean air quality objective data of 16.25 µg/m$^3$.

## Toluene, Ethylbenzene and Xylene (TEX)

There are no air quality objectives for the TEX compounds so they will be discussed here briefly in terms of local distribution and any observable trends.

Many the measured TEX (in particular ethylbenzene) concentrations were below their respective limits of detection. Measured concentrations above detection limits were most common at Cowdenbeath (Table 3.9 to Table 3.11).

There were few trends in the individual TEX concentrations with results recorded above the detection limit generally sporadic. The diffusion tube sample from the first deployment at Donibristle was the only one to show consistently higher concentration of the TEX compounds (and benzene). This would suggest an exposure to petroleum hydrocarbons for that sample; however, the source of those hydrocarbons cannot be determined.

## Total Hydrocarbons (C4-C10)

As with the TEX compounds there are no air quality objectives for the total hydrocarbons so they will again be discussed briefly in terms of local distribution and any observable trends.

Total hydrocarbons are the sum of hydrocarbons in the boiling point range between butane ($C_4$) and decane ($C_{10}$), it includes the majority of compounds observable in the example from an active ground flare site (Figure 4.1). There is no conversion factor from parts per billion (ppb) to micrograms per cubic metre (µg/m$^3$) for total hydrocarbons. This is due to the large number of compounds potentially present within the range measured and the varying molecular weights of those compounds.

Concentrations of total hydrocarbons measured throughout the monitoring period were broadly similar across the sites and ranged from < 5 to 26 ppb (v/v). The mean concentrations across the four sites ranged from 7 to 9 ppb (v/v) and, aside from Donibristle (81 %), RSD was moderate (41 to43 %).

The highest total hydrocarbon concentration was recorded during the first deployment period at Donibristle. This result was almost three times the next highest recorded level at that location during the monitoring period and suggests an isolated occurrence.

Although total hydrocarbon concentrations fluctuated across the sites between deployments the levels at Cowdenbeath and Little Raith appeared slightly higher overall. This observation likely reflects the exposure to traffic emissions at the former and proximity of farm vehicles and fuel sources at the latter.

# 5 Conclusions

A seven-month air quality monitoring study was undertaken in the vicinity of the Mossmorran complex during the plant shut-down and restart of the FEP. The aim of the study was to determine whether there were any notable impacts on air quality from the continuous ground flaring and intermittent elevated flaring. The following text is a summary of the findings from the monitoring study.

- Wind speed and direction measured was comparable to that measured at Gogarbank Met Office weather station over the preceding five years and was deemed to be representative of a normal weather pattern. This strengthens the comparison between the measured data and the objectives, giving a useful indication of the air quality over the longer term.
- Data capture was greater than 90 % for most of the monitoring undertaken. The lowest data

capture for a continuous analyser was 83 %. Given the complexities of remote sensing this level data capture was deemed robust.

- Particulate matter ($PM_{10}$ and $PM_{2.5}$) concentrations were within the DAQI ‘Low’ banding and there were no breaches of assigned air quality objectives. Any daily increases in particulate levels largely mirrored those measured regionally indicating no notable local influences.
- Nitrogen dioxide ($NO_2$) concentrations were within the DAQI ‘Low’ banding and there were no breaches of assigned air quality objectives. Any hourly increase in $NO_2$ levels largely mirrored those measured regionally indicating no notable local influences.
- Baseline $SO_2$ levels (15-minute mean) were generally similar to, or slightly higher, at Little Raith compared to the selected reference site. The only notable spike in $SO_2$ concentration at Little Raith was replicated at the urban reference site suggesting a wider, regional increase. This indicates no notable local influences. The $SO_2$ concentrations were all within the DAQI ‘Low’ banding and significantly lower than the assigned air quality objective.
- Carbon monoxide (CO) concentrations were below the method limit of detection which is substantially lower than the assigned air quality objective.
- The concentrations of the VOCs, benzene and 1,3-butadiene were below their respective air quality objective values.

In conclusion, air quality monitoring data typically followed regional trends and there were no breaches of air quality objectives or values recorded above the DAQI ‘Low’ banding. This would suggest no impact upon local air quality from the extended period of flaring during the FEP shut-down and restart.

# 6 References


1 *Air Quality: Public Health Impacts and Local Actions*, Department for Environment Food & Rural Affairs (Defra), 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 *Report: 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-AHER-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-AHER-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

16 *"Directive 2004/42/CE of the European Parliament and the Council"* EUR-Lex. European Union Publications Office.

17 *Air Pollution from Agriculture: Air Quality Expert Group*, Department for Environment Food & Rural Affairs (Defra), https://uk-air.defra.gov.uk/assets/documents/reports/aqeg/2800829_Agricultural_emissions_vfinal2.pdf, accessed on 13 May 2020

18 Baker, A. K., Slemr, F., and Brenninkmeijer, C. A. M., 2009. Analysis of non-methane hydrocarbons in air samples collected aboard the CARIBIC passenger aircraft. *Atmos. Meas. Tech.*, 3, 311–321, 2010

19 SEPA Procedure ES-NFC-WP-067, *Measurement of total suspended particulate matter (TSP), PM10, PM4, PM2.5 and PM1 using a fine dust monitor system (FIDAS) 200S,* Issue no.1

20 SEPA Procedure ES-NFC-WP-031, *Measurement of total suspended particulate, $PM_{10}$, $PM_{2.5}$ AND $PM_1$ using an OSIRIS monitor,* Issue no.4

21 SEPA Procedure ES-NFC-WP-021, *The use of diffusion tubes for the measurement of ambient air,* Issue no.1

# 2. Appendices

# A. Equipment Details and Methodologies

## A.1. Weather Station

A Campbell Scientific CR200 weather station was set up and operated according to SEPA in-house procedure ES-NFC-WP-019[7]. The CR200 is configured to record wind speed and direction, air temperature, relative humidity and rainfall.

## A.2. Continuous Analysers

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

### A.2.1. Particulate Matter ($PM_{10}$ and $PM_{2.5}$)

Particulate matter was measured using light-scattering type analysers (GRIMM EDM180, Palas Fidas 200S, Turnkey Osiris).

The GRIMM EDM180 is certified (Sira MC120198/04 issued 08 February 2018) to measure $PM_{10}$ in the range 0 to 10,000 µg/m$^3$ and $PM_{2.5}$ in the range 0 to 6,000 µg/m$^3$. Monitoring was completed using a calibrated analyser following SEPA procedure ES-AHER-WP-020[14].

Palas Fidas 200S

The Palas FIDAS 200 is a light scattering-type analyser which is certified (Sira MC16290/02 issued 23 February 2017) to measure $PM_{10}$ and $PM_{2.5}$ in the range 0 to 10,000 µg/m$^3$. Monitoring was completed using a calibrated analyser following SEPA procedure ES-NFC-WP-067[19].

Turnkey Osiris

The Turnkey Osiris is a light scattering-type analyser which is certified (Sira MC090157/06 initial certification 30 September 2009, Renewed 29 September 2019) to measure $PM_{10}$ in the range 0 to 100 µg/m$^3$. Turnkey Osiris units are capable of measuring $PM_{10}$ and $PM_{2.5}$ up to 6000 µg/m$^3$; however the unit is not certified for $PM_{10}$ or $PM_{2.5}$ levels above 100 µg/m$^3$. This means that results for these are classed as “indicative”. Monitoring was completed using a calibrated analyser following SEPA procedure ES-NFC-WP-031 [20].

### Nitrogen Dioxide ($NO_2$)

Nitrogen dioxide ($NO_2$) 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-AHER-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 500 ppb and NO in the range 0 to 1000 ppb. Nitrogen dioxide measurements in parts per billion (ppb) were subsequently converted to mass concentrations in micrograms per cubic metre (µg/m$^3$) (see Table A.1).

### Sulphur Dioxide ($SO_2$)

Sulphur dioxide ($SO_2$) 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 500 ppb. Sulphur dioxide measurements in parts per billion (ppb) were subsequently converted to mass concentrations in micrograms per cubic metre (µg/m$^3$) (see Table A.1).

### Carbon Monoxide (CO)

Carbon monoxide (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 50 ppm (0 to 50 000 ppb). Carbon monoxide measurements in parts per billion (ppb) were subsequently converted to mass concentrations in micrograms per cubic metre (µg/m$^3$) (see Table A.1).

## A.3. Diffusion tubes

The diffusion tubes were deployed at 4 locations for 6 fortnightly periods between 23 October 2019 and 20 February 2020 following SEPA method ES-NFC-WP-057[21]. The tubes and subsequent analyses were supplied by the National Physical Laboratory (NPL) and Gradko International Ltd.

The $NO_2$ diffusion tubes consist of an acrylic tube fitted with coloured and white thermoplastic rubber caps. The coloured cap contains the absorbent triethanolamine (TEA) - grey cap for 20 % TEA/Water and red cap for 50 % TEA/Acetone. The $NO_2$ is adsorbed as nitrite ions and the concentrations of nitrite ions and hence the $NO_2$ chemically adsorbed are quantitatively determined by UV-Vis spectrophotometry with reference to a calibration curve derived from the analysis of standard nitrite solutions (UKAS Accredited Methods).

VOC monitoring was carried out using Automatic Thermal Desorption (ATD) type Perkin Elmer diffusive tubes containing Carbopack-X media. Quality assurance of the diffusion tube data analysis was carried out by NPL. All sample tubes passed the quality control checks prior to deployment.

Volatile organic compound (VOC) sampling and analysis was based on EN ISO 16017-2:2003 and BS EN 14662-4:2005 and carried out using UKAS (United Kingdom Accreditation Service) accredited method QPAS/B/566. This method combines ATD with Gas Chromatography, with a Flame Ionisation Detector (GC-FID).

UKAS accreditation does not cover the total hydrocarbon ($C_4$ to $C_{10}$) measurements, as accurate uptake factors have not been obtained for this group and a composite uptake factor used total hydrocarbon ($C_4$ to $C_{10}$) measurements.

The total hydrocarbons concentrations are given for comparative purposes and are not covered by UKAS for the reasons given below.

- It is assumed that all the species detected are hydrocarbons.
- An averaged calibration value is used (mean of the n-hexane, benzene, n-octane, toluene, ethylbenzene, m/p-xylene, o-xylene and n-decane calibrations).
- An averaged uptake rate ($C_4$ to $C_{10}$) is used, as individual values have been calculated for relatively few species.
- It is assumes 100 % retention of all the species, $C_4$ to $C_{10}$ using Carbopack-X.

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. A summary of the conversion factors is provided in Table A.1. However it should be noted that the results for total hydrocarbons ($C_4$ to $C_{10}$) are reported in ppb as conversion to a mass concentration isnot possible when analysing for multiple compounds with different molecular weights.

<u>Statement received from NPL in relation to a previous sampling campaign:</u>

*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.*

Analysis of ‘travel blank’ tubes submitted along with the monitoring location sample tubes measured concentrations below detection limits for five of the six deployments.

**Table A.1: Conversion factors for each measured parameter at 20°C and 1013mb.**

| Compound | Molecular Weight (g/mol) | Conversion Factor 1 ppb = x µg/m$^3$ |
|---|---|---|
| Nitrogen dioxide | 46.006 | 1.9125 |
| Benzene | 78.11 | 3.2430 |
| Toluene | 92.14 | 3.831 |
| Ethylbenzene | 106.17 | 4.414 |
| Xylene | 106.17 | 4.414 |
| 1,3-Butadiene | 54.092 | 2.2452 |
| Total Hydrocarbons ($C_4$-$C_{10}$) | Not applicable | Not applicable |
| Sulphur dioxide | 64.07 | 2.6609 |
| Carbon monoxide | 28.01 | 1.1642 |

**Notes:**

* Conversion factors from ppb to µg/m3 obtained from UK AIR Website[6]

# B. Quality Control

The continuous analysers used in this investigation were calibrated in line with the procedures cited in Appendix A. Once deployed the gas 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).

Table B.1 to Table B.8 present a summary of the quality control data for each of the deployed analysers. The associated tolerances for zero and span checks are drawn from the relevant British Standards (Section 6).

Quality assurance of the diffusion tube data analysis was carried out by NPL (VOCs) and their subcontractor Gradko International Ltd ($NO_2$). Quality assurance data for the diffusion tubes is presented in Table B.9, Figure B.1 and Figure B.2.

Sample tubes from the second deployment failed the quality control checks for VOCs. Sample tubes from the fifth and sixth deployments failed quality control checks for $NO_2$.

## B.1. Continuous Analysers

### B.1.1. Uncertainty of continuous analysers

The continuous analyser results presented in this report 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.

### B.1.2. Particulate matter ($PM_{2.5}$ & $PM_{10}$)

**Table B.1: Quality control data for the GRIMM ED180**

| Particulate Matter ($PM_{10}$ & $PM_{2.5}$) | |
|---|---|
| **Serial Number/Unit ID:** | GRIMM EDM180 |
| **Calibration date:** | 09/10/2019 |
| **Deployment date:** | 06/12/2019 |
| **End of monitoring period:** | 12/03/2020 |
| **Notes:** Calibrated externally by manufacturer (GRIMM) | |

### Table B.2: Quality control data for the Palas Fidas 200S

| Particulate Matter ($PM_{10}$ & $PM_{2.5}$) | | | | |
|---|---|---|---|---|
| **Instrument:** | FIDAS 200S - QP-00804 | | | |
| **Calibration date:** | 19/09/2017 | | | |
| **Deployment date:** | 09/08/2019 | | | |
| **End of monitoring period:** | 12/03/2020 | | | |
| **Date** | **FIDAS Serial no.** | **Web Logger Serial no.** | **Peak Channel** | **Pass/Fail** |
| 12/08/2019 10:05 | SN8602 | SN1328 | 141.12 | Pass |
| 06/11/2019 12:02 | SN8602 | SN1328 | 141.59 | Pass |
| 20/12/2019 11:23 | SN8602 | SN1328 | 141.28 | Pass |
| 21/01/2020 11:24 | SN8602 | SN1328 | 141.39 | Pass |
| 04/02/2020 10:39 | SN8602 | SN1328 | 141.29 | Pass |
| 02/03/2020 12:00 | SN8602 | SN1328 | 141.39 | Pass |

**Notes:**

Regular calibration checks carried out using MonoDust 1500 - Measured peak set point at 141.1 (i.e. the peak of the raw data is in channel 141.1).

If the measured calibration check deviates more than 141.1 ± 1.5 channels the instrument needs to be recalibrated.

### Table B.3 Quality control data for the Turnkey Osiris

| Particulate Matter ($PM_{10}$ & $PM_{2.5}$) | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Instrument:** | | Osiris TNO 3093 | | | | | |
| **Calibration date:** | | 22/05/2020* | | | | | |
| **Deployment date:** | | 13/08/2019 | | | | | |
| **End of monitoring period:** | | 09/02/2020 | | | | | |
| **Date** | **Calibration Number** | **Reference Instrument** | **Calibration Factor** | **Delta** ($\mu g/m^3$)** | | **Delta*** (%)** | |
| | | | | **$PM_{10}$** | **$PM_{2.5}$** | **$PM_{10}$** | **$PM_{2.5}$** |
| 17/07/2017 | 11710 | TNO 2126 | 1 | -3.7 | -7.69 | -2 | -4 |
| 02/08/2018 | 13035 | TNO 2126 | 1 | -0.6 | -7.54 | 0 | -3 |
| 22/05/2019 | 13879 | TNO 2267 | 1 | -17.6 | -6.03 | -5 | -2 |

**Notes:**

* External calibration by Turnkey Instruments Ltd

** Reference Instrument Reading minus Actual Instrument Reading

*** Tolerance between Actual and Reference within ±10 %

**Table B.4: Quality control data for the Turnkey Osiris**

| Particulate Matter ($PM_{10}$ & $PM_{2.5}$) | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Instrument:** | | Osiris TNO 3094 | | | | | |
| **Calibration date:** | | 12/02/2020* | | | | | |
| **Deployment date:** | | 09/02/2020 | | | | | |
| **End of monitoring period:** | | 12/03/2020 | | | | | |
| **Date** | **Calibration Number** | **Reference Instrument** | **Calibration Factor** | **Delta** ($\mu g/m^3$)** | | **Delta*** (%)** | |
| | | | | **$PM_{10}$** | **$PM_{2.5}$** | **$PM_{10}$** | **$PM_{2.5}$** |
| 09/02/2017 | 11292 | TNO 2126 | 1 | -7.8 | -8.85 | -3 | -4 |
| 16/01/2018 | 12370 | TNO 2126 | 1 | 5.5 | 5.72 | 2 | 2 |
| 12/02/2019 | 13591 | TNO 2163 | 1 | 9.4 | 5.55 | 5 | 3 |

**Notes:**

* External calibration by Turnkey Instruments Ltd

** Reference Instrument Reading minus Actual Instrument Reading

*** Tolerance between Actual and Reference within ±10 %

**Table B.5: Quality control data for the Turnkey Osiris**

| Particulate Matter ($PM_{10}$ & $PM_{2.5}$) | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Instrument:** | | Osiris TNO 3106 | | | | | |
| **Calibration date:** | | 14/03/2019* | | | | | |
| **Deployment date:** | | 13/08/2019 | | | | | |
| **End of monitoring period:** | | 12/03/2020 | | | | | |
| **Date** | **Calibration Number** | **Reference Instrument** | **Calibration Factor** | **Delta** ($\mu g/m^3$)** | | **Delta*** (%)** | |
| | | | | **$PM_{10}$** | **$PM_{2.5}$** | **$PM_{10}$** | **$PM_{2.5}$** |
| 23/03/2017 | 11423 | TNO 2163 | 1 | 0.6 | -2.43 | 0 | -1 |
| 19/02/2018 | 12505 | TNO 2163 | 1 | -4.7 | -3.08 | -2 | -1 |
| 14/03/2019 | 13728 | TNO 2163 | 1 | 0.7 | 0.26 | 0 | 0 |

**Notes:**

* External calibration by Turnkey Instruments Ltd

** Reference Instrument Reading minus Actual Instrument Reading

*** Tolerance between Actual and Reference within ±10 %

### B.1.3. Nitrogen dioxide ($NO_2$)

**Table B.6: Quality control data for the $NO_2$ analyser**

| Oxides of Nitrogen (NOx) | | | | |
|---|---|---|---|---|
| **Instrument:** | Teledyne T200 - T AHER 003 | | | |
| **Calibration date:** | 28/11/2019 | | | |
| **Deployment date:** | 06/12/2019 | | | |
| **End of monitoring period:** | 12/03/2020 | | | |
| **Date** | **Instrument serial no.** | **Zero check* (ppb)** | **Span check** (ppb)** | **Span drift (%)** |
| 09/12/2019 13:00 | SN81 | 0.00 | 520.3 | |
| 17/12/2019 12:00 | SN81 | -0.10 | 519.0 | -0.2 |
| 20/12/2019 12:15 | SN81 | -0.30 | 515.4 | -0.9 |
| 07/01/2020 14:15 | SN81 | -0.40 | 513.8 | -1.2 |
| 16/01/2020 11:26 | SN81 | -0.10 | 508.2 | -2.3 |
| 23/01/2020 11:50 | SN81 | -0.30 | 509.1 | -2.2 |
| 30/01/2020 11:49 | SN81 | 0.10 | 509.3 | -2.1 |
| 06/02/2020 11:46 | SN81 | -0.60 | 503.3 | -3.3 |
| 13/02/2020 12:25 | SN81 | -0.20 | 499.8 | -3.9 |
| 20/02/2020 13:00 | SN81 | 1.00 | 478.4 | -8.1 |
| 27/02/2020 13:00 | SN81 | 0.80 | 496.9 | -4.5 |
| 05/03/2020 13:46 | SN81 | 1.00 | 497.8 | -4.3 |
| 12/03/2020 11:57 | SN81 | -0.40 | 497.5 | -4.4 |

**Notes**:

Span drift ≥ 5 % of initial span value on 20/02/2020

* 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 520.3 ppb NO (SEPA ref: GAS 068.3); span check action criteria ≥ 5 % of initial span value

### B.1.4. Sulphur dioxide ($SO_2$)

**Table B.7: Quality control data for the $SO_2$ analyser**

| Sulphur Dioxide ($SO_2$) | | | | |
|---|---|---|---|---|
| **Instrument:** | Teledyne T100 - T AHER 005 | | | |
| **Calibration date:** | 27/11/2019 | | | |
| **Deployment date:** | 06/12/2019 | | | |
| **End of monitoring period:** | 12/03/2020 | | | |
| **Date** | **Instrument serial no.** | **Zero check* (ppb)** | **Span check** (ppb)** | **Span drift (%)** |
| 09/12/2019 13:00 | SN82 | 2.1 | 408.7 | |
| 17/12/2019 11:45 | SN82 | 2.7 | 408.2 | -0.1 |
| 20/12/2019 12:00 | SN82 | 2.8 | 409.5 | 0.2 |
| 07/01/2020 13:46 | SN82 | 2.2 | 405.4 | -0.8 |
| 16/01/2020 11:00 | SN82 | 2.7 | 406.5 | -0.5 |
| 23/01/2020 11:40 | SN82 | 0.8 | 391.8 | -4.1 |
| 30/01/2020 11:46 | SN82 | 2.2 | 399.6 | -2.2 |
| 06/02/2020 11:44 | SN82 | 1.9 | 396.2 | -3.1 |
| 13/02/2020 13:00 | SN82 | 3 | 410 | 0.3 |
| 20/02/2020 13:00 | SN82 | 2.7 | 400.4 | -2.0 |
| 27/02/2020 13:00 | SN82 | 4.2 | 402.7 | -1.5 |
| 05/03/2020 13:00 | SN82 | 3.3 | 399.3 | -2.3 |
| 12/03/2020 12:00 | SN82 | 4.6 | 401.1 | -1.9 |

**Notes:**

Zero drift ≥ 4 ppb of initial zero value on 27/02/2020 and 12/03/2020

* 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 408.7 ppb $SO_2$ (SEPA ref: GAS 075.4); span check action criteria ≥ 5 % of initial span value

### B.1.5. Carbon monoxide (CO)

**Table B.8: Quality control data for the CO analyser**

| Carbon Monoxide (CO) | | | | |
|---|---|---|---|---|
| **Instrument:** | Teledyne T300 - T AHER 002 SN 76 | | | |
| **Calibration date:** | 26/11/2019 | | | |
| **Deployment date:** | 06/12/2019 | | | |
| **End of monitoring period:** | 12/03/2020 | | | |
| **Date** | **Instrument serial no.** | **Zero check* (ppb)** | **Span check** (ppb)** | **Span drift (%)** |
| 09/12/2019 13:00 | SN76 | 95.0 | 39944.0 | |
| 17/12/2019 11:45 | SN76 | 103.0 | 40179.0 | 0.6 |
| 20/12/2019 12:00 | SN76 | 132.0 | 40328.0 | 1.0 |
| 09/01/2020 12:00 | SN76 | 250.0 | 40470.0 | 1.3 |
| 16/01/2020 11:00*** | SN76 | 243.0 | 40517.0 | 1.4 |
| 17/01/2020 12:00*** | SN76 | -200.0 | 39100.0 | 0.0 |
| 23/01/2020 11:30 | SN76 | 300.0 | 40500.0 | 0.0 |
| 30/01/2020 11:46 | SN76 | 349.3 | 40952.0 | 1.1 |
| 06/02/2020 11:44 | SN76 | 402.4 | 40675.7 | 0.4 |
| 13/02/2020 13:00 | SN76 | 500.0 | 41000.0 | 1.2 |
| 20/02/2020 13:00 | SN76 | 477.5 | 41106.0 | 1.5 |
| 27/02/2020 13:00 | SN76 | 703.3 | 41585.5 | 2.7 |
| 05/03/2020 13:00 | SN76 | 601.8 | 41121.7 | 1.5 |
| 12/03/2020 12:00 | SN76 | 571.0 | 41369.0 | 2.1 |

**Notes:**

Span check action criteria ≥ 5 % of initial span value.

* Zero check - Air drawn through silica gel, Purafil and activated carbon; zero check action criteria ≥ 0.5 ppm (500 ppb)

** Span check - Instrument SN76 deployed but suffered sporadic power failures - Span check gas - initial span at 39944 ppb CO on SN76 (SEPA ref: GAS 080.1)

*** SN76 suffered a power failure from 11/01/2020 until 20/01/2020 and two span checks were completed during this time but unit powered off as soon as SEPA left site. A new initial span value was therefore completed on 23/01/2020 as unit was unpowered for 9 days - Span check gas initial span at 40500 ppb CO on unit SN76 (SEPA ref: GAS 080.1); Data between 20/01/2020 and 23/01/2020 reported as indicative only and drift correction applied as an estimate of expected analyser span and zero drift for this period only.

## B.2. Diffusion tube quality control

Details noted here have been provided by SEPA's approved contractor NPL and their subcontractor Gradko International Ltd.

### B.2.1. $NO_2$ Tubes

Analysis of the $NO_2$ diffusion tubes is carried out using an accredited method. Proficiency testing schemes must be participated in to maintain accreditation and performance is continually assessed. Satisfactory performance requires the majority of Z-scores to be within ±2, with some results allowed within ±3. Any result outside ±3 is deemed unsatisfactory. The example below shows performance for $NO_2$ in the period immediately prior to monitoring well within ±2 (Table B.9).

**Table B.9: Proficiency testing data for $NO_2$ diffusion tube analysis (supplied by GRADKO)**

| AIR PT Proficiency Scheme - Nitrogen Dioxide 2019 | | | | | |
|---|---|---|---|---|---|
| Date | Round | Assigned Value | Procedure GLM 7 | | |
| | | | Measured Concentration | z-Score | % Bias |
| Feb-19 | AIR PT 30-1 | 0.8 | 0.8 | 0 | 0.0 % |
| Feb-19 | AIR PT 30-2 | 0.8 | 0.8 | 0 | 0.0 % |
| Feb-19 | AIR PT 30-3 | 2.35 | 1.98 | -2.1 | -15.7 % |
| Feb-19 | AIR PT 30-4 | 2.42 | 2.39 | -0.16 | -1.2 % |
| | | | | | |
| May-19 | AIR PT 31-1 | 1.82 | 1.65 | -1.24 | -9.3 % |
| May-19 | AIR PT 31-2 | 1.82 | 1.64 | -1.31 | -9.9 % |
| May-19 | AIR PT 31-3 | 1.01 | 0.97 | -0.53 | -4.0 % |
| May-19 | AIR PT 31-4 | 0.99 | 0.89 | -1.35 | -10.1 % |
| | | | | | |
| Aug-19 | AIR PT 33-1 | 0.72 | 0.75 | 0.56 | 4.2 % |
| Aug-19 | AIR PT 33-2 | 0.71 | 0.71 | 0 | 0.0 % |
| Aug-19 | AIR PT 33-3 | 2.09 | 2.03 | -0.38 | -2.9 % |
| Aug-19 | AIR PT 33-4 | 2.04 | 2.02 | -0.13 | -1.0 % |
| | | | | | |
| Oct-19 | AIR PT 34-1 | 1.57 | 1.61 | 0.38 | 2.5 % |
| Oct-19 | AIR PT 34-2 | 1.56 | 1.49 | -0.56 | -4.5 % |
| Oct-19 | AIR PT 34-3 | 1.19 | 1.19 | 0 | 0.0 % |
| Oct-19 | AIR PT 34-4 | Sample wasted not submitted | | | |

### B.2.2. VOC Tubes

Before the tube leaves the laboratory, it is cleaned and analysed to ensure its levels are below those limits set out in the method. The detection limits for the monitoring method are based upon the cleaning criteria for the sampling tube.

For Carbopack-X the limits are:

| Species | Cleaning criteria (in ng) |
|---|---|
| Benzene | <2 |
| Other VOC's | <5 |
| Total hydrocarbons ($C_4$ to $C_{10}$) | <100 |

Using a 14-day exposure (20160 minutes), these quantities equate to a detection limit as given in the following table.

| Species | Detection limit (in ppb v/v) |
|---|---|
| Benzene | 0.1 |
| Other VOC's | 0.3 |
| Total hydrocarbons ($C_4$ to $C_{10}$) | 5 |

Analysis of the diffusion tubes is carried out using an accredited method (total hydrocarbons are outside scope of accreditation). Proficiency testing schemes must be participated in to maintain accreditation and performance is continually assessed. Satisfactory performance requires the majority of Z-scores to be within ±2, with some results allowed within ±3. Any result outside ±3 is deemed unsatisfactory. The example below shows performance for benzene well within ±2.

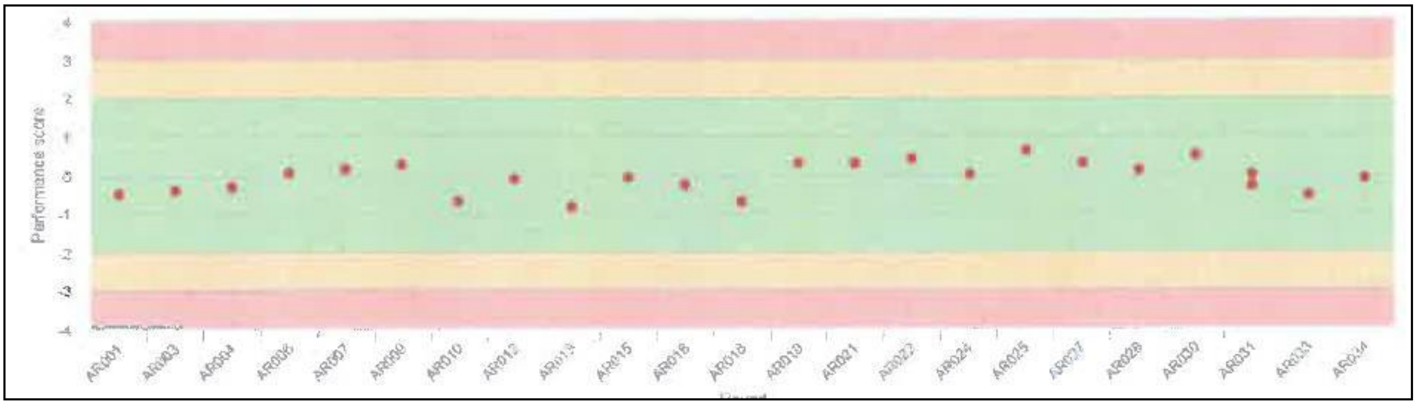


**Figure B.1: Benzene proficiency testing Z-score control chart (supplied by NPL)**

## C. Photographic Record of Monitoring Sites

**Air Monitoring Trailer**



**Osiris PM Analysers**


**FIDAS PM Analyser**

**CR200 Met. Station**

**Diffusion Tube Housing Sites**

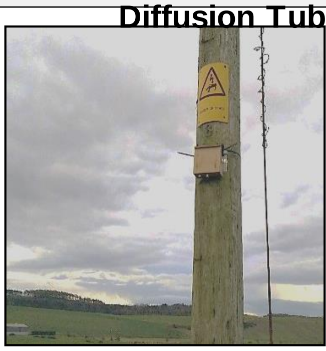



**Figure C.1: Photographic record of the monitoring sites in the vicinity of Mossmorran between 10 January 2019 and 18 April 2019**

## 2.1 D. 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 D.1.

**Table D.1: Summary of relevant Scottish and UK air quality objectives**

| Pollutant | Applies to | Air Quality Objective Concentration (as µg/m³ unless stated) | Measured as |
|---|---|---|---|
| **Benzene** | UK | 16.25 | Running annual mean |
| | Scotland | 3.25 | Running annual mean |
| **1,3-Butadiene** | UK | 2.25 | Running annual mean |
| **CO** | Scotland | 10.0* | Running 8-hour mean |
| **$NO_2$** | UK | 200 - not to be exceeded more than 18 times a year | 1-hour mean |
| | UK | 40 | Annual mean |
| **$PM_{10}$** | UK | 50 - not to be exceeded more than 35 times a year | 24-hour mean |
| | UK | 40 | Annual mean |
| | Scotland | 50 - not to be exceeded more than 7 times a year | 24-hour mean |
| | Scotland | 18 | Annual mean |
| **$PM_{2.5}$** | UK | 25 - target | Annual mean |
| | Scotland | 10 - limit | Annual mean |
| **$SO_2$** | UK | 350 - not to be exceeded more than 24 times a year | 1-hour mean |
| | UK | 125 - not to be exceeded more than 3 times a year | 24-hour mean |
| | UK | 266 - not to be exceeded more than 35 times a year | 15-minute mean |

**Note:**
Table adapted from www.scottishairquality.scot/air-quality/standards [2]
* concentration in mg/m³

The air quality objectives summarised in Table D.1 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 six 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.

## D.1. 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*"[8].

A summary of the relevant indices (i.e. $PM_{2.5}$, $PM_{10}$, $NO_2$ and $SO_2$) is presented in Table D.2.

**Table D.2: Summary of relevant daily air quality indices (adapted from *https://uk-air.defra.gov.uk/air-pollution/daqi* [3])**

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

**Table D.2 Continued**

| Air Pollution Banding | Value | Accompanying health messages for at-risk individuals* | Accompanying health messages for the general population |
|---|---|---|---|
| Low | 1-3 | **Enjoy** your usual outdoor activities. | **Enjoy** your usual outdoor activities. |
| Moderate | 4-6 | Adults and children with lung problems, and adults with heart problems, **who experience symptoms**, should **consider reducing** strenuous physical activity, particularly outdoors. | **Enjoy** your usual outdoor activities. |
| High | 7-9 | Adults and children with lung problems, and adults with heart problems, should **reduce** strenuous physical exertion, particularly outdoors, and particularly if they experience symptoms. People with asthma may find they need to use their reliever inhaler more often. Older people should also **reduce** physical exertion. | Anyone experiencing discomfort such as sore eyes, cough or sore throat should **consider reducing** activity, particularly outdoors. |
| Very High | 10 | Adults and children with lung problems, adults with heart problems, and older people, should **avoid** strenuous physical activity. People with asthma may find they need to use their reliever inhaler more often. | **Reduce** physical exertion, particularly outdoors, especially if you experience symptoms such as cough or sore throat. |

**Note:**

* Adults and children with heart or lung problems are at greater risk of symptoms. Follow your doctor's usual advice about exercising and managing your condition. It is possible that very sensitive individuals may experience health effects even on Low air pollution days. Anyone experiencing symptoms should follow the guidance provided on the Defra UK-AIR website.

# E. Measured Pollutant Concentrations – Charts and Data

## E.1. Particulate Matter

**Table E.1: Daily Mean Particulate Matter Data**

| Date | Particulate matter concentrations expressed as µg/m³ | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Lochgelly | | Auchtertool | | Donibristle | | Little Raith | |
| | $PM_{10}$ | $PM_{2.5}$ | $PM_{10}$ | $PM_{2.5}$ | $PM_{10}$ | $PM_{2.5}$ | $PM_{10}$ | $PM_{2.5}$ |
| 14/08/2019 | 6.12 | 3.28 | 6.3 | 1.90 | 6.4 | 1.70 | - | - |
| 15/08/2019 | 6.87 | 3.04 | 10.1 | 3.52 | 9.4 | 3.53 | - | - |
| 16/08/2019 | 6.58 | 2.74 | 6.0 | 3.27 | 5.8 | 3.36 | - | - |
| 17/08/2019 | 10.40 | 4.18 | 16.6 | 7.07 | 12.2 | 7.15 | - | - |
| 18/08/2019 | 8.73 | 4.37 | 10.7 | 7.97 | 11.2 | 8.84 | - | - |
| 19/08/2019 | 9.81 | 4.18 | 9.8 | 7.10 | 11.6 | 7.95 | - | - |
| 20/08/2019 | 6.49 | 3.62 | 6.7 | 3.93 | 6.7 | 4.26 | - | - |
| 21/08/2019 | 8.27 | 4.40 | 11.4 | 4.04 | 7.1 | 4.28 | - | - |
| 22/08/2019 | 8.20 | 3.80 | 14.0 | 5.30 | 9.2 | 5.12 | - | - |
| 23/08/2019 | 7.86 | 4.87 | 8.2 | 6.21 | 9.3 | 6.96 | - | - |
| 24/08/2019 | 11.44 | 6.73 | 7.6 | 3.42 | 10.6 | 4.09 | - | - |
| 25/08/2019 | 23.06 | 15.63 | 14.6 | 6.54 | 13.6 | 6.52 | - | - |
| 26/08/2019 | 13.81 | 10.47 | 8.1 | 5.48 | 8.6 | 5.44 | - | - |
| 27/08/2019 | 10.84 | 6.66 | 9.7 | 2.97 | 6.0 | 2.59 | - | - |
| 28/08/2019 | 6.55 | 2.76 | 6.7 | 2.98 | 5.0 | 2.94 | - | - |
| 29/08/2019 | 7.73 | 4.01 | 6.9 | 5.26 | 7.4 | 5.65 | - | - |
| 30/08/2019 | 7.96 | 4.41 | 9.5 | 6.67 | 9.0 | 7.04 | - | - |
| 31/08/2019 | 7.57 | 4.10 | 8.8 | 6.49 | 9.3 | 7.22 | - | - |
| 01/09/2019 | 4.85 | 2.72 | 4.2 | 3.22 | 5.2 | 3.65 | - | - |
| 02/09/2019 | 3.30 | 1.65 | 3.0 | 2.16 | 3.6 | 2.43 | - | - |
| 03/09/2019 | 2.87 | 1.11 | 2.4 | 1.19 | 3.1 | 1.31 | - | - |
| 04/09/2019 | 6.30 | 2.92 | 7.8 | 5.51 | 9.3 | 5.97 | - | - |
| 05/09/2019 | 9.93 | 5.00 | 10.6 | 8.85 | 7.5 | 5.66 | - | - |
| 06/09/2019 | 5.75 | 3.06 | 5.6 | 4.54 | 6.7 | 5.23 | - | - |
| 07/09/2019 | 4.48 | 1.93 | 3.3 | 1.82 | 3.6 | 1.94 | - | - |
| 08/09/2019 | 6.49 | 3.64 | 4.3 | 2.44 | 4.7 | 2.57 | - | - |
| 09/09/2019 | 5.08 | 3.18 | 9.5 | 2.36 | 3.1 | 1.46 | - | - |
| 10/09/2019 | 5.17 | 3.06 | 5.4 | 3.56 | 5.2 | 3.53 | - | - |
| 11/09/2019 | 6.77 | 3.39 | 7.4 | 6.07 | 8.4 | 6.48 | - | - |
| 12/09/2019 | 5.39 | 2.78 | 6.5 | 4.73 | 7.2 | 5.09 | - | - |
| 13/09/2019 | 9.62 | 4.63 | 10.8 | 8.36 | 12.0 | 9.05 | - | - |
| 14/09/2019 | 7.43 | 3.62 | 7.2 | 5.31 | 8.0 | 5.74 | - | - |
| 15/09/2019 | 16.14 | 8.39 | 16.9 | 14.06 | 18.2 | 14.96 | - | - |
| 16/09/2019 | 9.57 | 4.84 | 10.1 | 7.41 | 10.5 | 7.76 | - | - |
| 17/09/2019 | 9.57 | 4.75 | 9.1 | 6.50 | 9.2 | 6.75 | - | - |
| 18/09/2019 | 7.67 | 3.59 | 7.3 | 4.75 | 7.2 | 4.67 | - | - |
| 19/09/2019 | 6.92 | 4.76 | 5.0 | 3.16 | 5.3 | 3.15 | - | - |
| 20/09/2019 | 13.24 | 9.00 | 8.6 | 5.37 | 9.5 | 6.06 | - | - |
| 21/09/2019 | 19.68 | 11.66 | 14.6 | 10.20 | 14.7 | 10.60 | - | - |
| 22/09/2019 | 15.59 | 11.06 | 16.4 | 12.57 | 14.4 | 11.43 | - | - |
| 23/09/2019 | 5.90 | 3.76 | 6.6 | 2.86 | 4.6 | 2.20 | - | - |

| DAQI Index | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|

| Date | Particulate matter concentrations expressed as µg/m³ | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Lochgelly | | Auchtertool | | Donibristle | | Little Raith | |
| | $PM_{10}$ | $PM_{2.5}$ | $PM_{10}$ | $PM_{2.5}$ | $PM_{10}$ | $PM_{2.5}$ | $PM_{10}$ | $PM_{2.5}$ |
| 24/09/2019 | 5.13 | 3.42 | 7.0 | 4.60 | 5.4 | 3.53 | - | - |
| 25/09/2019 | 4.66 | 2.85 | 5.8 | 3.40 | 5.1 | 3.15 | - | - |
| 26/09/2019 | 5.86 | 3.32 | 6.7 | 4.77 | 6.6 | 4.65 | - | - |
| 27/09/2019 | 4.94 | 2.44 | 5.5 | 3.52 | 5.6 | 3.61 | - | - |
| 28/09/2019 | 5.08 | 3.04 | 3.8 | 1.84 | 3.8 | 2.00 | - | - |
| 29/09/2019 | 4.50 | 2.79 | 5.2 | 3.15 | 4.5 | 2.94 | - | - |
| 30/09/2019 | 3.29 | 1.65 | 3.9 | 2.03 | 3.7 | 2.07 | - | - |
| 01/10/2019 | 5.66 | 2.59 | 5.4 | 3.55 | 5.2 | 3.72 | - | - |
| 02/10/2019 | 3.83 | 1.88 | 3.0 | 2.12 | 3.0 | 2.04 | - | - |
| 03/10/2019 | 4.70 | 2.53 | 3.7 | 2.41 | 4.4 | 2.73 | - | - |
| 04/10/2019 | 7.81 | 4.67 | 9.1 | 6.84 | 8.5 | 6.68 | - | - |
| 05/10/2019 | 7.34 | 4.05 | 8.1 | 5.46 | 7.0 | 5.03 | - | - |
| 06/10/2019 | 7.57 | 4.47 | 11.2 | 7.14 | 8.4 | 6.14 | - | - |
| 07/10/2019 | 7.84 | 4.57 | 9.1 | 7.35 | 8.1 | 6.13 | - | - |
| 08/10/2019 | 8.71 | 4.81 | 10.8 | 9.32 | 10.3 | 8.52 | - | - |
| 09/10/2019 | 7.66 | 4.35 | 10.4 | 9.24 | 11.4 | 9.82 | - | - |
| 10/10/2019 | 5.71 | 3.38 | 8.0 | 6.93 | 8.8 | 7.34 | - | - |
| 11/10/2019 | 7.48 | 4.17 | 9.0 | 7.93 | 8.4 | 7.12 | - | - |
| 12/10/2019 | 5.75 | 3.11 | 4.9 | 3.35 | 5.5 | 3.81 | - | - |
| 13/10/2019 | 5.69 | 4.15 | 3.6 | 2.39 | 3.5 | 2.41 | - | - |
| 14/10/2019 | 7.29 | 5.52 | 3.2 | 1.84 | 3.4 | 2.05 | - | - |
| 15/10/2019 | 6.82 | 4.69 | 4.4 | 2.79 | 4.4 | 2.94 | - | - |
| 16/10/2019 | 7.66 | 4.78 | 5.1 | 3.23 | 5.3 | 3.60 | - | - |
| 17/10/2019 | 7.58 | 4.37 | 5.4 | 3.72 | 6.8 | 4.73 | - | - |
| 18/10/2019 | 6.92 | 5.06 | 4.2 | 2.77 | 3.8 | 2.58 | - | - |
| 19/10/2019 | 4.88 | 2.54 | 5.3 | 3.96 | 5.5 | 4.25 | - | - |
| 20/10/2019 | 4.69 | 2.42 | 3.9 | 3.14 | 3.2 | 2.43 | - | - |
| 21/10/2019 | 3.82 | 1.98 | 2.9 | 1.99 | 3.5 | 2.32 | - | - |
| 22/10/2019 | 5.39 | 2.94 | 4.1 | 3.16 | 4.2 | 2.99 | - | - |
| 23/10/2019 | 5.21 | 3.00 | 5.2 | 3.98 | 5.7 | 4.47 | - | - |
| 24/10/2019 | 4.58 | 2.53 | 3.8 | 3.09 | 5.2 | 3.94 | - | - |
| 25/10/2019 | 6.44 | 3.20 | 4.8 | 3.63 | 5.7 | 4.18 | - | - |
| 26/10/2019 | 5.14 | 3.01 | 3.3 | 2.63 | 4.5 | 3.30 | - | - |
| 27/10/2019 | 4.92 | 3.18 | 3.5 | 2.99 | 4.2 | 3.48 | - | - |
| 28/10/2019 | 5.85 | 2.88 | 4.1 | 2.57 | 3.9 | 2.71 | - | - |
| 29/10/2019 | 5.69 | 2.58 | 4.4 | 3.41 | 3.3 | 2.56 | - | - |
| 30/10/2019 | 4.21 | 2.19 | 3.4 | 2.58 | 4.1 | 2.92 | - | - |
| 31/10/2019 | 10.77 | 7.91 | 4.2 | 2.93 | 7.1 | 4.15 | - | - |
| 01/11/2019 | 9.40 | 8.88 | 2.2 | 1.65 | 2.1 | 1.62 | - | - |
| 02/11/2019 | 6.34 | 4.06 | 5.4 | 3.59 | 5.6 | 3.96 | - | - |
| 03/11/2019 | 8.20 | 5.19 | 12.0 | 8.98 | 11.7 | 9.27 | - | - |
| 04/11/2019 | 3.36 | 2.06 | 9.4 | 6.87 | 5.9 | 4.47 | - | - |
| 05/11/2019 | 7.46 | 4.18 | 6.8 | 5.11 | 6.5 | 4.92 | - | - |
| 06/11/2019 | 5.31 | 2.92 | 3.7 | 2.44 | 3.6 | 2.34 | - | - |

| DAQI Index | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|

| Date | Particulate matter concentrations expressed as µg/m³ | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Lochgelly | | Auchtertool | | Donibristle | | Little Raith | |
| | $PM_{10}$ | $PM_{2.5}$ | $PM_{10}$ | $PM_{2.5}$ | $PM_{10}$ | $PM_{2.5}$ | $PM_{10}$ | $PM_{2.5}$ |
| 07/11/2019 | 3.69 | 1.93 | - | - | 4.8 | 3.52 | - | - |
| 08/11/2019 | 6.68 | 3.63 | 8.1 | 4.45 | 4.2 | 3.29 | - | - |
| 09/11/2019 | 7.42 | 3.26 | 4.5 | 3.09 | - | - | - | - |
| 10/11/2019 | 7.10 | 4.31 | 3.7 | 2.58 | - | - | - | - |
| 11/11/2019 | 3.14 | 2.28 | 1.8 | 1.33 | - | - | - | - |
| 12/11/2019 | 2.07 | 1.29 | 1.2 | 0.86 | - | - | - | - |
| 13/11/2019 | 7.09 | 4.89 | 3.6 | 2.72 | - | - | - | - |
| 14/11/2019 | 4.48 | 3.33 | 1.9 | 1.51 | 2.9 | 2.33 | - | - |
| 15/11/2019 | 3.22 | 2.20 | 2.4 | 1.79 | 2.6 | 1.98 | - | - |
| 16/11/2019 | 6.13 | 4.68 | 2.9 | 2.24 | 3.2 | 2.35 | - | - |
| 17/11/2019 | 5.00 | 3.81 | 2.4 | 1.74 | 3.2 | 2.35 | - | - |
| 18/11/2019 | 6.87 | 3.98 | 3.7 | 2.52 | 4.4 | 3.09 | - | - |
| 19/11/2019 | 8.48 | 5.54 | 2.6 | 1.92 | 4.2 | 2.99 | - | - |
| 20/11/2019 | 13.53 | 11.85 | 4.1 | 3.22 | 4.7 | 3.62 | - | - |
| 21/11/2019 | 8.93 | 5.72 | 7.4 | 5.67 | 7.6 | 5.73 | - | - |
| 22/11/2019 | 10.32 | 7.20 | 8.2 | 5.98 | 8.4 | 6.17 | - | - |
| 23/11/2019 | 10.52 | 8.44 | 13.3 | 11.41 | 13.1 | 10.89 | - | - |
| 24/11/2019 | 20.23 | 16.80 | 13.6 | 10.63 | 13.4 | 10.49 | - | - |
| 25/11/2019 | 12.22 | 10.63 | 6.5 | 5.21 | 8.2 | 5.52 | - | - |
| 26/11/2019 | 3.57 | 3.27 | 2.2 | 1.72 | 2.2 | 1.26 | - | - |
| 27/11/2019 | 5.11 | 4.06 | 2.4 | 1.94 | 7.3 | 3.92 | - | - |
| 28/11/2019 | 5.04 | 2.63 | 1.1 | 0.46 | 5.8 | 4.50 | - | - |
| 29/11/2019 | 6.26 | 4.14 | 3.9 | 2.75 | 5.0 | 3.24 | - | - |
| 30/11/2019 | 5.95 | 3.92 | 3.3 | 2.43 | 4.2 | 2.96 | - | - |
| 01/12/2019 | 7.13 | 5.69 | 2.5 | 1.99 | 3.6 | 2.85 | - | - |
| 02/12/2019 | 6.66 | 4.85 | 5.9 | 4.55 | 6.1 | 4.86 | - | - |
| 03/12/2019 | 8.14 | 5.73 | 6.6 | 5.53 | 6.0 | 5.45 | - | - |
| 04/12/2019 | 6.95 | 4.08 | 8.2 | 6.81 | 7.8 | 7.01 | 9.3 | 7.1 |
| 05/12/2019 | 3.92 | 2.39 | 4.1 | 3.74 | 3.9 | 3.73 | 5.1 | 4.4 |
| 06/12/2019 | 3.21 | 2.06 | 4.2 | 3.61 | 4.2 | 3.80 | 2.8 | 2.5 |
| 07/12/2019 | 2.60 | 1.66 | 3.3 | 2.63 | 3.5 | 2.79 | 1.8 | 1.7 |
| 08/12/2019 | 4.03 | 2.53 | 6.2 | 5.43 | 5.0 | 4.80 | 2.0 | 1.9 |
| 09/12/2019 | 8.55 | 4.81 | 7.8 | 6.42 | 8.2 | 6.88 | 6.8 | 4.5 |
| 10/12/2019 | 4.02 | 2.31 | 5.5 | 4.70 | 5.4 | 4.86 | 1.7 | 1.6 |
| 11/12/2019 | 5.42 | 3.26 | 7.1 | 6.18 | 6.8 | 6.38 | 2.4 | 2.3 |
| 12/12/2019 | 8.08 | 5.60 | 6.4 | 5.28 | 7.0 | 5.94 | 7.4 | 6.8 |
| 13/12/2019 | 3.61 | 2.98 | 1.0 | 0.75 | 1.5 | 1.09 | 5.6 | 4.2 |
| 14/12/2019 | 4.03 | 2.81 | 4.8 | 4.10 | 4.2 | 3.90 | 2.8 | 2.7 |
| 15/12/2019 | 5.39 | 3.19 | 6.1 | 4.48 | 6.8 | 5.21 | 4.4 | 3.8 |
| 16/12/2019 | 4.84 | 3.02 | 4.1 | 3.33 | 4.5 | 3.76 | 3.7 | 3.5 |
| 17/12/2019 | 4.19 | 2.71 | 2.8 | 2.18 | 3.2 | 2.57 | 3.3 | 2.9 |
| 18/12/2019 | 7.15 | 5.13 | 3.9 | 2.87 | 4.1 | 3.20 | 7.9 | 7.2 |
| 19/12/2019 | 8.03 | 5.30 | 7.5 | 6.06 | 8.5 | 6.77 | 7.6 | 6.8 |
| 20/12/2019 | 4.37 | 3.11 | 3.5 | 2.85 | 4.4 | 3.56 | 4.9 | 4.4 |

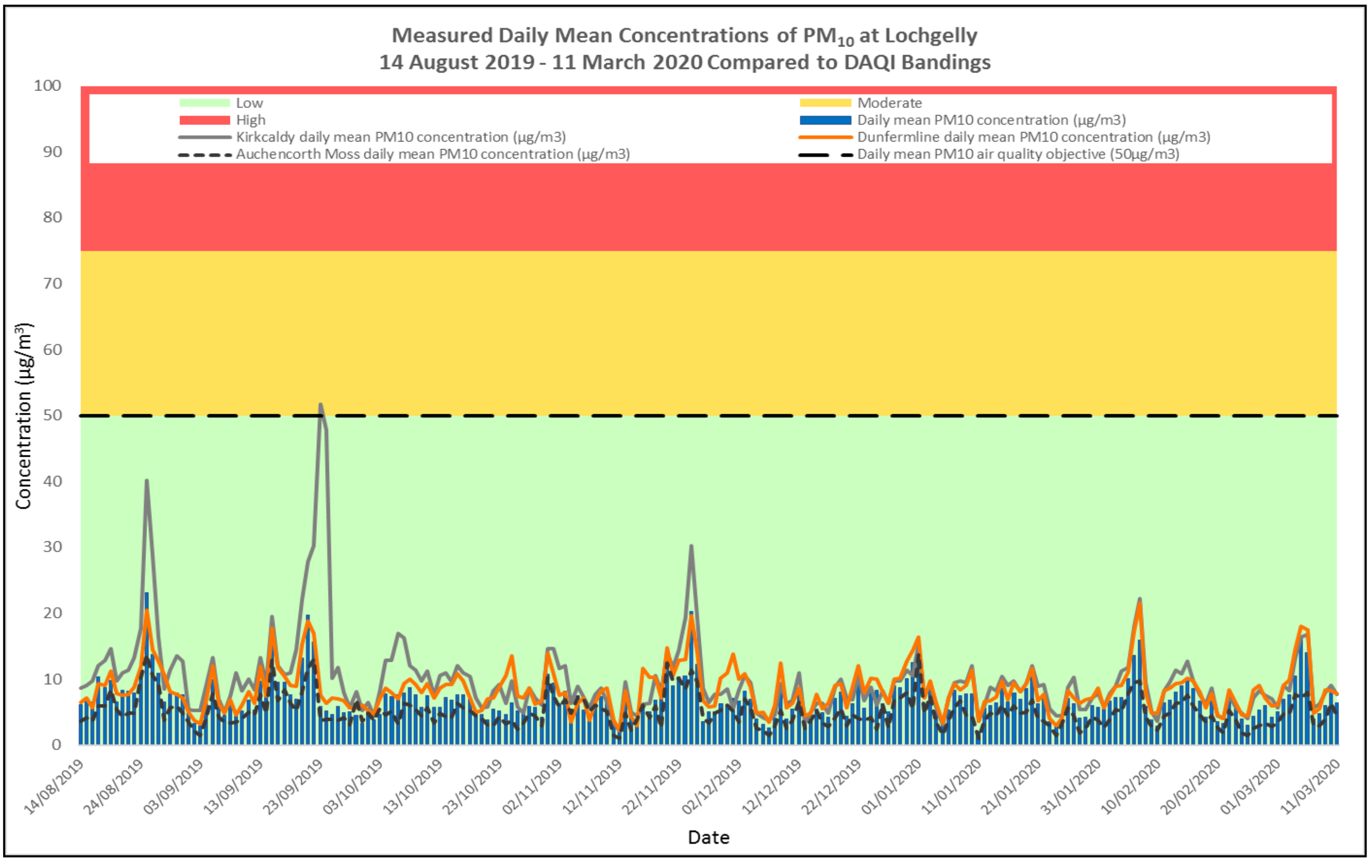
| DAQI Index | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|

| Date | Particulate matter concentrations expressed as µg/m³ | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Lochgelly | | Auchtertool | | Donibristle | | Little Raith | |
| | $PM_{10}$ | $PM_{2.5}$ | $PM_{10}$ | $PM_{2.5}$ | $PM_{10}$ | $PM_{2.5}$ | $PM_{10}$ | $PM_{2.5}$ |
| 21/12/2019 | 6.34 | 5.16 | 2.7 | 2.11 | 3.1 | 2.45 | 7.8 | 7.4 |
| 22/12/2019 | 10.36 | 9.17 | 2.2 | 1.63 | 3.1 | 2.35 | 10.8 | 10.1 |
| 23/12/2019 | 5.54 | 3.64 | 6.4 | 5.27 | 6.2 | 5.53 | 3.9 | 3.6 |
| 24/12/2019 | 8.80 | 6.25 | 6.8 | 5.62 | 8.0 | 6.70 | 9.5 | 8.0 |
| 25/12/2019 | 8.27 | 7.30 | 2.4 | 1.84 | 2.7 | 1.78 | 10.2 | 8.5 |
| 26/12/2019 | 6.32 | 4.43 | 5.3 | 4.25 | 5.3 | 4.27 | 6.8 | 6.2 |
| 27/12/2019 | 4.99 | 3.24 | 3.4 | 2.55 | 3.9 | 2.74 | 5.3 | 4.7 |
| 28/12/2019 | 9.05 | 5.91 | 11.6 | 10.57 | 12.7 | 11.73 | 5.6 | 5.2 |
| 29/12/2019 | 8.74 | 5.68 | 11.0 | 9.76 | 10.6 | 9.80 | 5.5 | 5.1 |
| 30/12/2019 | 10.01 | 6.40 | 11.7 | 9.98 | 11.5 | 10.14 | 7.4 | 6.4 |
| 31/12/2019 | 12.53 | 9.48 | 7.1 | 5.65 | 8.8 | 7.11 | 10.9 | 8.8 |
| 01/01/2020 | 15.01 | 13.48 | 5.8 | 5.06 | 6.1 | 5.43 | 19.6 | 19.1 |
| 02/01/2020 | 6.20 | 3.97 | 6.0 | 5.02 | 5.7 | 4.94 | 4.2 | 3.9 |
| 03/01/2020 | 8.25 | 4.63 | 10.5 | 9.29 | 10.6 | 9.88 | 5.8 | 4.5 |
| 04/01/2020 | 5.10 | 3.33 | 7.1 | 6.05 | 6.7 | 6.17 | 3.5 | 3.3 |
| 05/01/2020 | 3.12 | 2.25 | 1.9 | 1.57 | 2.1 | 1.73 | 3.0 | 2.9 |
| 06/01/2020 | 5.34 | 3.04 | 6.8 | 5.77 | 6.8 | 6.23 | 2.7 | 2.3 |
| 07/01/2020 | 8.25 | 5.12 | 11.3 | 10.30 | 10.3 | 9.70 | 3.5 | 3.3 |
| 08/01/2020 | 7.51 | 4.49 | 9.9 | 8.81 | 9.0 | 8.49 | 4.7 | 4.1 |
| 09/01/2020 | 7.70 | 5.61 | 6.9 | 5.37 | 6.4 | 5.02 | 10.7 | 8.8 |
| 10/01/2020 | 7.76 | 6.11 | 6.3 | 5.38 | 6.7 | 5.34 | 9.1 | 8.3 |
| 11/01/2020 | 2.12 | 1.25 | 2.9 | 2.41 | 2.8 | 2.42 | 1.2 | 1.1 |
| 12/01/2020 | 5.62 | 3.28 | 6.8 | 5.26 | 7.5 | 5.83 | 3.9 | 3.4 |
| 13/01/2020 | 5.94 | 3.31 | 6.6 | 5.57 | 7.4 | 6.55 | 2.4 | 2.2 |
| 14/01/2020 | 6.36 | 3.63 | - | - | 7.3 | 6.87 | 2.4 | 2.3 |
| 15/01/2020 | 8.63 | 4.97 | - | - | 9.9 | 9.03 | 3.2 | 3.0 |
| 16/01/2020 | 6.50 | 3.54 | - | - | 16.7 | 10.82 | 3.2 | 2.9 |
| 17/01/2020 | 7.91 | 4.36 | 9.9 | 7.41 | 9.9 | 8.49 | 4.7 | 4.1 |
| 18/01/2020 | 6.98 | 4.09 | 6.8 | 5.26 | 7.3 | 6.30 | 7.9 | 4.8 |
| 19/01/2020 | 8.64 | 5.55 | 8.6 | 6.11 | 8.8 | 7.08 | 7.4 | 6.6 |
| 20/01/2020 | 10.35 | 7.15 | 11.8 | 9.21 | 9.2 | 8.90 | 7.1 | 6.7 |
| 21/01/2020 | 6.31 | 4.99 | 5.1 | 4.19 | 4.3 | 3.95 | 7.0 | 6.8 |
| 22/01/2020 | 7.03 | 5.29 | 6.9 | 4.74 | 8.1 | 6.16 | 6.8 | 6.3 |
| 23/01/2020 | 3.58 | 2.65 | 3.8 | 2.79 | 1.5 | 1.28 | 3.5 | 3.3 |
| 24/01/2020 | 3.33 | 2.71 | 1.2 | 1.03 | 1.2 | 1.03 | 3.3 | 3.2 |
| 25/01/2020 | 3.75 | 3.14 | 1.9 | 1.56 | 1.9 | 1.59 | 4.1 | 4.0 |
| 26/01/2020 | 7.13 | 4.05 | 7.1 | 5.54 | 7.2 | 5.58 | 4.2 | 3.8 |
| 27/01/2020 | 6.30 | 3.07 | 8.4 | 4.45 | 6.9 | 5.61 | 3.5 | 2.7 |
| 28/01/2020 | 4.12 | 2.83 | 3.8 | 2.77 | 3.9 | 3.08 | 3.2 | 3.1 |
| 29/01/2020 | 4.24 | 2.52 | 6.0 | 4.95 | 6.0 | 5.30 | 2.3 | 2.1 |
| 30/01/2020 | 6.03 | 3.70 | 5.2 | 4.29 | 5.2 | 5.01 | 2.8 | 2.5 |
| 31/01/2020 | 5.66 | 3.54 | - | - | 7.2 | 6.77 | 2.8 | 2.6 |
| 01/02/2020 | 5.47 | 3.86 | - | - | 5.2 | 4.91 | 2.3 | 2.2 |

| DAQI Index | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|

| Date | Particulate matter concentrations expressed as µg/m³ | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Lochgelly | | Auchtertool | | Donibristle | | Little Raith | |
| | $PM_{10}$ | $PM_{2.5}$ | $PM_{10}$ | $PM_{2.5}$ | $PM_{10}$ | $PM_{2.5}$ | $PM_{10}$ | $PM_{2.5}$ |
| 02/02/2020 | 6.68 | 4.35 | - | - | 8.2 | 6.13 | 4.8 | 4.5 |
| 03/02/2020 | 7.24 | 4.42 | - | - | 7.8 | 7.68 | 3.0 | 2.8 |
| 04/02/2020 | 7.17 | 3.90 | 7.7 | 6.57 | 7.2 | 5.93 | 5.6 | 3.6 |
| 05/02/2020 | 10.09 | 5.54 | 11.7 | 10.03 | 12.2 | 9.81 | 7.2 | 5.9 |
| 06/02/2020 | 13.59 | 9.98 | - | - | - | - | 13.9 | 12.0 |
| 07/02/2020 | 15.91 | 12.82 | 8.4 | 6.82 | - | - | 16.5 | 14.8 |
| 08/02/2020 | 5.91 | 3.54 | 6.9 | 6.45 | 7.1 | 6.53 | 2.5 | 2.4 |
| 09/02/2020 | 3.78 | 2.34 | 4.4 | 4.07 | 2.9 | 2.78 | 2.0 | 1.8 |
| 10/02/2020 | 2.93 | 1.83 | 4.6 | 4.25 | 3.8 | 3.54 | 1.3 | 1.2 |
| 11/02/2020 | 6.39 | 3.85 | 9.8 | 9.27 | 6.9 | 6.64 | 3.2 | 2.9 |
| 12/02/2020 | 6.80 | 3.68 | 8.2 | 7.45 | 6.8 | 6.22 | 4.1 | 3.4 |
| 13/02/2020 | 8.09 | 4.81 | 14.5 | 9.51 | 10.6 | 8.14 | 5.8 | 4.8 |
| 14/02/2020 | 9.00 | 5.06 | 7.0 | 5.77 | 10.1 | 8.76 | 4.7 | 4.2 |
| 15/02/2020 | 9.89 | 5.33 | 13.3 | 11.49 | 13.1 | 11.35 | 5.0 | 4.3 |
| 16/02/2020 | 8.63 | 4.94 | 8.2 | 8.00 | 8.2 | 8.03 | 2.8 | 2.4 |
| 17/02/2020 | 6.70 | 4.29 | 6.9 | 6.90 | 6.9 | 6.90 | 2.3 | 2.2 |
| 18/02/2020 | 4.30 | 2.57 | 5.4 | 5.00 | 5.4 | 5.01 | 2.0 | 1.9 |
| 19/02/2020 | 6.65 | 3.54 | 5.3 | 4.74 | 8.2 | 7.48 | 3.3 | 2.9 |
| 20/02/2020 | 3.54 | 2.17 | 4.8 | 4.34 | 4.0 | 3.72 | 3.2 | 2.5 |
| 21/02/2020 | 3.22 | 2.08 | 4.1 | 3.96 | 3.4 | 3.26 | 1.6 | 1.5 |
| 22/02/2020 | 7.09 | 4.34 | 9.5 | 9.00 | 6.3 | 6.24 | 3.4 | 3.0 |
| 23/02/2020 | 5.87 | 3.84 | 6.4 | 5.72 | 6.1 | 5.46 | 4.8 | 3.2 |
| 24/02/2020 | 3.96 | 2.69 | 3.9 | 2.89 | 4.8 | 3.26 | 2.6 | 2.3 |
| 25/02/2020 | 3.04 | 2.30 | 1.5 | 1.18 | 1.7 | 1.28 | 2.3 | 2.0 |
| 26/02/2020 | 4.33 | 2.77 | 2.9 | 2.49 | 2.8 | 2.40 | - | - |
| 27/02/2020 | 5.32 | 3.26 | 4.1 | 3.66 | 4.2 | 3.59 | 12.8 | 5.3 |
| 28/02/2020 | 5.96 | 4.42 | 4.1 | 3.14 | 3.9 | 2.96 | - | - |
| 29/02/2020 | 4.17 | 2.52 | 5.6 | 4.60 | 5.2 | 4.39 | 2.2 | 2.1 |
| 01/03/2020 | 5.10 | 3.10 | 6.6 | 6.27 | 5.6 | 5.32 | 1.9 | 1.8 |
| 02/03/2020 | 6.93 | 3.87 | 7.5 | 6.57 | 7.8 | 6.74 | 3.5 | 3.2 |
| 03/03/2020 | 7.57 | 4.77 | 6.5 | 5.61 | 7.2 | 5.93 | 8.8 | 4.6 |
| 04/03/2020 | 10.51 | 5.54 | 9.2 | 7.19 | 10.6 | 7.86 | 10.3 | 6.7 |
| 05/03/2020 | 16.37 | 12.76 | 6.5 | 5.07 | 7.9 | 5.86 | 25.9 | 15.6 |
| 06/03/2020 | 14.03 | 9.61 | 5.7 | 4.55 | 6.4 | 4.84 | 14.1 | 12.7 |
| 07/03/2020 | 3.95 | 2.63 | 4.8 | 4.39 | 5.0 | 4.40 | 2.2 | 2.1 |
| 08/03/2020 | 4.74 | 2.77 | 5.4 | 5.02 | 5.0 | 4.67 | 2.2 | 2.0 |
| 09/03/2020 | 5.95 | 3.54 | 6.9 | 6.14 | 6.8 | 5.99 | 3.4 | 3.2 |
| 10/03/2020 | 7.83 | 5.06 | 11.5 | 10.95 | 8.8 | 8.56 | 4.2 | 3.5 |
| 11/03/2020 | 6.44 | 3.82 | 8.2 | 7.49 | 7.6 | 6.99 | 2.9 | 2.7 |

| DAQI Index | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|



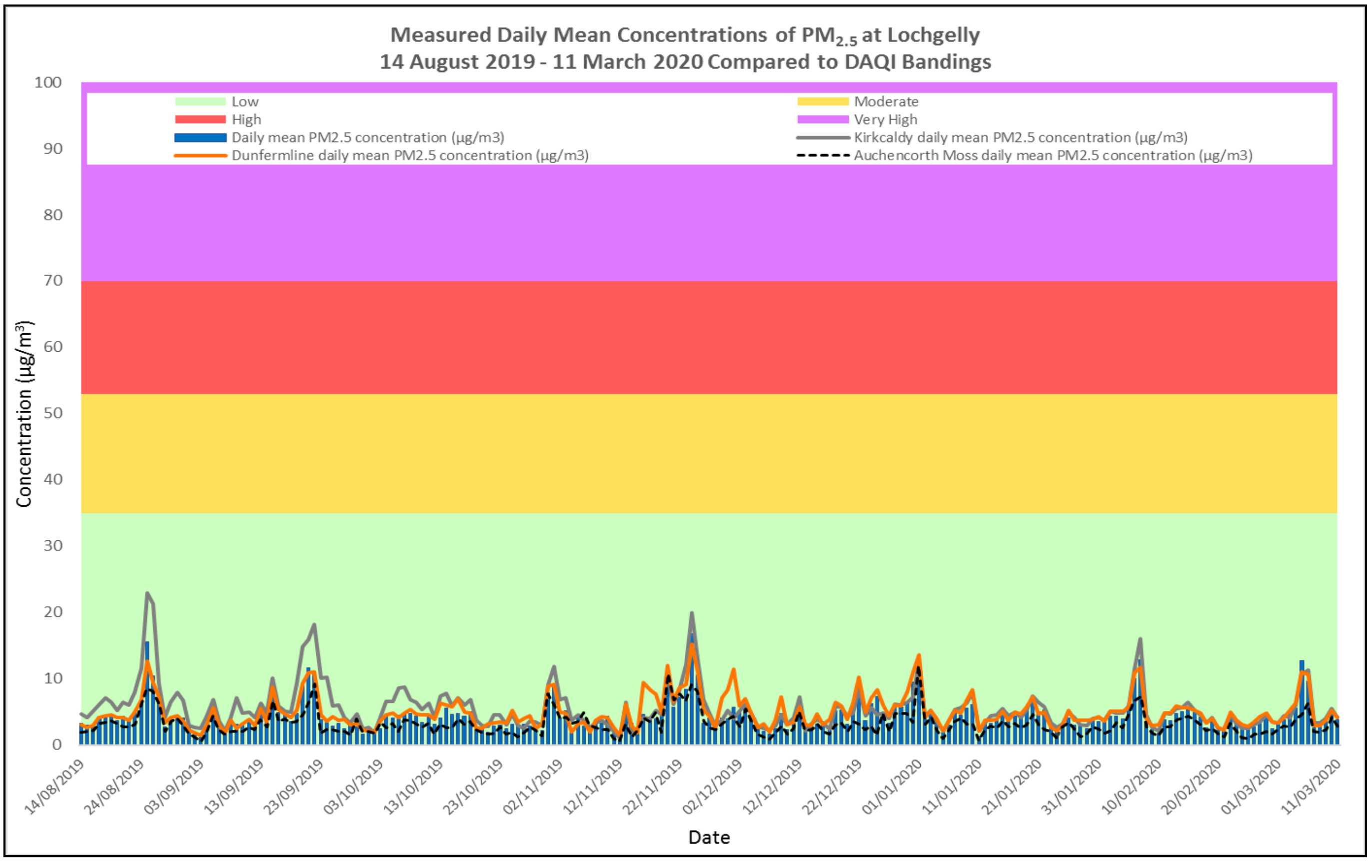
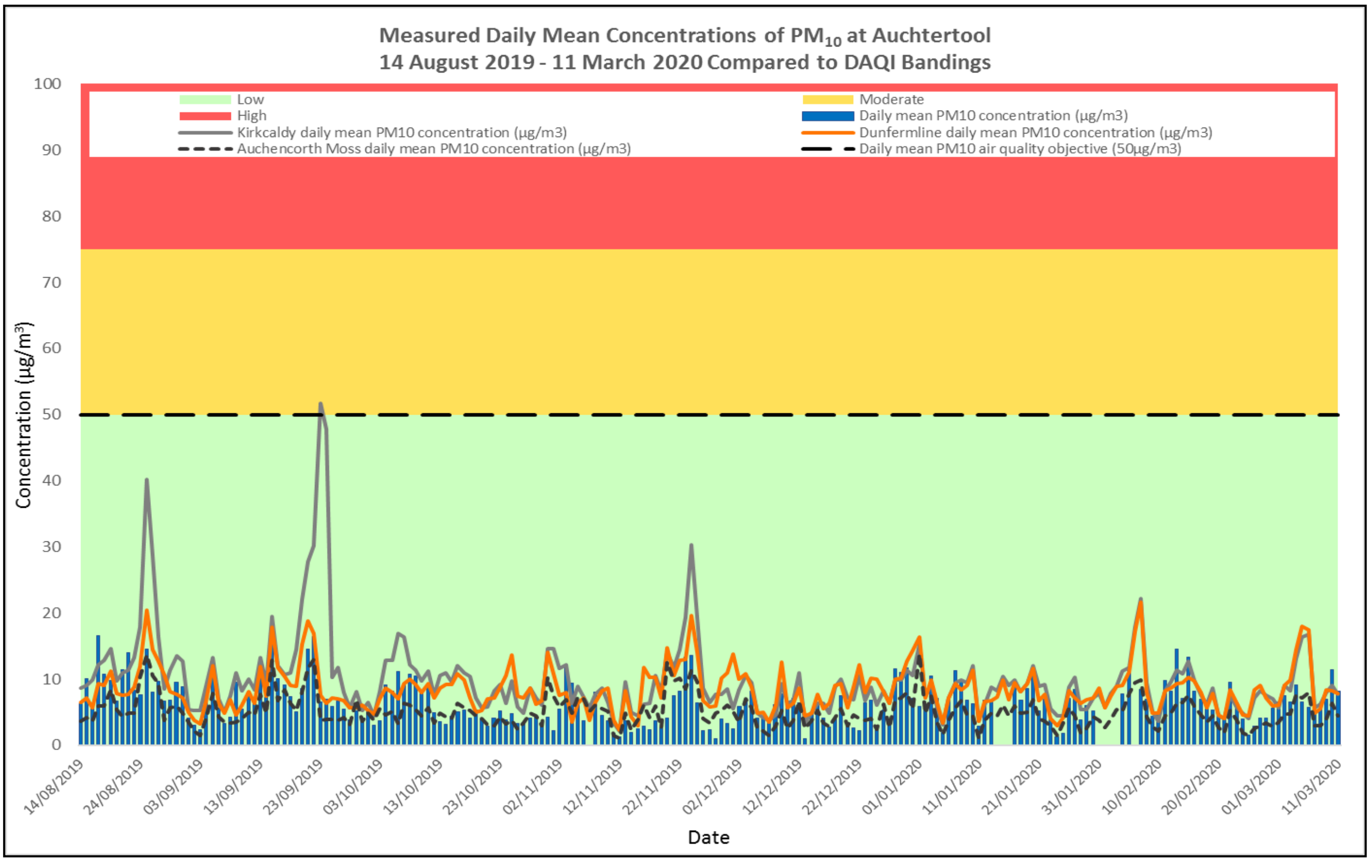




**Figure E.1: Measured daily mean concentrations of $PM_{10}$ and $PM_{2.5}$ at Lochgelly compared to DAQI bandings and regional background data from rural and urban locations**



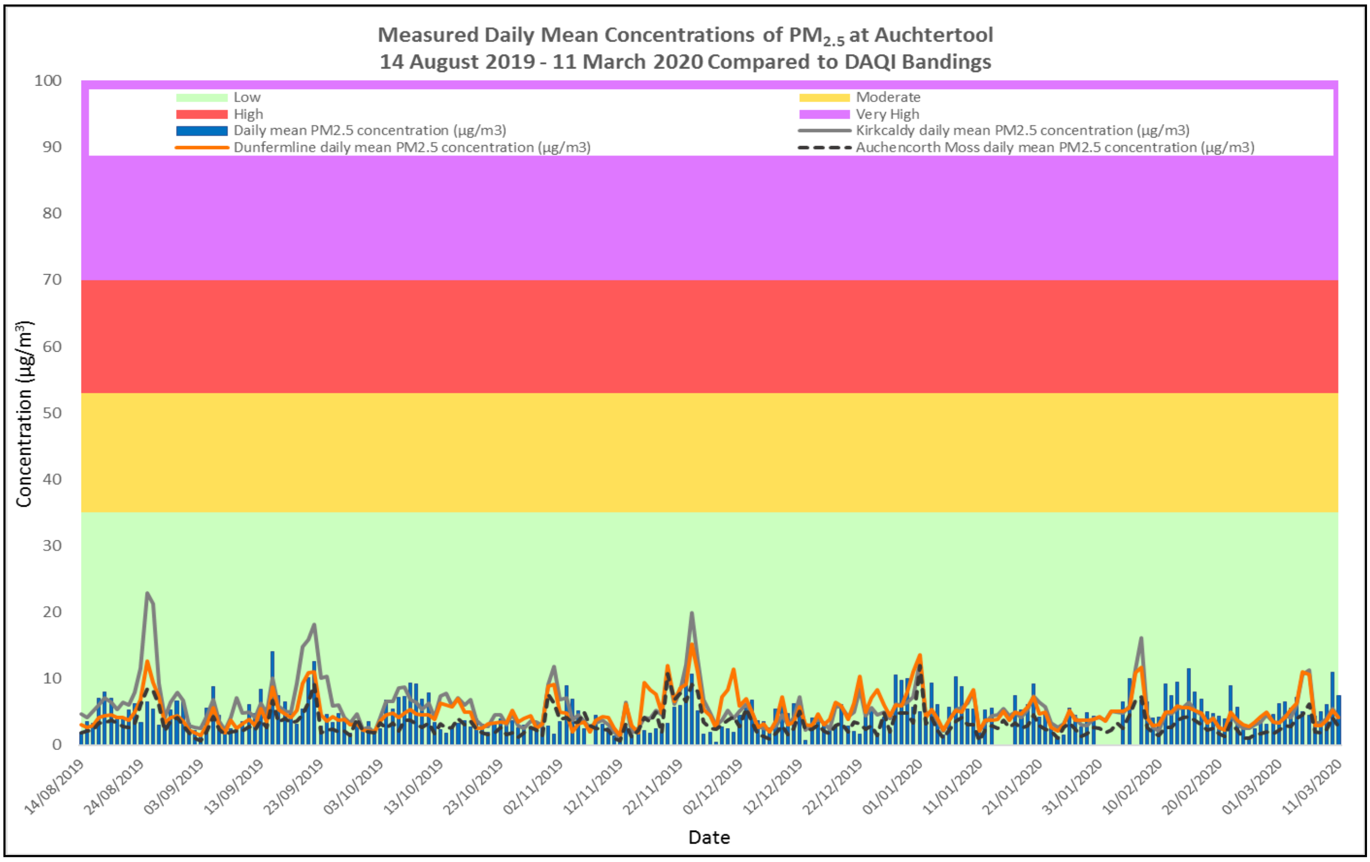
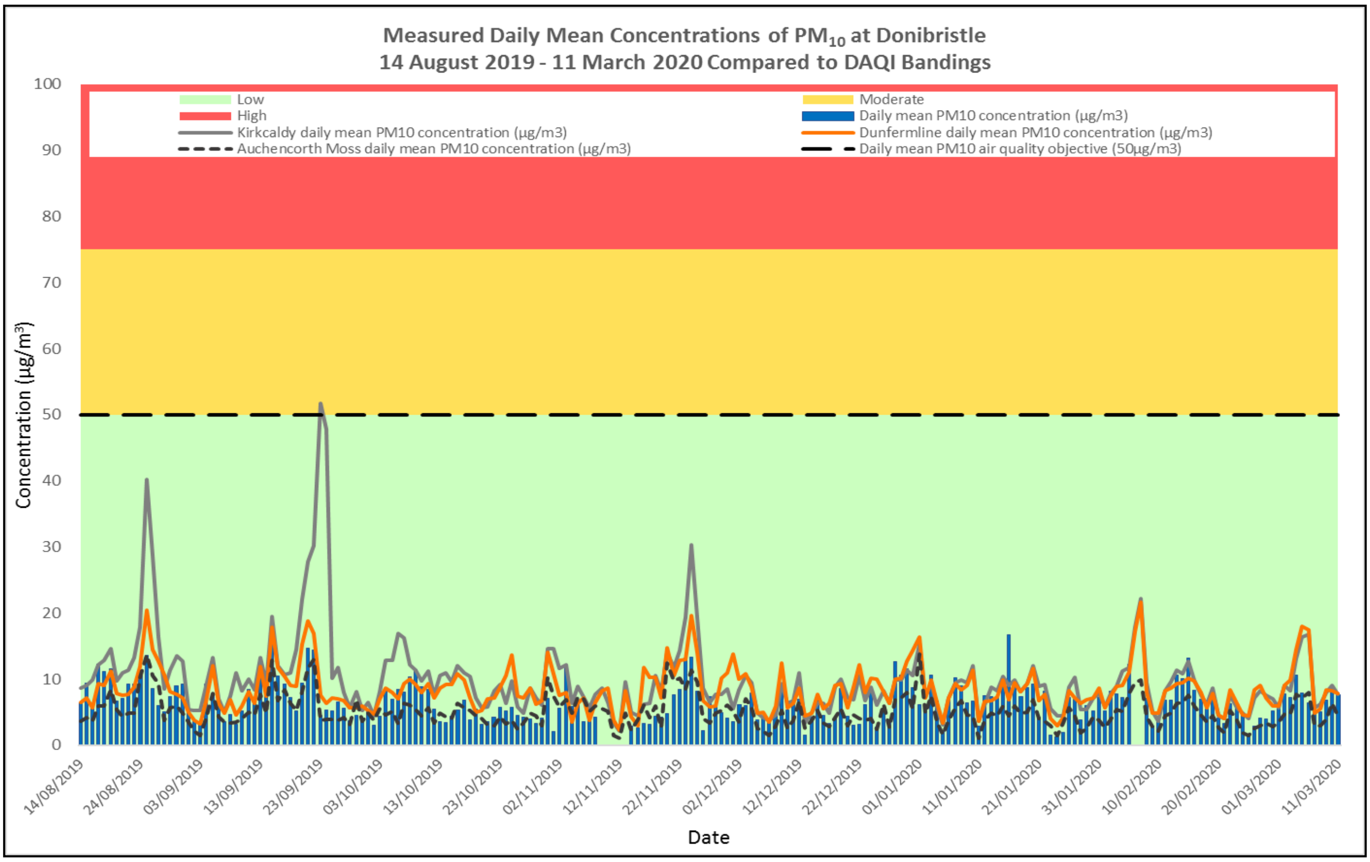




**Figure E.2: Measured daily mean concentrations of $PM_{10}$ and $PM_{2.5}$ at Auchtertool compared to DAQI bandings and regional background data from rural and urban locations**



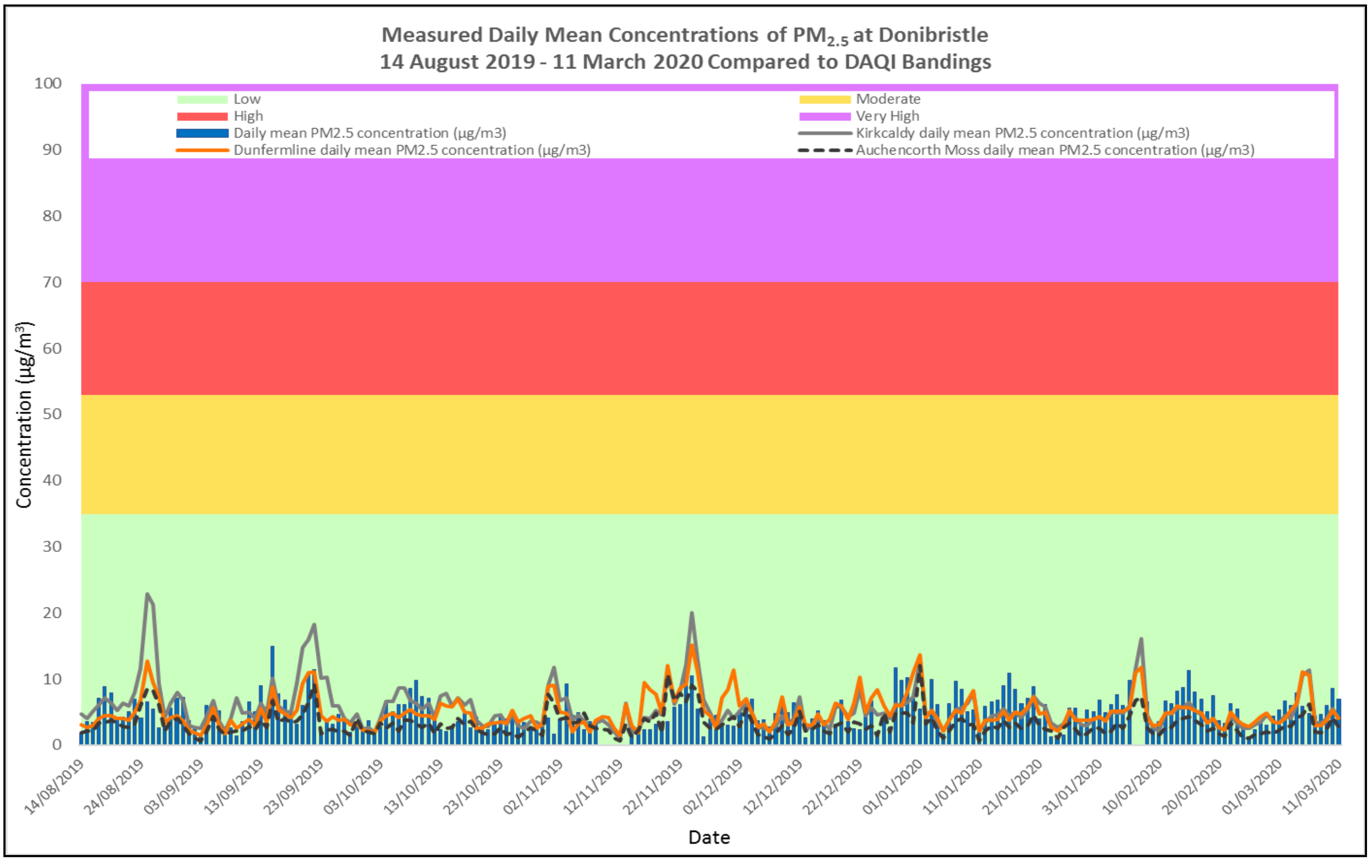
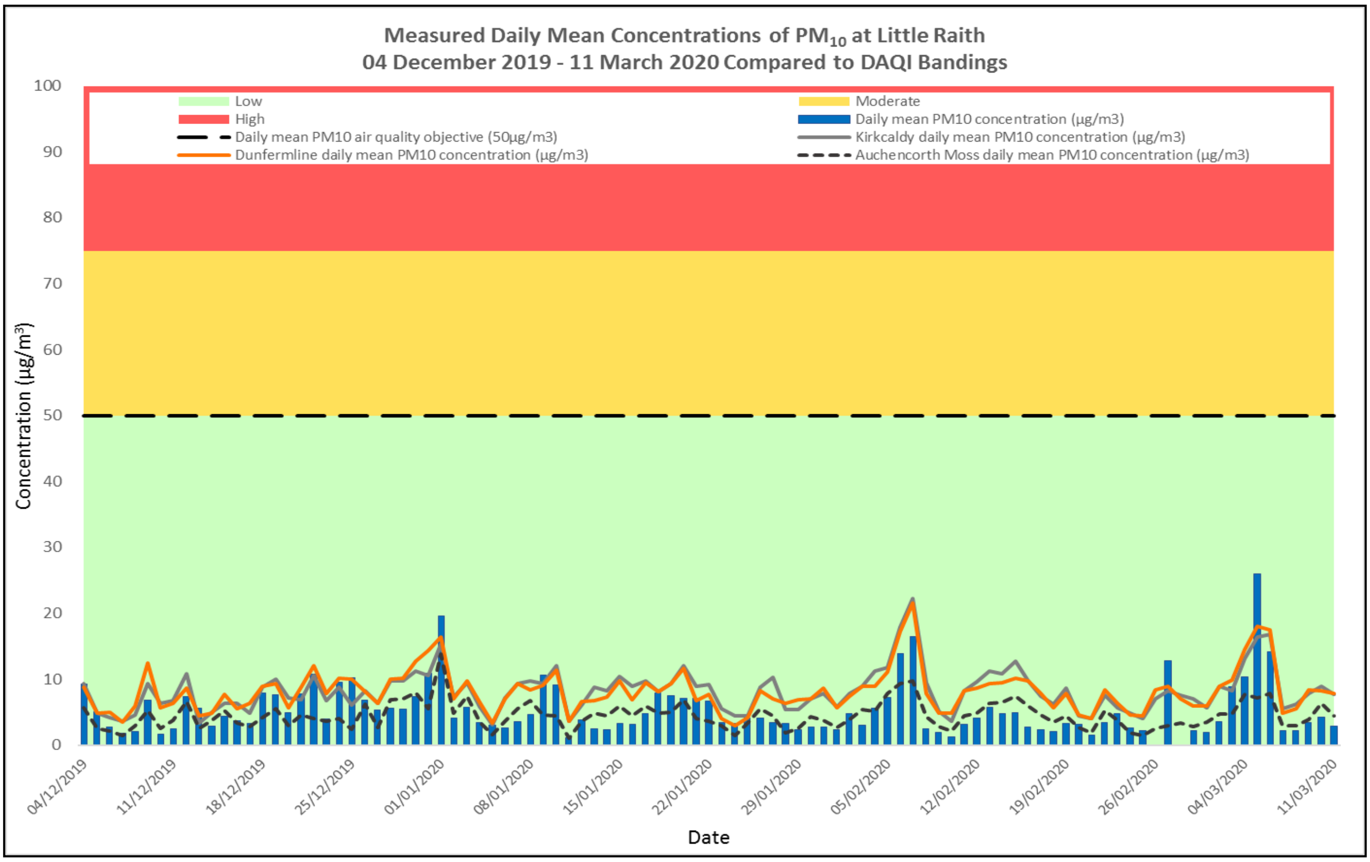




**Figure E.3: Measured daily mean concentrations of $PM_{10}$ and $PM_{2.5}$ at Donibristle compared to DAQI bandings and regional background data from rural and urban locations**



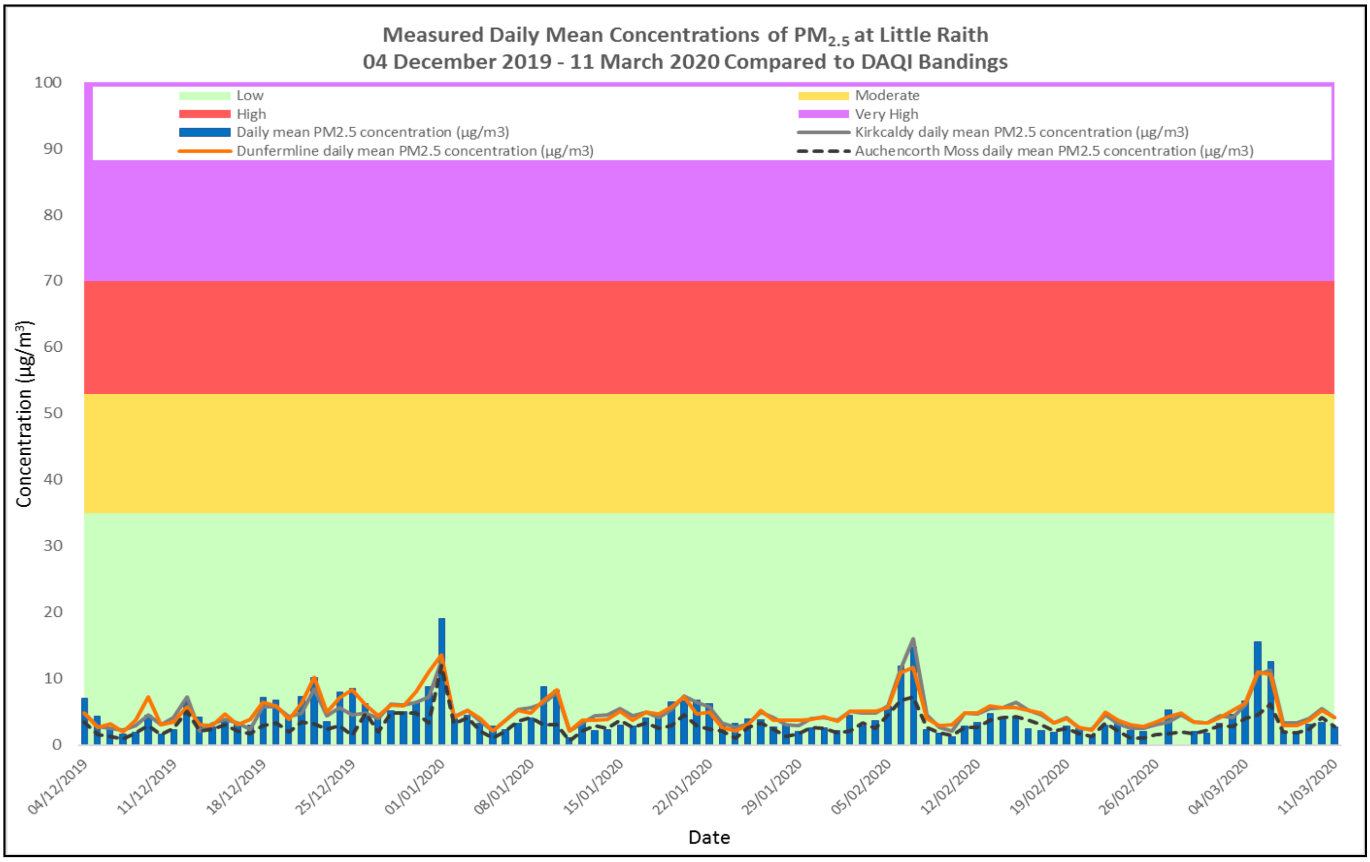




**Figure E.4: Measured daily mean concentrations of $PM_{10}$ and $PM_{2.5}$ at Little Raith compared to DAQI bandings and regional background data from rural and urban locations**

## E.2. Nitrogen Dioxide ($NO_2$)

**Table E.2: Maximum recorded daily 1-hour mean $NO_2$ concentrations at Little Raith**

| Date | $NO_2$ (µg/m$^3$) | Date | $NO_2$ (µg/m$^3$) | Date | $NO_2$ (µg/m$^3$) |
|---|---|---|---|---|---|
| 10/12/2019 | 9.2 | 10/01/2020 | 42.4 | 10/02/2020 | 26.5 |
| 11/12/2019 | 12.7 | 11/01/2020 | 14.4 | 11/02/2020 | 10.7 |
| 12/12/2019 | 24.2 | 12/01/2020 | 16.6 | 12/02/2020 | 24.6 |
| 13/12/2019 | 40.3 | 13/01/2020 | 6.9 | 13/02/2020 | 17.0 |
| 14/12/2019 | 21.7 | 14/01/2020 | 13.8 | 14/02/2020 | 35.7 |
| 15/12/2019 | 16.6 | 15/01/2020 | 22.2 | 15/02/2020 | 27.4 |
| 16/12/2019 | 25.6 | 16/01/2020 | 12.4 | 16/02/2020 | 42.9 |
| 17/12/2019 | 23.5 | 17/01/2020 | 25.7 | 17/02/2020 | 34.7 |
| 18/12/2019 | 20.9 | 18/01/2020 | 17.5 | 18/02/2020 | 28.5 |
| 19/12/2019 | 19.1 | 19/01/2020 | 20.6 | 19/02/2020 | 23.8 |
| 20/12/2019 | 31.5 | 20/01/2020 | 18.0 | 20/02/2020 | 20.4 |
| 21/12/2019 | 37.0 | 21/01/2020 | 26.9 | 21/02/2020 | 40.9 |
| 22/12/2019 | 42.7 | 22/01/2020 | 30.4 | 22/02/2020 | 6.6 |
| 23/12/2019 | 18.4 | 23/01/2020 | 24.9 | 23/02/2020 | 17.3 |
| 24/12/2019 | 27.1 | 24/01/2020 | 24.0 | 24/02/2020 | 14.2 |
| 25/12/2019 | 24.2 | 25/01/2020 | 17.3 | 25/02/2020 | 15.1 |
| 26/12/2019 | 5.9 | 26/01/2020 | 20.0 | 26/02/2020 | - |
| 27/12/2019 | 26.8 | 27/01/2020 | 16.4 | 27/02/2020 | 22.6 |
| 28/12/2019 | 10.8 | 28/01/2020 | 27.4 | 28/02/2020 | 22.6 |
| 29/12/2019 | 13.5 | 29/01/2020 | 18.5 | 29/02/2020 | 32.2 |
| 30/12/2019 | 15.1 | 30/01/2020 | 29.1 | 01/03/2020 | 41.2 |
| 31/12/2019 | 49.5 | 31/01/2020 | 26.7 | 02/03/2020 | 28.7 |
| 01/01/2020 | 22.9 | 01/02/2020 | 28.7 | 03/03/2020 | 13.1 |
| 02/01/2020 | 13.0 | 02/02/2020 | 19.0 | 04/03/2020 | 17.2 |
| 03/01/2020 | 12.6 | 03/02/2020 | 20.0 | 05/03/2020 | 37.1 |
| 04/01/2020 | 13.7 | 04/02/2020 | 42.6 | 06/03/2020 | 70.6 |
| 05/01/2020 | 11.1 | 05/02/2020 | 29.0 | 07/03/2020 | 21.4 |
| 06/01/2020 | 15.6 | 06/02/2020 | 28.1 | 08/03/2020 | 28.5 |
| 07/01/2020 | 12.4 | 07/02/2020 | 32.9 | 09/03/2020 | 19.4 |
| 08/01/2020 | 22.8 | 08/02/2020 | 15.4 | 10/03/2020 | 10.2 |
| 09/01/2020 | 42.4 | 09/02/2020 | 33.4 | 11/03/2020 | 23.9 |

| DAQI Index | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

**Notes:**

Data from 1-hour mean $NO_2$ summarised to show the highest recorded value from each day

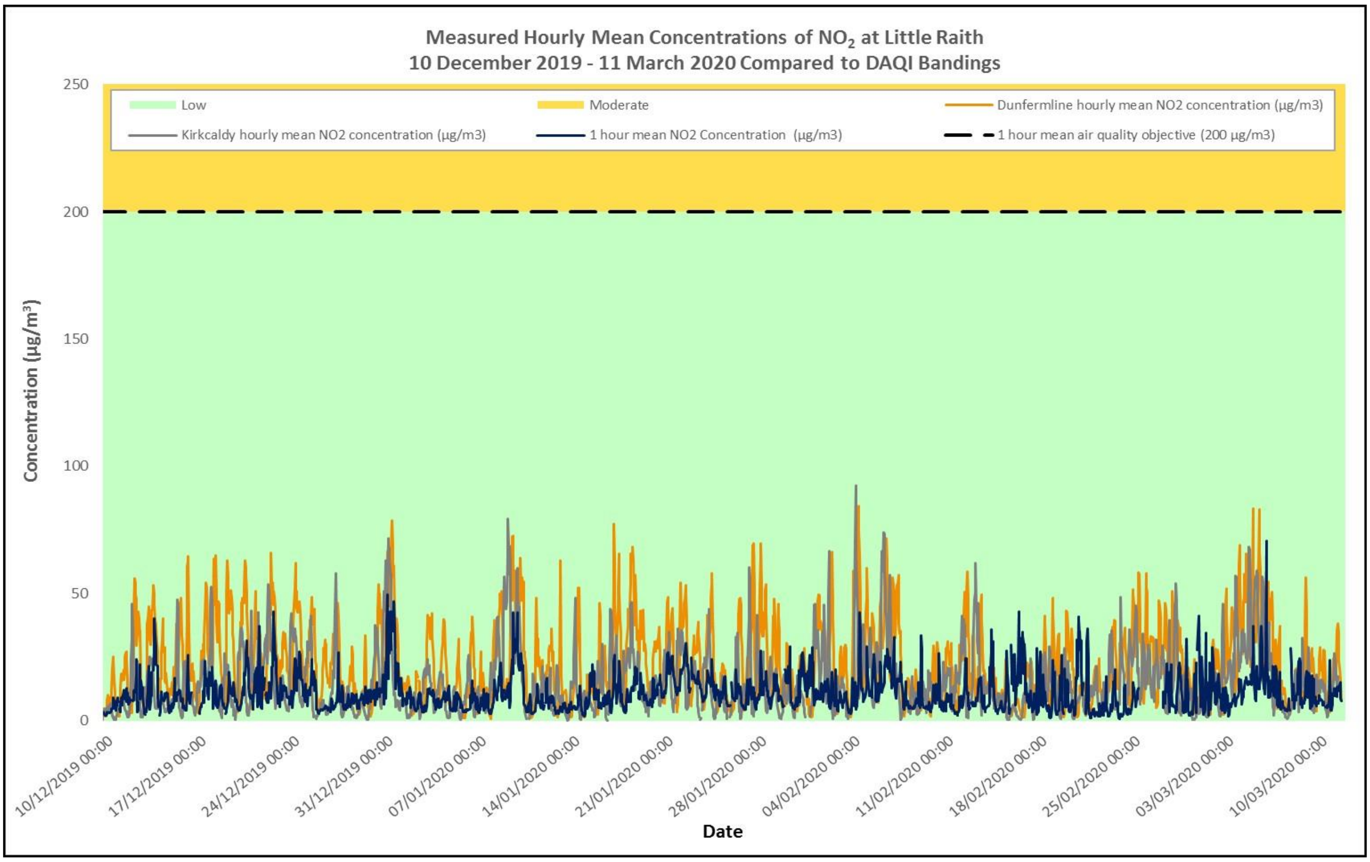



**Figure E.5: Measured hourly mean concentrations of $NO_2$ at Little Raith compared to DAQI bandings and regional background data**

## E.3. Sulphur dioxide ($SO_2$)

**Table E.3: Maximum recorded daily 15 minute mean $SO_2$ concentrations at Little Raith**

| Date | $SO_2$ (µg/m$^3$) | Date | $SO_2$ (µg/m$^3$) | Date | $SO_2$ (µg/m$^3$) |
|---|---|---|---|---|---|
| 10/12/2019 | 2.3 | 10/01/2020 | 4.2 | 10/02/2020 | 6.2 |
| 11/12/2019 | 3.4 | 11/01/2020 | 3.4 | 11/02/2020 | 5.9 |
| 12/12/2019 | 5.3 | 12/01/2020 | 3.8 | 12/02/2020 | 1.8 |
| 13/12/2019 | 5.1 | 13/01/2020 | 3.4 | 13/02/2020 | 1.1 |
| 14/12/2019 | 4.6 | 14/01/2020 | 3.8 | 14/02/2020 | 0.7 |
| 15/12/2019 | 4.5 | 15/01/2020 | 3.7 | 15/02/2020 | 4.3 |
| 16/12/2019 | 3.2 | 16/01/2020 | 2.2 | 16/02/2020 | 2.8 |
| 17/12/2019 | 3.2 | 17/01/2020 | 2.7 | 17/02/2020 | 3.7 |
| 18/12/2019 | 2.1 | 18/01/2020 | 3.1 | 18/02/2020 | 3.0 |
| 19/12/2019 | 1.2 | 19/01/2020 | 4.5 | 19/02/2020 | 4.2 |
| 20/12/2019 | 3.8 | 20/01/2020 | 8.7 | 20/02/2020 | 4.7 |
| 21/12/2019 | 2.8 | 21/01/2020 | 4.6 | 21/02/2020 | 3.4 |
| 22/12/2019 | 3.3 | 22/01/2020 | 1.1 | 22/02/2020 | 3.7 |
| 23/12/2019 | 2.9 | 23/01/2020 | 3.0 | 23/02/2020 | 3.2 |
| 24/12/2019 | 1.4 | 24/01/2020 | 3.7 | 24/02/2020 | 2.0 |
| 25/12/2019 | 1.8 | 25/01/2020 | 2.0 | 25/02/2020 | 1.7 |
| 26/12/2019 | 1.6 | 26/01/2020 | 7.4 | 26/02/2020 | - |
| 27/12/2019 | 0.1 | 27/01/2020 | 4.0 | 27/02/2020 | 0.7 |
| 28/12/2019 | 0.0 | 28/01/2020 | 5.5 | 28/02/2020 | 0.7 |
| 29/12/2019 | 0.0 | 29/01/2020 | 6.0 | 29/02/2020 | 3.6 |
| 30/12/2019 | 1.2 | 30/01/2020 | 4.0 | 01/03/2020 | 5.9 |
| 31/12/2019 | 21.9 | 31/01/2020 | 3.4 | 02/03/2020 | 2.0 |
| 01/01/2020 | 3.5 | 01/02/2020 | 4.6 | 03/03/2020 | 1.7 |
| 02/01/2020 | 1.9 | 02/02/2020 | 2.6 | 04/03/2020 | 5.4 |
| 03/01/2020 | 2.6 | 03/02/2020 | 5.7 | 05/03/2020 | 9.3 |
| 04/01/2020 | 4.0 | 04/02/2020 | 4.4 | 06/03/2020 | 10.6 |
| 05/01/2020 | 0.9 | 05/02/2020 | 4.9 | 07/03/2020 | 1.3 |
| 06/01/2020 | 4.0 | 06/02/2020 | 1.9 | 08/03/2020 | 2.3 |
| 07/01/2020 | 2.2 | 07/02/2020 | 2.6 | 09/03/2020 | 6.5 |
| 08/01/2020 | 4.4 | 08/02/2020 | 2.8 | 10/03/2020 | 5.0 |
| 09/01/2020 | 3.8 | 09/02/2020 | 4.1 | 11/03/2020 | 1.3 |

| DAQI Index | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|

**Notes:**

Data from 15 minute mean $SO_2$ summarised to show the highest recorded value from each day

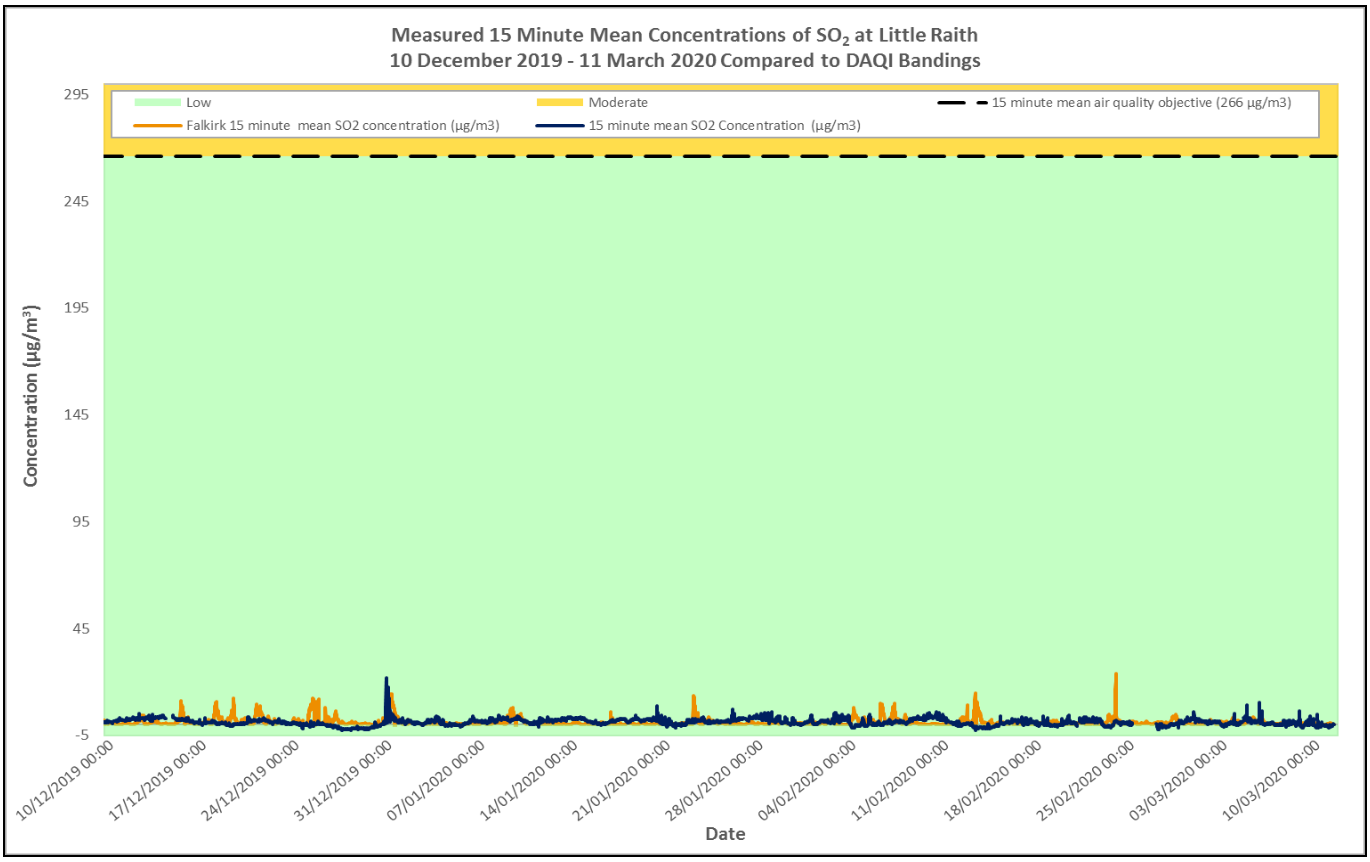



**Figure E.6: Measured 15 minute mean concentrations of $SO_2$ at Little Raith compared to DAQI bandings and regional background data from an urban location**

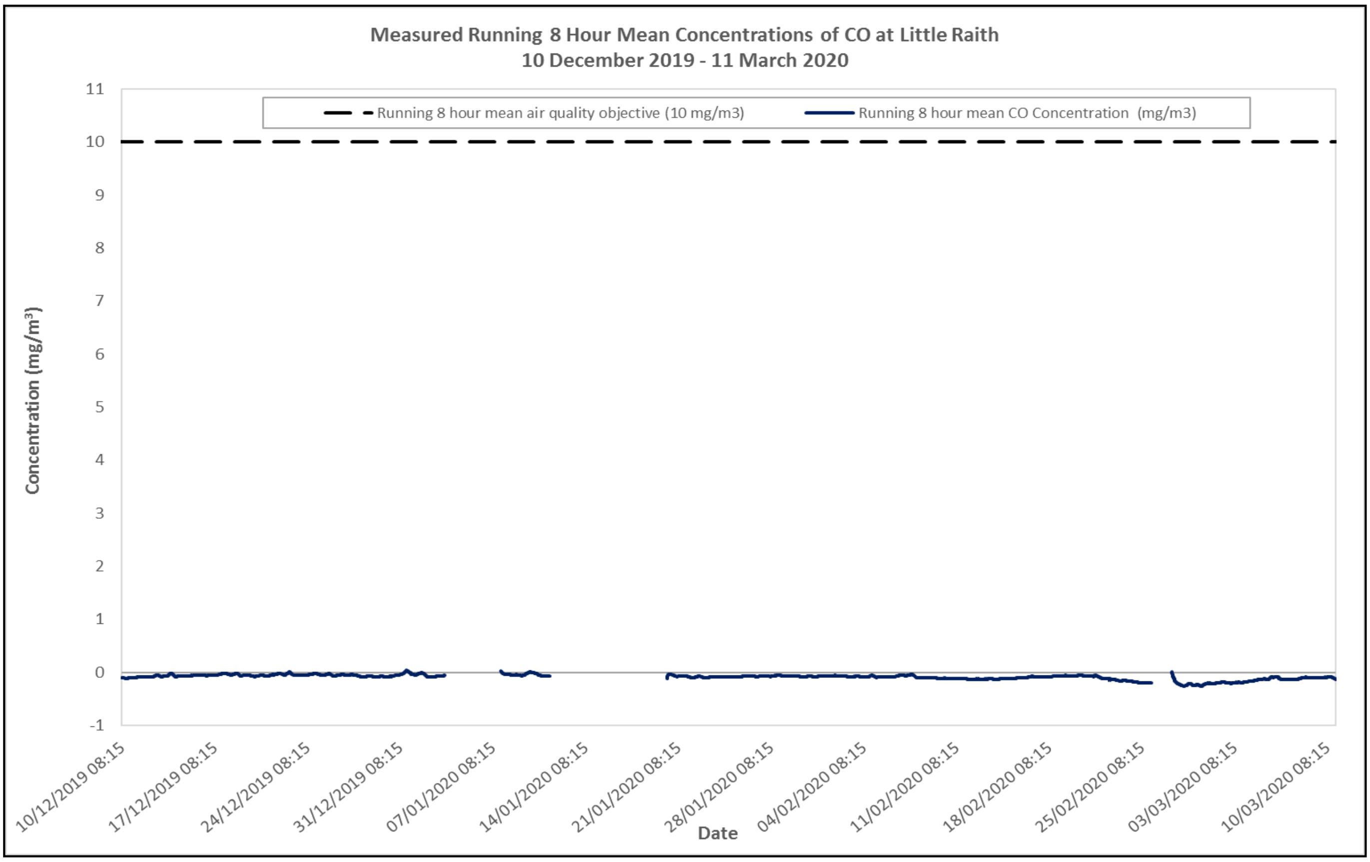



**Figure E.7: Measured running 8 hour mean concentrations of CO at Little Raith**

## E.4. Diffusion Tube Results

The diffusion tubes were prepared and analysed by the National Physical Laboratory (NPL), with deployment and collection undertaken by SEPA. The analysis results were reported by NPL in units of parts per billion (ppb) volume by volume (v/v).

The diffusion tube analysis results for each ca. 14 day deployment period between 23 October 2019 and 20 February 2020 are presented as originally reported ppb values in Table E.4 and as mass concentration values (µg/m$^3$) in Table E.5 (based upon conversion factors at 20°C and 1013 mb as stated in Table A.1).

**Table E.4: Diffusion tube data as supplied by NPL in ppb (v/v)**

| Sample Location | Date | Concentrations expressed as ppb (v/v) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Benzene | Toluene | Ethyl-benzene | Xylene | THC | 1,3-butadiene | $NO_2$ |
| Travel Blank | 23/10/2019 to 06/11/2019 | <0.1 | <0.3 | <0.3 | <0.3 | <5 | <0.1 | <0.6 |
| Travel Blank | | <0.1 | <0.3 | <0.3 | <0.3 | <5 | <0.1 | <0.6 |
| Donibristle | | 0.4 | 0.6 | <0.3 | 1.1 | 26 | <0.1 | 7.7 |
| Cowdenbeath | | 0.4 | 0.4 | <0.3 | 0.4 | 8 | <0.1 | 11.4 |
| Lochgelly | | 0.2 | <0.3 | <0.3 | <0.3 | <5 | <0.1 | 7.3 |
| Little Raith | | 0.2 | <0.3 | <0.3 | <0.3 | 5 | <0.1 | 5.6 |
| | | | | | | | | |
| Travel Blank* | 06/11/2019 to 22/11/2019 | **0.2** | **<0.3** | **<0.3** | **<0.3** | **<5** | **<0.1** | <0.6 |
| Travel Blank* | | **0.2** | **1.1** | **<0.3** | **0.5** | **13** | **<0.1** | <0.6 |
| Donibristle | | 0.3 | <0.3 | <0.3 | 0.3 | 6 | <0.1 | 8.9 |
| Cowdenbeath* | | **<0.1** | **<0.3** | **<0.3** | **<0.3** | **<5** | **<0.1** | 11.9 |
| Lochgelly* | | **<0.1** | **<0.3** | **<0.3** | **<0.3** | **<5** | **<0.1** | 8.8 |
| Little Raith | | 0.4 | 0.5 | <0.3 | 0.5 | 10 | <0.1 | 7.2 |
| | | | | | | | | |
| Travel Blank | 22/11/2019 to 06/12/2019 | <0.1 | <0.3 | <0.3 | <0.3 | <5 | <0.1 | 2.5 |
| Travel Blank | | <0.1 | <0.3 | <0.3 | <0.3 | <5 | <0.1 | <0.6 |
| Donibristle | | 0.3 | 0.3 | <0.3 | <0.3 | 5 | <0.1 | 9.0 |
| Cowdenbeath | | 0.4 | 0.4 | <0.3 | 0.5 | 10 | <0.1 | 13.0 |
| Lochgelly | | 0.2 | <0.3 | <0.3 | <0.3 | <5 | <0.1 | 9.3 |
| Little Raith | | 0.3 | <0.3 | <0.3 | 0.5 | 8 | <0.1 | 8.2 |
| | | | | | | | | |
| Travel Blank | 06/12/2019 to 20/12/2019 | <0.1 | <0.3 | <0.3 | <0.3 | <5 | <0.1 | <0.6 |
| Travel Blank | | <0.1 | <0.3 | <0.3 | <0.3 | 5 | <0.1 | <0.6 |
| Donibristle | | 0.2 | <0.3 | <0.3 | 0.4 | 9 | <0.1 | 6.9 |
| Cowdenbeath | | 0.3 | 1.1 | <0.3 | 0.3 | 16 | <0.1 | 12.2 |
| Lochgelly | | 0.1 | <0.3 | <0.3 | <0.3 | 6 | <0.1 | 7.5 |
| Little Raith | | 0.2 | 0.5 | <0.3 | <0.3 | 14 | <0.1 | 6.6 |
| | | | | | | | | |
| Travel Blank | 23/01/2020 to 06/02/2020 | <0.1 | <0.3 | <0.3 | <0.3 | <5 | <0.1 | <0.6 |
| Travel Blank | | <0.1 | <0.3 | <0.3 | <0.3 | <5 | <0.1 | <0.6 |
| Donibristle | | 0.2 | <0.3 | <0.3 | <0.3 | <5 | <0.1 | FS |
| Cowdenbeath | | 0.2 | <0.3 | <0.3 | <0.3 | 7 | <0.1 | FS |
| Lochgelly | | 0.2 | 0.8 | <0.3 | <0.3 | 12 | <0.1 | FS |
| Little Raith | | <0.1 | <0.3 | <0.3 | <0.3 | <5 | <0.1 | FS |
| | | | | | | | | |
| Travel Blank | 06/02/2020 to 20/02/2020 | <0.1 | <0.3 | <0.3 | <0.3 | <5 | <0.1 | <0.6 |
| Travel Blank | | <0.1 | <0.3 | <0.3 | <0.3 | <5 | <0.1 | <0.6 |
| Donibristle | | 0.1 | <0.3 | <0.3 | <0.3 | <5 | <0.1 | FS |
| Cowdenbeath | | 0.1 | <0.3 | <0.3 | <0.3 | <5 | <0.1 | FS |
| Lochgelly | | <0.1 | <0.3 | <0.3 | <0.3 | <5 | <0.1 | FS |
| Little Raith | | 0.1 | <0.3 | <0.3 | <0.3 | 5 | <0.1 | FS |

**Notes:**

* VOC sample and travel blank tubes returned questionable results

FS Failed Sample (see 3.3.2)

**Table E.5: Diffusion tube data as calculated using conversion factors in µg/m³**

| Sample Location | Date | Concentrations expressed as µg/m³ | | | | | |
|---|---|---|---|---|---|---|---|
| | | Benzene | Toluene | Ethylbenzene | Xylene | 1,3-butadiene | $NO_2$ |
| Travel Blank | 23/10/2019 to 06/11/2019 | <0.3 | <1.1 | <1.3 | <1.3 | <0.2 | <1.2 |
| Travel Blank | | <0.3 | <1.1 | <1.3 | <1.3 | <0.2 | <1.2 |
| Donibristle | | 1.2 | 2.1 | <1.3 | 4.9 | <0.2 | 14.7 |
| Cowdenbeath | | 1.1 | 1.5 | <1.3 | 1.9 | <0.2 | 21.9 |
| Lochgelly | | 0.6 | <1.1 | <1.3 | <1.3 | <0.2 | 13.9 |
| Little Raith | | 0.6 | <1.1 | <1.3 | <1.3 | <0.2 | 10.7 |
| | | | | | | | |
| Travel Blank* | 06/11/2019 to 22/11/2019 | **0.7** | **<1.1** | **<1.3** | **<1.3** | **<0.2** | <1.2 |
| Travel Blank* | | **0.7** | **4.1** | **<1.3** | **2.1** | **<0.2** | <1.2 |
| Donibristle | | 1.0 | <1.1 | <1.3 | 1.5 | <0.2 | 17.0 |
| Cowdenbeath* | | **<0.3** | **<1.1** | **<1.3** | **<1.3** | **<0.2** | 22.8 |
| Lochgelly* | | **<0.3** | **<1.1** | **<1.3** | **<1.3** | **<0.2** | 16.9 |
| Little Raith | | 1.4 | 1.9 | <1.3 | 2.1 | <0.2 | 13.7 |
| | | | | | | | |
| Travel Blank | 22/11/2019 to 06/12/2019 | <0.3 | <1.1 | <1.3 | <1.3 | <0.2 | 4.7 |
| Travel Blank | | <0.3 | <1.1 | <1.3 | <1.3 | <0.2 | <1.2 |
| Donibristle | | 0.9 | 1.3 | <1.3 | <1.3 | <0.2 | 17.2 |
| Cowdenbeath | | 1.2 | 1.7 | <1.3 | 2.2 | <0.2 | 24.8 |
| Lochgelly | | 0.6 | <1.1 | <1.3 | <1.3 | <0.2 | 17.7 |
| Little Raith | | 1.0 | <1.1 | <1.3 | 2.2 | <0.2 | 15.7 |
| | | | | | | | |
| Travel Blank | 06/12/2019 to 20/12/2019 | <0.3 | <1.1 | <1.3 | <1.3 | <0.2 | <1.2 |
| Travel Blank | | <0.3 | <1.1 | <1.3 | <1.3 | <0.2 | <1.2 |
| Donibristle | | 0.6 | <1.1 | <1.3 | 1.7 | <0.2 | 13.2 |
| Cowdenbeath | | 0.9 | 4.1 | <1.3 | 1.5 | <0.2 | 23.4 |
| Lochgelly | | 0.4 | <1.1 | <1.3 | <1.3 | <0.2 | 14.4 |
| Little Raith | | 0.7 | 1.8 | <1.3 | <1.3 | <0.2 | 12.7 |
| | | | | | | | |
| Travel Blank | 23/01/2020 to 06/02/2020 | <0.3 | <1.1 | <1.3 | <1.3 | <0.2 | <1.2 |
| Travel Blank | | <0.3 | <1.1 | <1.3 | <1.3 | <0.2 | <1.2 |
| Donibristle | | 0.6 | <1.1 | <1.3 | <1.3 | <0.2 | FS |
| Cowdenbeath | | 0.7 | <1.1 | <1.3 | <1.3 | <0.2 | FS |
| Lochgelly | | 0.7 | 3.0 | <1.3 | <1.3 | <0.2 | FS |
| Little Raith | | <0.3 | <1.1 | <1.3 | <1.3 | <0.2 | FS |
| | | | | | | | |
| Travel Blank | 06/02/2020 to 20/02/2020 | <0.3 | <1.1 | <1.3 | <1.3 | <0.2 | <1.2 |
| Travel Blank | | <0.3 | <1.1 | <1.3 | <1.3 | <0.2 | <1.2 |
| Donibristle | | 0.4 | <1.1 | <1.3 | <1.3 | <0.2 | FS |
| Cowdenbeath | | 0.4 | <1.1 | <1.3 | <1.3 | <0.2 | FS |
| Lochgelly | | <0.3 | <1.1 | <1.3 | <1.3 | <0.2 | FS |
| Little Raith | | 0.4 | <1.1 | <1.3 | <1.3 | <0.2 | FS |

**Notes:**

* VOC sample and travel blank tubes returned questionable results

FS Failed Sample (see 3.2.2)