Air quality monitoring in the vicinity of Bobov Dol coal fired power station, Bulgaria

21st February - 22nd May 2019

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Contents

1 Introduction

1.1 This report describes the results of a three-month air pollutant monitoring survey carried out at Golemo Selo, near to Bobov Dol Coal Fired Power Plant (CFPP), Bulgaria. Monitoring of ambient air pollutants including SO_2, NO_2 and PM_{10} was undertaken from 21st February 2019 until 22nd May 2019. Results of a previously completed diffusion tube monitoring survey and official monitoring carried out by the Bulgarian Executive Environment Agency are also used in the analysis.

Power Plant and Study Area

1.2 The Bobov Dol coal fired power plant is located immediately south-west of the village of Golemo Selo, approximately 15 km south of Bobov Dol coal mine and 70 km south west of Sofia. The Bobov Dol Power Plant and Golemo Selo are within a wide open valley where local topography is unlikely to reduce the potential for pollutant dispersion.

1.3 Bobov Dol CFPP is reported to be a 210 MW unit which is fired with lignite and subbituminous coals from multiple coal basins in Bulgaria; Bobov Dol, Pernik, Oranovo-Simitli, Chukurovo, Stanyanci, Beli Breg, Bourgas, and Balkan[1]. The mix of coal used at the plant is known to vary over time, and it can therefore be expected that pollutant emission rates may also change with variations in the coal mix used.

1.4 CFPPs usually operate continuously, with periodic shut down for maintenance. On 17 March, during the study period, the CFPP stopped working due to low electricity prices. It resumed operation at 08:00 on 18 March. It stopped once again (for planned repair work) on 6 April and resumed operation in the morning of 8 April[2].

1.5 The study area considered in this report is defined by Figure 1 and comprises the Bobov Dol Power Plant, Golemo Selo and surrounding settlements in Kyustendil Province, western Bulgaria. The area contains residential properties and a kindergarten whose occupants are sensitive to the effects of air pollution. There are residences within 500 m of the CFPP flue and across the surrounding area.

1.6 The principle sources of atmospheric pollution within the study area are likely to be burning solid fuels, in particular coal burning for domestic heating in Golemo Selo and for electricity generation at the Bobov Dol coal fired power plant.

1.7 Only minor roads pass close to Golemo Selo and local traffic is therefore likely to be a relatively minor source of air pollution. However, some coal supplied to the CFPP is delivered by roads with trucks passing through Golemo Selo several times per day. While the truck load is covered to prevent emission of dust,

[1] Kostova, I., Vassileva, C., Hower, J., Mastalerz, M., Vassilev, S., Nikolova, N. (2011) Mercury in coals and fly ashes from republika and bobov dol thermoelectric power plants. Comptes Rendus de L'Academie Bulgare des Sciences, 64(2): 253-262

[2] News.bg. https://news.bg/regions/tets-bobov-dol-spira-rabota-planovo-do-ponedelnik.html

these trucks has the potential to generate additional local air pollution through, exhaust gases, resuspension and related processes.

1.8 A freight railway is used to transport the coal to the CFPP. Coal transport trains have been observed running twice per day. According to local media reports, in recent months the railway has been used for the delivery of refuse-derived fuels (RDF) to the power plant[3]. The railway line is located between the village of Golemo Selo and the power plant. It is equipped with electric power lines and electric locomotives have been observed operating on the line. This suggests that the railway itself is also unlikely to be a major source of local air pollution.

1.9 Land use in the study area is predominantly agricultural, and may give rise to emissions of particulate matter and associated air pollutants. The Bobov Dol Power Plant and associated installations are the single significant industrial presence.

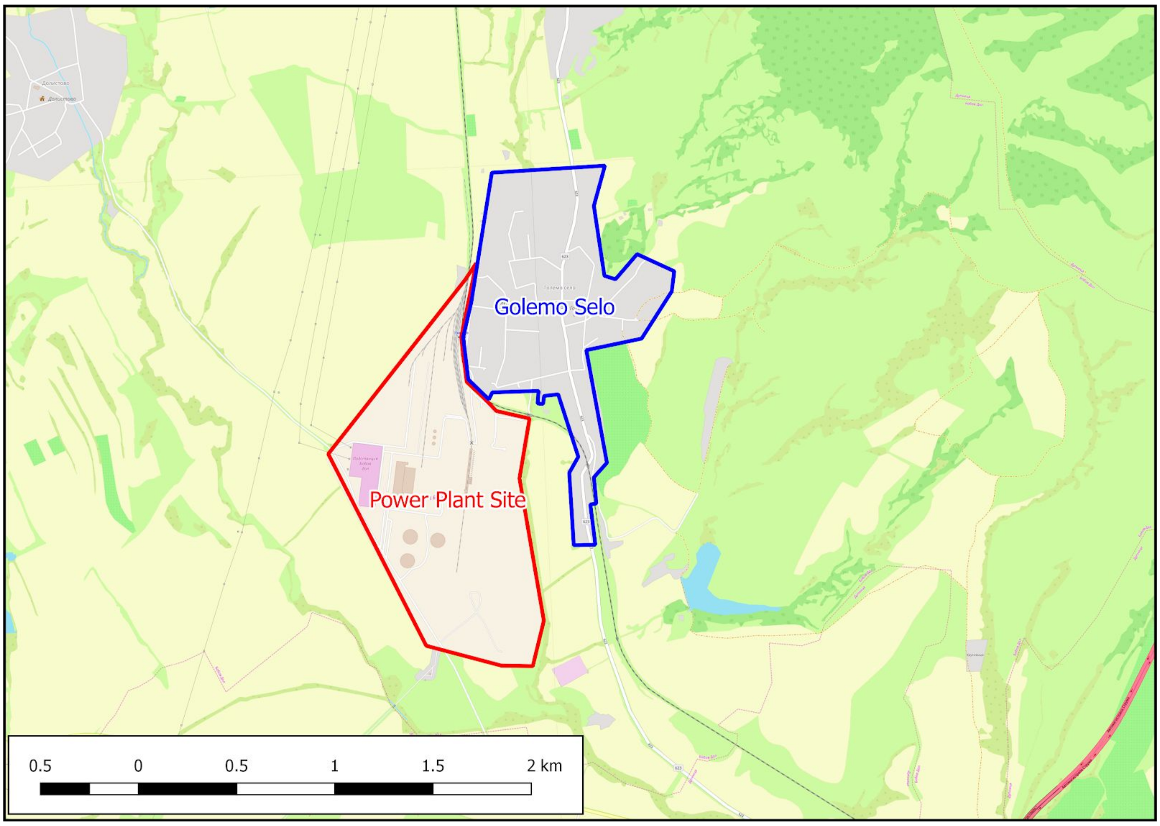

Figure 1: The Study Area

Map data copyrighted OpenStreetMap contributors and available from https://www.openstreetmap.org

[3] Kamerton. http://kamerton.news/content/content/details/1282/lang/1

Policy Context

1.10 The emission of pollutants to air is regulated within the European Union, and member states are required to maintain ambient air quality standards for a number of air pollutants. Legislation relevant to Air Quality in Bulgaria is summarised below.

1.11 The National Emissions Ceiling Directive[4] is responsible for setting the national emissions reduction commitments for Member States of the European Union, for the following pollutants: fine particulates; nitrogen oxides (NOx); non-methane volatile compounds; sulphur dioxide (SO_2); and ammonia (NH_3). The Directive came into effect on 31st December 2016. The legislation relates to emissions from all sources and Member States are responsible for ensuring that their citizens and industries comply. Bulgaria's commitments under the Directive are shown in Table 1.

1.12 The Large Combustion Plant Directive (LCPD)[5] and Industrial Emissions Directive[6] limit emissions of certain pollutants into the air from combustion plant and industry. The LCPD manages emissions of SO_2, NO_2 and dust from combustion plants with a thermal input capacity equal to or greater than 50 MWth. This includes power stations, petroleum refineries, steelworks and other industrial processes running on solid, liquid and gaseous fuels. "New" plants must meet the emission limit values (ELVs). Member States can choose to meet obligations for existing plants (i.e. those in operation pre-1987) either by complying with the ELVs or by operating within a national emission reduction plan (NERP) that sets a ceiling for each pollutant. The Industrial Emissions Directive requires the use of Best Available Techniques (BAT) for managing environmental impact in industry.

1.13 Standards relating to the ambient concentration of air pollutants and exposure in the European Union are set out in the Air Quality Directive[7] (and four Daughter Directives). The air quality standards for SO_2 imposed by the Directive are summarised in Table 2a.

1.14 Table 2b shows the World Health Organisation Air Quality Guidelines, these guidelines are not in regulations but are a widely accepted benchmark for assessing air quality, with regard to minimising health impacts.

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[4] Directive (EU) 2016/2284 of the European Parliament and of the Council of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC

[5] Directive 2001/80/EC of the European Parliament and of the Council of 23 October 2001 on the limitation of emissions of certain pollutants into the air from large combustion plants

[6] Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control)

[7] Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe

Table 1: National Emissions Ceiling Directive Commitments for Bulgaria

	For any year from 2020 to 2029	For any year from 2030
SO_2 reduction compared with 2005	78%	88%
NO_x reduction compared with 2005	41%	58%
NMVOC reduction compared with 2005	21%	50%
NH_3 reduction compared with 2005	3%	12%
$PM_{2.5}$ reduction compared with 2005	20%	41%

Table 2a: European Ambient Air Quality Standards

Pollutant	Concentration (μg/m^3)	Averaging period	Permitted exceedances each year
SO_2	350	1 hour	24
	125	24 hours	3
PM_{10}	50	1 day	35
	40	Calendar Year	-
$PM_{2.5}$	25	Calendar Year	-
O_3	180	1 hour	-
	120	Maximum 8-hour running mean	25 days/year averaged over 3 years
NO_2	200	1 hour	18
	40	Calendar Year	-

Table 2b: World Health Organisation Air Quality Guidelines

Pollutant	Concentration (μg/m^3)	Averaging period	Permitted exceedances each year
SO_2	500	10 minutes	0
	20	24 hours	0
PM_{10}	50	24 hours	0
	20	Calendar Year	-
$PM_{2.5}$	25	24 hours	0
	10	Calendar Year	-
O_3	100	Maximum 8-hour running mean	0
NO_2	200	1 hour	0
	40	Calendar Year	-

2 Materials and Methods

Local Air Quality Monitoring

2.1 A network of automatic air quality monitoring stations is operated in Bulgaria by the Executive Environment Agency. None of these monitors are located within the study area; however a mobile monitoring station was placed in the center of Golemo Selo by the Executive Environment Agency during the study (Figure 2). The mobile monitoring station operated for two periods: 15 March 2019 - 29 March 2019, and 23 April 2019 - 11 May 2019, collecting hourly measurements of air pollutants including SO_2, NO, NO_2, O_3 and PM_{10}. The results from the official monitoring have been provided by the Executive Environment Agency through an Access to Information Request.

2017-2018 Diffusion Tube Survey

2.2 Diffusion tubes measuring the concentration of NO_2 and SO_2 were deployed by Greenpeace in the study area between December 2017 and March 2018. The diffusion tubes were deployed in 31 locations in Bulgaria, including at monitoring sites in Golemo Selo and Bobov Dol (Figure 2). Three 1-month periods of monitoring were undertaken and duplicate diffusion tubes were installed in each monitoring location.

2.3 NO_2 diffusion tubes used were prepared and analysed by the independent laboratory Buro Blauw (Netherlands) and SO_2 diffusion tubes were prepared and analysed by Gradko (UK). Full details of the laboratory results are provided in supplementary information

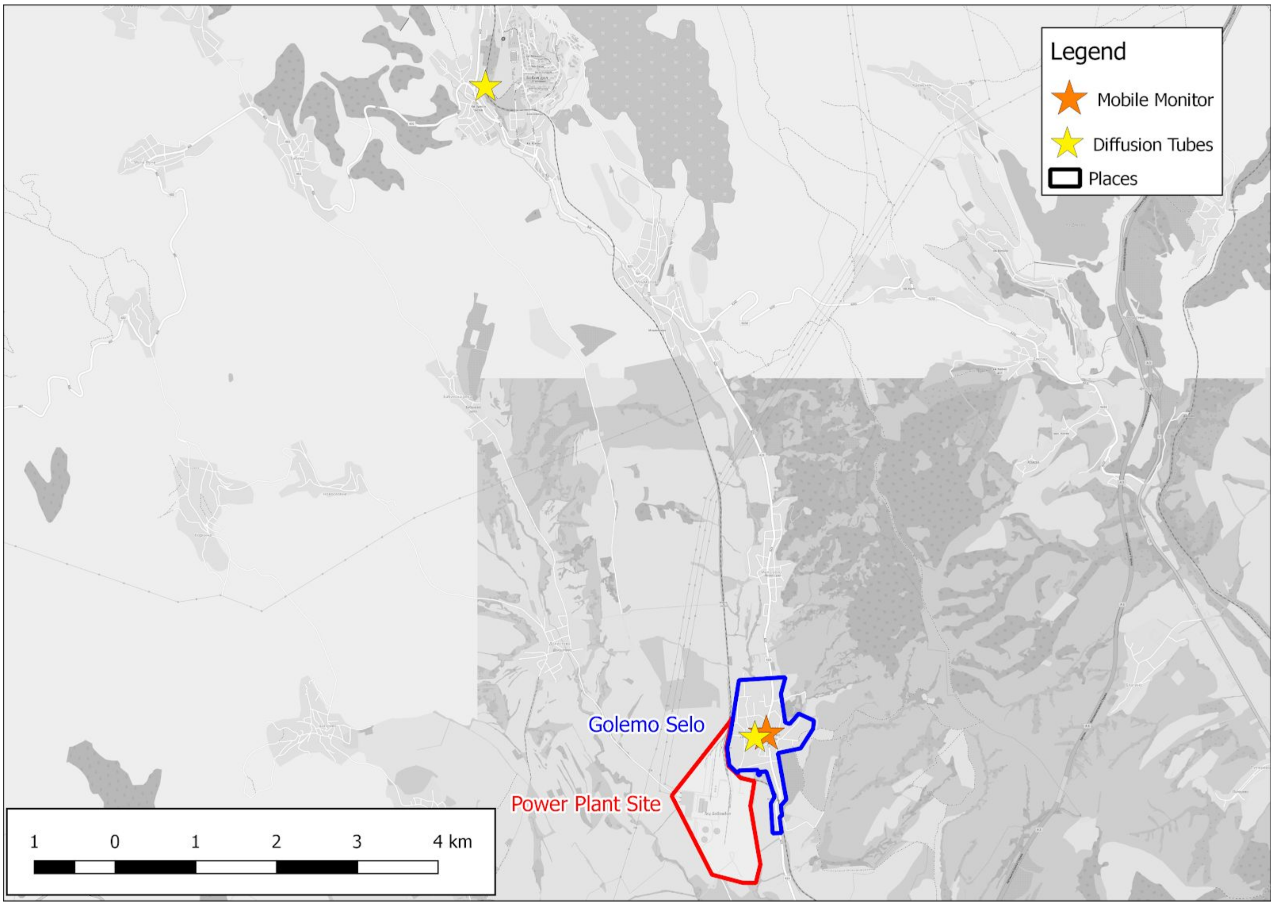

Figure 2: **2017-2018 Diffusion Tube Monitoring Locations**

Map data copyrighted OpenStreetMap contributors and available from https://www.openstreetmap.org

Trace Gas Measurements - AQMesh

2.4 AQMesh pods (Environmental Instruments Ltd, UK, www.aqmesh.com) are self contained units that measure ambient concentrations of gaseous species (SO_2, NO, NO_2 and O_3) and operate on battery power. Data gathered by the electrochemical gas sensors is processed by a proprietary algorithm which corrects for cross-interferences and for the effect of temperature and relative humidity. The AQMesh pod, therefore, also measures temperature, relative humidity and atmospheric pressure to enable the correction algorithm. An integrated GPRS modem allows data transfer to the AQMesh database server, where it is processed and prepared for analysis.

2.5 A further important step to correct for error resulting from changes in environmental conditions when the instrument is deployed is a local field-calibration. In the field-calibration, a comparison with a reference instrument is used to determine scaling factors which are applied to the AQMesh measurements. The official monitoring station located at Hipodruma residential area in Sofia was used to conduct a field-calibration of the instrument used in this survey.

2.6 The raw AQMesh measurements were found to be in good agreement with the official monitor for NO (R=0.99), NO_2 (R=0.97) and O_3 (R=0.91). Scaling factors were then applied to the results of these sensors to further improve the performance of the AQMesh. The AQMesh SO_2 sensor did not achieve a close correlation with the official monitoring results (R=0.17). The AQMesh SO_2 measurements are therefore not used in this study. Further details of the field-calibration process and scaling factors applied are presented in Appendix 1.

2.7 The AQMesh pod was deployed in a residential area of Golemo Selo, from 21st February 2019 until 22nd May 2019. It was positioned at a height of approximately 2 m. Nearby residential properties commonly use coal burning stoves for heating and cooking. The closest residential property to the monitoring location ceased using its stove in mid-April, although others nearby were observed continuing to burn solid fuel after that date.

Particulate Matter Measurements - pDR

2.8 The personal DataRAM 1500 (pDR) is a portable particulate matter monitor distributed by Thermo Scientific. The pDR 1500 uses carefully controlled air flow rates and specific cyclone attachments to separate incoming size fractions of particulate matter before a light scattering method is used to measure accurately the mass concentrations of fine particulates in air. The pDR can compensate for changes in relative humidity and can be run to collect readings over a period of several days at any one location.

2.9 The pDR pod was also deployed at the residential location in Golemo Selo. It was located east of the CFPP from 21st February 2019 until 22nd May 2019. It was positioned at a height of approximately 2 m. The instrument was deployed to monitor PM_{10} concentration with the PM_{10} specific cyclone installed. The pDR operates continuously while power is provided by the inbuilt battery. The monitoring record is therefore dis-continous with missing data in periods between battery failure and re-charging. A log of pDR operating times is shown in table 3.

Table 3: Log of pDR operating times

Number	Start Date	End Date Time	Duration
1	28 February	1 March	2 days
2	8 March	9 March	2 days
3	16 March	18 March	3 days
4	28 March	29 March	2 days
5	3 April	21 April	19 days

3 Results

Local Air Quality Monitoring

3.1 Results of monitoring undertaken at the Executive Environment Agency mobile monitoring station located in Golemo Selo are summarised in Table 4 and shown in Figure 3. These data have been provided by the Bulgarian Executive Environment Agency through an Access to Information request.

3.2 There were no recorded exceedances of the EU air quality standards for NO_2 or O_3 during the periods of monitoring; however the short-term monitoring data do not allow an assessment for exceedances of the annual mean air quality standards (Table 2a and 2b).

3.3 The EU 1-hour mean standard for SO_2 was exceeded once (3 May 2019). 35 exceedances are permitted annually. The EU daily mean standard for PM_{10} was exceeded once (9 May 2019). 25 exceedances are permitted annually. Monitoring was only performed from 15 March 2019 - 29 March 2019, and 23 April 2019 - 11 May 2019. It is therefore likely that further exceedances of these standards would be recorded during the calendar year. There were a further 11 exceedances of the WHO 24 hour mean guideline for SO_2 and one exceedance of the WHO 24 hour mean guideline for PM_{10} (Table 5).

3.4 Analysis of the temporal variations in recorded NO, NO_2 and O_3 concentrations are presented in Figure 4. There is a well pronounced diurnal cycle of NO_2 and O_3, where both species concentrations increase from overnight minima. The maximum O_3 concentration coincides with the hours of maximum insolation while NO_2 reaches two peaks each day. The midday NO_2 minima are likely the result of depletion caused by reactions in the presence of sunlight, which generate the O_3 and NO maximums at midday. Each NO_2 peak coincides with times associated with domestic fuel burning, traffic and other local combustion processes, before and after midday.

3.5 The NO_2 night-time minima do not fall below 15 μg/m^3. In a rural area such as Golemo Selo, where there are limited sources of NO_2 at night, these elevated concentrations at night provide evidence to suggest that the regional background concentration is affected by emissions from the CFPP which operates on a near continuous basis. The diurnal cycle of SO_2 shows morning and evening peaks consistent with domestic solid fuel burning above the background concentration.

Table 4: Summary of Mobile Monitoring Station Results (μg/m^3)

Pollutant	Mean	Maximum	Daily Maximum	Maximum 8-hour Running Mean	Maximum 24-hour Running Mean
NO_2	24.2	50	34.4	46.6	34.7
SO_2	23.2	**715**	57.2	150	87.8
O_3	27.4	92	42.3	81.2	51.8
PM_{10}**	-	-	**120**	-	-

* Exceedance of the EU air quality standard level shown in bold

** Only Daily Mean Data Available

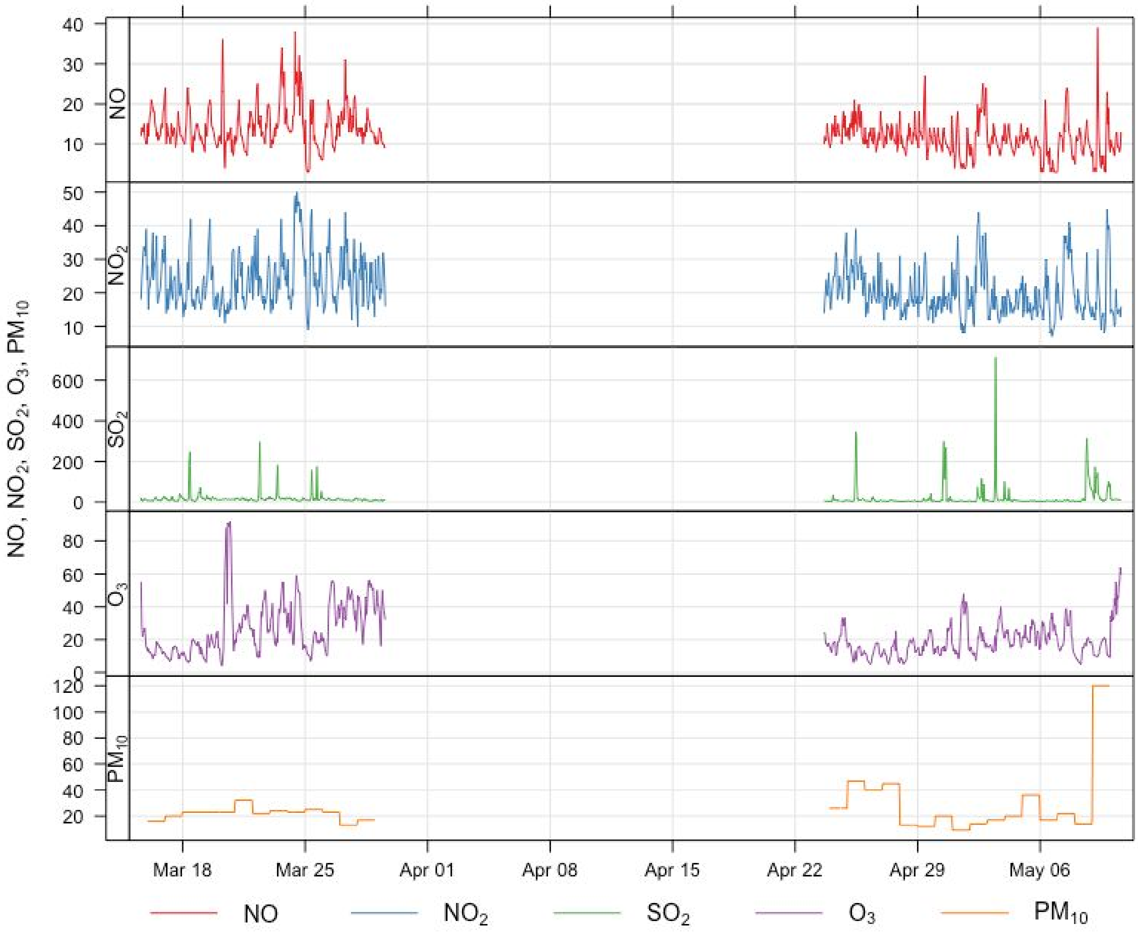

Figure 3: Monitored hourly mean NO, NO_2, SO_2 and O_3 and 24-hour mean PM_{10} concentrations (µg/m^3) measured by the mobile monitoring station during two periods of monitoring in Golemo Selo in 2019.

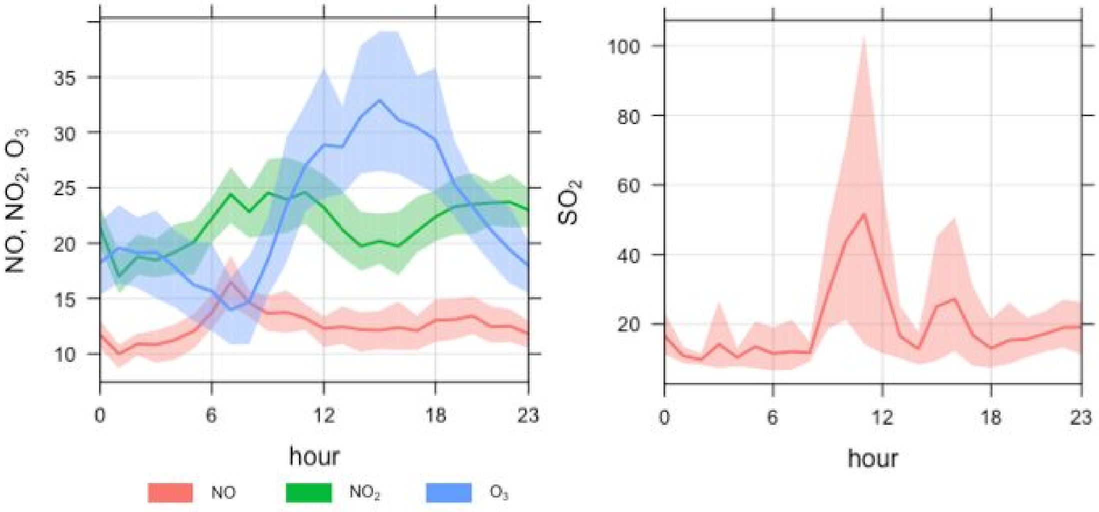

Figure 4: Left: Concentration of NO (Red), NO_2 (Green) and O_3 (Blue) measured by the Mobile Monitoring station (µg/m^3). Right: Concentration of SO_2 (Red) measured by the Mobile Monitoring station (µg/m^3). Plots show the mean and 95% confidence interval for each hour in the week.

Table 5: Summary of measured WHO daily mean SO_2 and PM_{10} guideline exceedances (µg/m^3)

Date	Daily Mean SO_2	Daily Mean PM_{10}
18/03/19	32.2	-
19/03/19	20.8	-
22/03/19	28.2	-
23/03/19	26.9	-
25/03/19	28.6	-
25/04/19	43.8	-
30/04/19	44.8	-
02/05/19	23.3	-
03/05/19	48.1	-
08/05/19	57.2	-
09/05/19	49.8	120

Diffusion Tube Monitoring Results

3.6 The results of the 3-month NO_2 and SO_2 diffusion tube survey deployed by Greenpeace in Golemo Selo and Bobov Dol between December 2017 and March 2018 are presented in Table 6. The duplicate NO_2 diffusion tubes deployed in each location show good agreement. The difference between duplicate samples is within 10% for both of the sites in the current study area. This provides good confidence in the measurement of average NO_2 concentrations during the monitoring period.

The duplicate diffusion tube results for the SO_2 are in reasonably close agreement at Bobov Dol. In Golemo Selo, however, the SO_2 concentrations were significantly above background and the difference between duplicates diffusion tubes was large (58% difference) during the first monitoring period, limiting confidence in the results for the first month of SO_2 monitoring. Laboratory monitoring results are provided in supplementary information.

Table 6: Summary of 2017-2018 Diffusion Tube Monitoring (μg/m^3)

Location	Start Date	End Date	Concentration NO_2	Concentration SO_2
Golemo Selo	16/12/2017	12/01/2018	12	187
			12	78
	12/01/2017	13/02/2017	10	36
			11	36
	13/02/2017	16/03/2017	8	37
			8	40
Bobov Dol	16/12/2017	12/01/2018	19	32
			21	36
	12/01/2017	13/02/2017	19	77
			-	73
	13/02/2017	16/03/2017	15	33
			16	31
Analysing Laboratory			Buro Blauw	Gradko

3.7 The recorded NO_2 concentrations are within the range expected for a semi-rural setting, with the highest monthly mean value recorded being 21 μg/m^3 in Bobov Dol. Concentrations during each month of monitoring are significantly below 40 μg/m^3 , suggesting that exceedance of the EU annual average standard for NO_2 is not likely at the monitoring sites in Golemo Selo or Bobov Dol. Measured monthly mean concentrations of SO_2 were regularly above 30 μg/m^3 and regularly exceeded 70 μg/m^3 . EU standards for SO_2 are averaged over 1-hour and 24-hours and it is not possible to make a direct comparison with the diffusion tube results which represent monthly-means.

Trace Gas Measurements - AQmesh

3.8 A summary of the measured NO_2 and O_3 concentrations recorded by the AQMesh monitor in Golemo Selo are presented in Table 7. As noted above, results for SO_2 are excluded from the analysis due to uncertainty in the instrument calibration. Further details can be found in Appendix 1.

Table 7: Summary of AQMesh Monitoring (µg/m^3)

Pollutant	Mean	Maximum	Daily Maximum	Maximum 8-hour Running Mean	Maximum 24-hour Running Mean
NO_2	41	89.1	65.1	77.1	69
O_3	40.5	103	54.6	91.6	70

3.9 The mean NO_2 and O_3 concentrations during the monitoring period are 41 and 40 µg/m^3 respectively, significantly higher than the monitoring period means recorded by the 2018 diffusion tube survey for NO_2 or the results of the mobile monitoring station. The monitoring results are not directly comparable because the monitoring locations and monitoring periods differ.

3.10 A direct comparison with the EU annual-average standard for NO_2 is not possible with short-term monitoring data. The monitoring NO_2 period mean (41 µg/m^3) is higher than the annual-average standard (40 µg/m^3). Therefore, if concentrations outside the monitoring period remain at similar levels the NO_2 standard will be exceeded. Neither the WHO guidelines, nor the EU standards for NO_2 (1-hour) or O_3 (8-hour running mean) were exceeded during the monitoring period at the QMesh monitoring location.

3.11 Analysis of the temporal variations in recorded NO, NO_2 and O_3 concentrations are presented in Figure 5 and Figure 6. The results of this analysis are in agreement with that undertaken using the mobile monitoring station data. There is a well pronounced diurnal cycle of NO_2 and O_3 and the interaction between NO_2, O_3 and NO results in O_3 depletion and a corresponding NO and O_3 peak in the middle of the day.

3.12 The NO_2 night-time minima do not fall below 20 µg/m^3. This elevated night-time concentration provides evidence that emissions from the CFPP is affecting regional background concentrations of NO_2. By increasing background concentrations of NO_2, the 'head-room' to accommodate emissions from other sources before the standards are exceeded is reduced. The likelihood of an exceedance of the air quality standards for $NO_2$is therefore increased as a consequence of the operation of the CFPP.

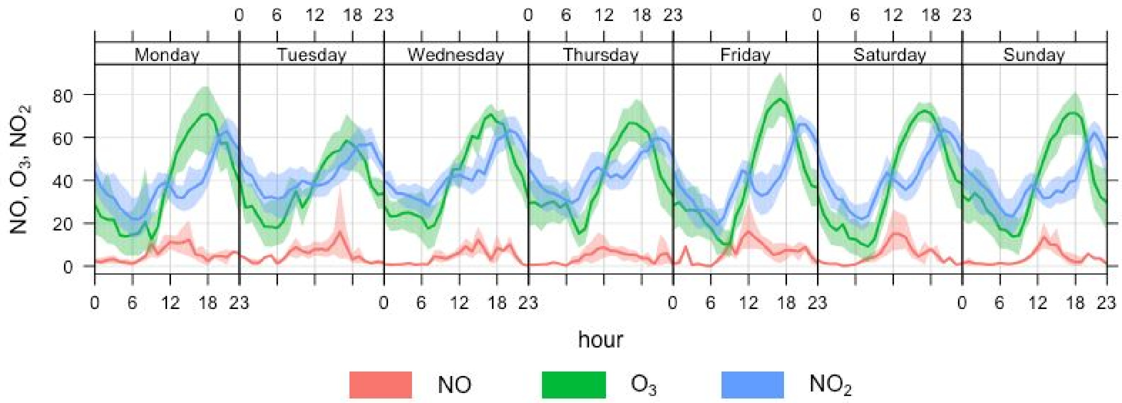

Figure 5: Concentration of NO (Red), NO_2 (Blue) and O_3 (Green) measured by the AQMesh (µg/m^3). Plots show the mean and 95% confidence interval for each hour in the week.

Figure 6: Concentration of NO (Red), NO_2 (Blue) and O_3 (Green) measured by the AQMesh (µg/m^3)

Particulate Matter Measurements - pDR

3.13 Hourly mean PM_{10} concentrations measured by the pDR monitor in Golemo Selo are presented in Figure 7 and a summary of exceedances of the EU daily mean standard is shown in Table 8.

3.14 Monitoring with the pDR was discontinuous with missing data in February and March being the result of power supply failures to the instrument. Near continuous monitoring was achieved between 3 April 2019 and 21st April 2019. During this period three exceedances of the WHO and EU daily mean standard were measured, while one exceedance was measured during February.

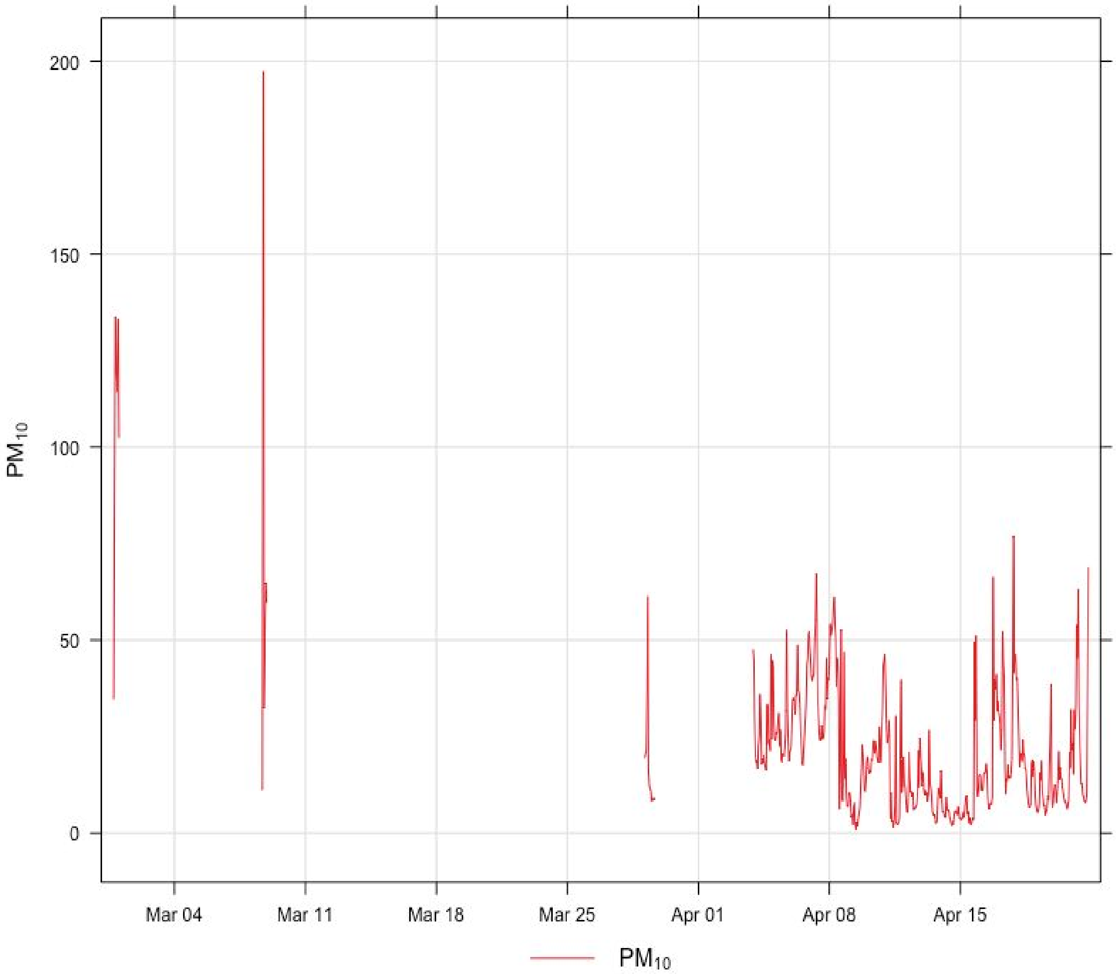

Figure 7: Concentration of PM_{10} (µg/m^3) measured using the pDR instrument.

Table 8: Summary of measured daily mean PM_{10} standard exceedances (µg/m^3)

Date	**Daily Mean PM_{10}**
28/02/19	102.4
01/03/19	54.5
08/03/19	57.3
17/03/19	54.6

4 Conclusions

4.1 Analysis of three air quality monitoring campaigns in Golemo Selo and Bobov Dol has been performed. The results of these campaigns have been compared, insofar as is possible, to EU and WHO air quality standards with respect to assessing the potential for health impacts resulting from atmospheric pollution.

4.2 Results from two periods of monitoring by a mobile monitoring station operated by the Executive Environment Agency show that EU standards for SO_2 and PM_{10} were exceeded in Golemo Selo. The data also show that there were 11 exceedances of the WHO 24-hour mean guideline for SO_2 and one exceedance of the WHO 24 hour mean guideline for PM_{10} during the monitoring period.

4.3 An NO_2 and SO_2 diffusion tube study performed by Greenpeace in 2018, which provides monthly average data, returned comparable period-means to those measured by the mobile monitoring station. These data therefore corroborate the mobile monitoring station data and suggest that the poor air quality conditions recorded by the mobile monitoring station are persistent.

4.4 An electrochemical air quality monitor (AQMesh) and optical particulate monitor (pDR) were also deployed in Golemo Selo. The results of monitoring with these instruments identified four24-hour periods exceeding both WHO and EU standards for the concentration of PM_{10}.

4.5 Analysis of hourly data retrieved from the AQMesh found that peaks in the diurnal cycle of NO_2 are likely the result of domestic fuel burning and road transportation. The analysis also found elevated night time concentrations of NO_2. This finding suggests that the regional background is influenced by the 24-hour operation of the Bobov Dol coal fired power plant. Any increase in background concentrations resulting from the operation of the CFPP increases the likelihood of an exceedance of the air quality standards. This is because the contribution needed from other sources of emissions to exceed the standards is reduced

5 Glossary

AQMesh	**An** electrochemical trace gas monitor
CFPP	Coal Fired Power Plant
CO	Carbon Monoxide
EU	European Union
Exceedance	A period of time when the concentration of an air pollutant is greater than the appropriate air quality guideline.
MWth	Megawatts thermal capacity

NH_3	Ammonia
NH_4	Ammonium
NMVOC	Non-methane volatile organic compounds
NO	Nitrogen oxide
NO_2	Nitrogen Dioxide
NOx	Mono-Nitrogen Oxides
O_3	Ozone
pDR	Personal DataRAM 1500, particulate matter monitor
PM_{10}	Particulate matter with aerodynamic diameter of less than 10 µm
$PM_{2.5}$	Particulate matter with aerodynamic diameter of less than 2.5 µm
ppm	Parts per million
RDF	Refuse Derived Fuels
SO_2	Sulphur dioxide
WHO	World Health Organisation
µg/m^3	Microgrammes per cubic metre

Appendix 1: Field-Calibration of the AQMesh

The AQMesh air quality monitoring instrument uses electrochemical sensors to determine ambient concentrations of trace gases. The sensors are sensitive to the environment that they are operating in, including the effects of temperature and humidity. Data gathered by the electrochemical gas sensors is processed by a proprietary algorithm which corrects for these effects using temperature, relative humidity and atmospheric pressure measurements were also made by the AQMesh.

A further important step to correct for error resulting from changes in environmental conditions when the instrumentis deployed is a local field-calibration. In the field-calibration a comparison with a reference instrument is used to determine scaling factors which are applied to the AQMesh measurements. The official monitoring station located at Hipodruma residential area in Sofia was used to conduct a field-calibration of the instrument used in this survey.

The official monitoring station located at Hipodruma reports hourly concentrations of SO_2, NO, NO_2, Ozone and other air pollutants. The AQMesh pod was co-located with the official monitor between 19th and 28th January 2019. Raw results from the co-location are shown in Figures A1, A4, A7 and A10 for NO, NO_2, SO_2 and O_3 respectively. The relationship between the AQMesh and official monitor results is shown in Figures

A2, A5, A8 and A11 which shows that the AQMesh was in good agreement with the official monitor for all NO (R=0.99), NO_2 (R=0.97) and O_3 (R=0.91). The AQMesh SO_2 sensor did not achieve a close correlation with the official monitoring results (R=0.17). The AQMesh SO_2 measurements are therefore not used in this study.

The scaling factors shown in Table A1 were then applied to the AQMesh monitoring results to further improve the performance of the instrument during its deployment at Golemo Selo. The scaled results of the field-calibration are shown in Figures A3, A5, A9 and A12 for NO, NO_2, SO_2 and O_3 respectively.

Table A1: Comparison of AQMesh and Official Monitoring Data

	NO	NO_2	SO_2	O_3
Slope	0.9	0.8	0.2	1.0
Intercept	1.7	-9.5	-1.7	10.0

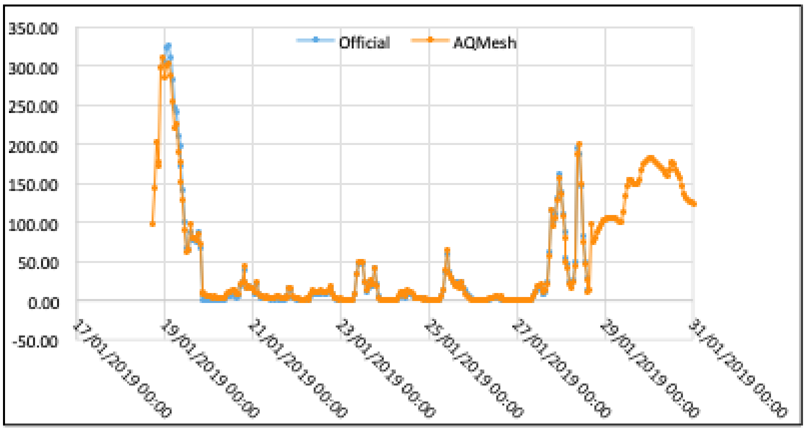

Figure A1: Measured NO concentration (µg/m³) from AQMesh (raw) and Official Monitor

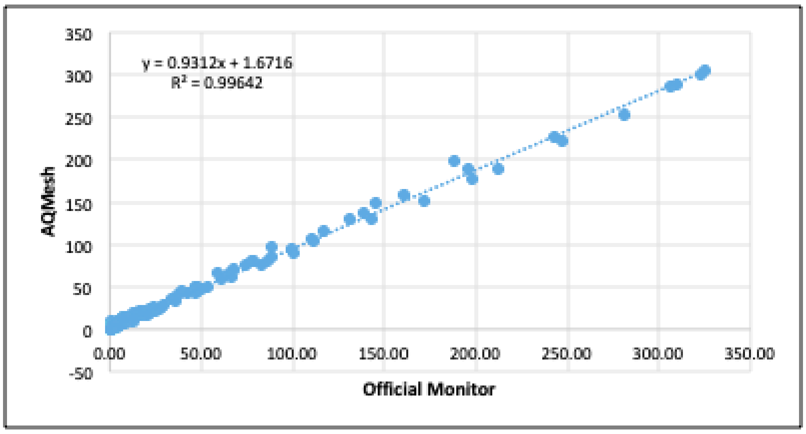

Figure A2: **Comparison of AQMesh and Official measured NO concentration (µg/m³)**

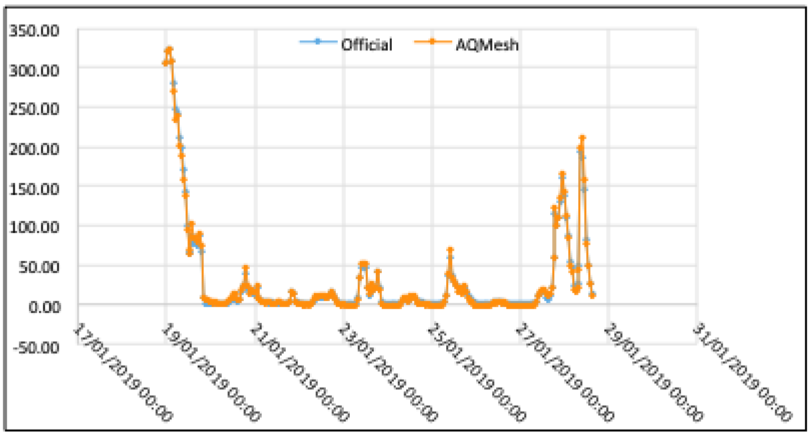

Figure A3: **Measured NO concentration (µg/m³) from AQMesh (adjusted) and Official Monitor**

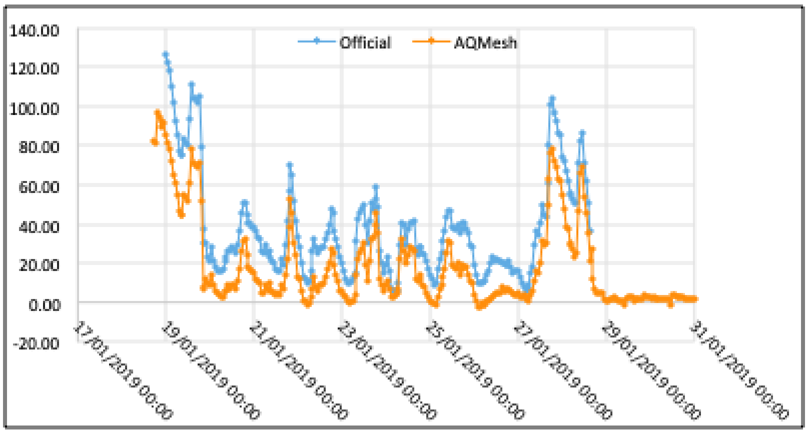

Figure A4: **Measured NO_2 concentration (µg/m³) from AQMesh (raw) and Official Monitor**

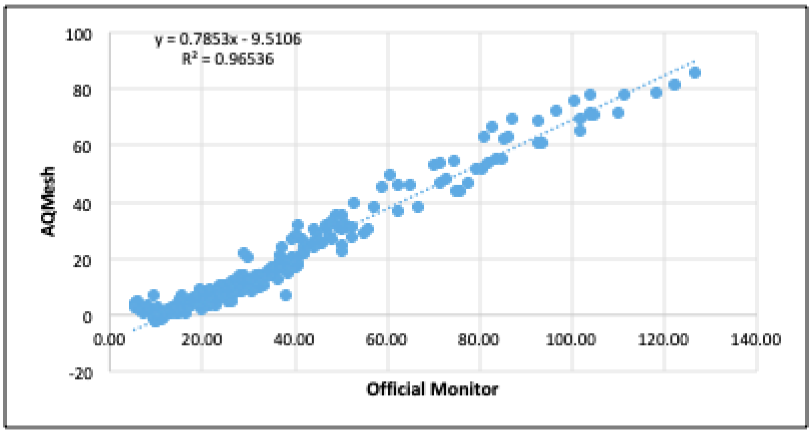

Figure A5: Comparison of AQMesh and Official measured NO_2 concentration (µg/m³)

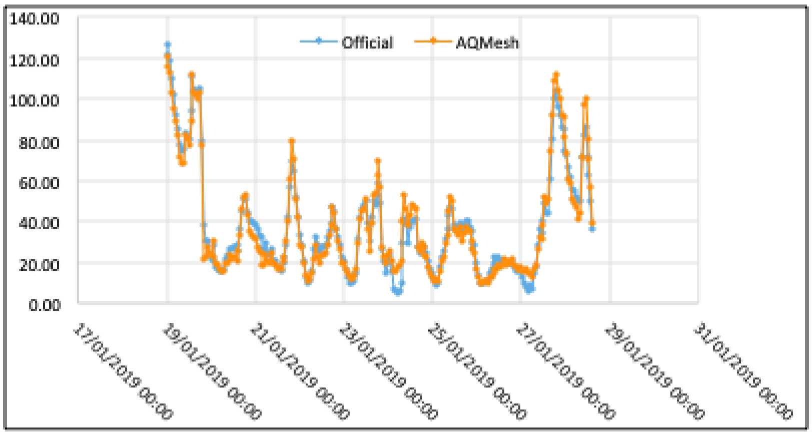

Figure A6: Measured NO_2 concentration (µg/m³) from AQMesh (adjusted) and Official Monitor

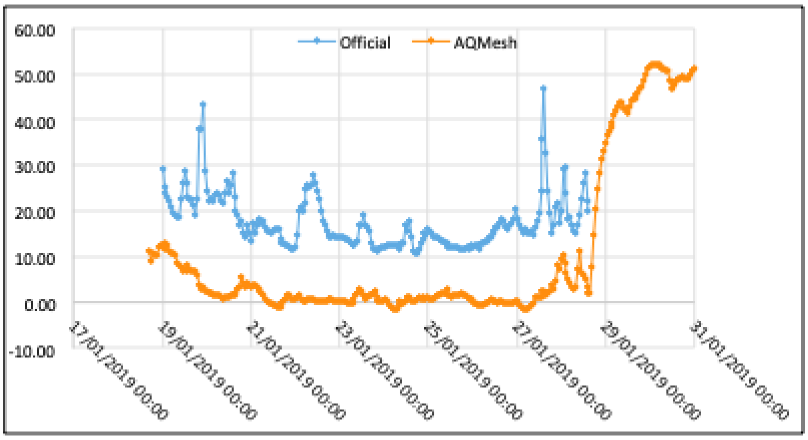

Figure A7: **Measured SO_2 concentration (µg/m^3) from AQMesh (raw) and Official Monitor**

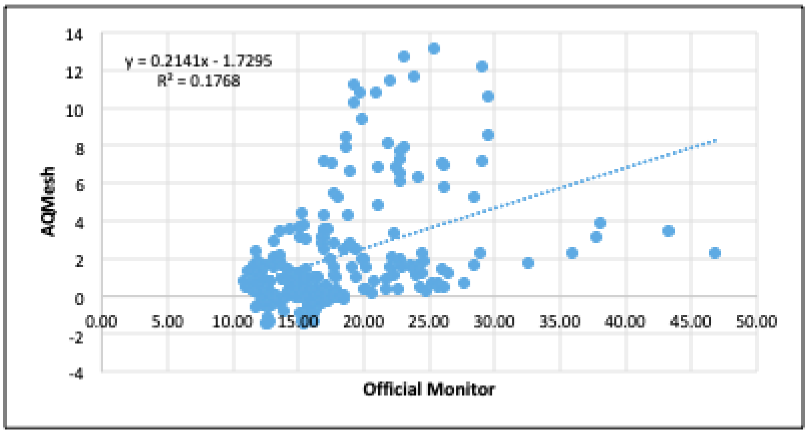

Figure A8: **Comparison of AQMesh and Official measured SO_2 concentration (µg/m^3)**

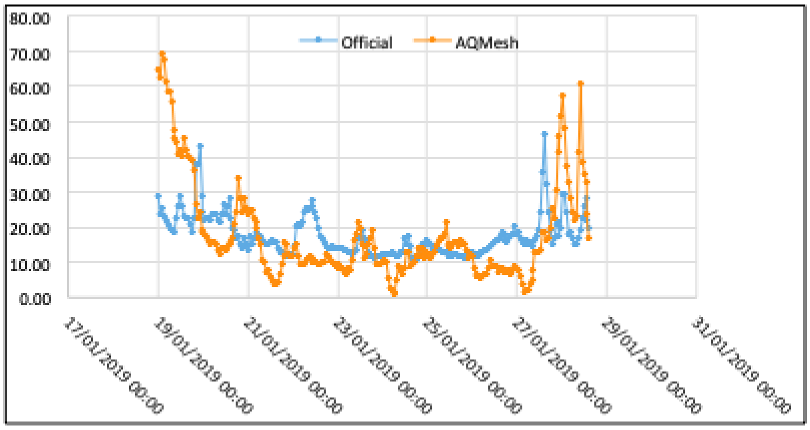

Figure A9: **Measured SO_2 concentration (µg/m^3) from AQMesh (adjusted) and Official Monitor**

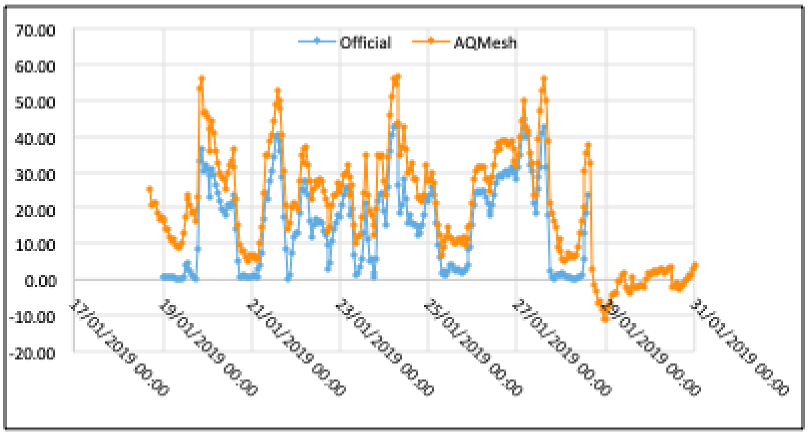

Figure A10: **Measured O_3 concentration (µg/m^3) from AQMesh (raw) and Official Monitor**

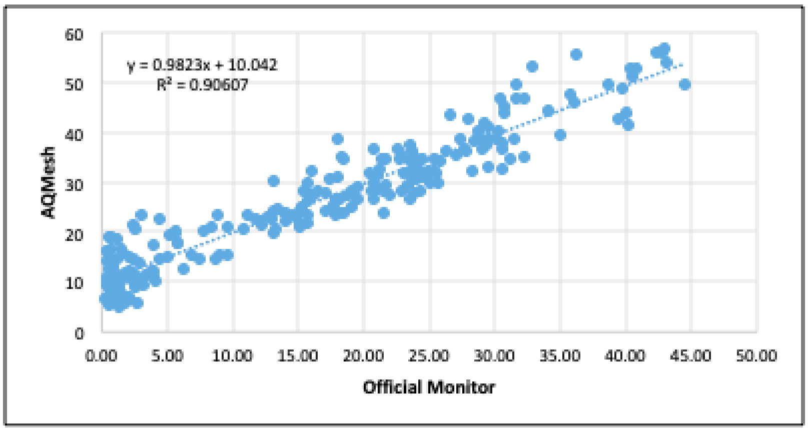

Figure A11: **Comparison of AQMesh and Official measured O_3 concentration (µg/m^3)**

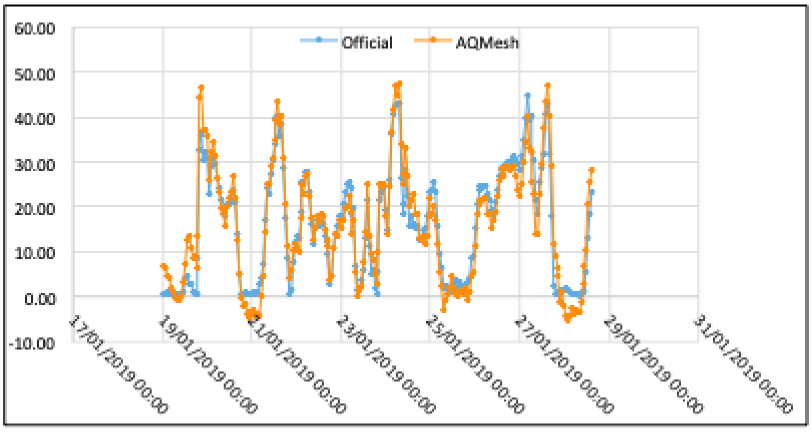

Figure A12: **Measured O_3 concentration (µg/m^3) from AQMesh (adjusted) and Official Monitor**

Supplementary Information

Raw Diffusion Tube Results