SO_2 Air Quality Monitoring in Deva, Romania, November 2018 - January 2019

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Contents

1 Introduction

1.1 This report describes the results of a three month Sulfur Dioxide (SO_2) diffusion tube monitoring survey carried out at locations surrounding the Mintia-Deva coal fired power station, Romania. Monitoring locations included sites within Deva and in surrounding settlements. Monitoring was undertaken from November 2018 to February 2019. Further analysis has been carried out using complementary data obtained from the Romania National Network for Monitoring Air Quality (RNMCA).

Policy Context

1.2 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 Romania is summarised below.

1.3 The National Emissions Ceiling Directive[1] 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 (NH4). The Directive came into effect on December 31, 2016. The legislation relates to emissions from all sources and Member States are responsible for ensuring that their citizens and industries comply. Romania's commitments under the directive are shown in Table 1.

1.4 **Table 1: National Emissions Ceiling Directive Commitments for Romania**

	For any year from 2020 to 2029	For any year from 2030
SO_2 reduction compared with 2005	77%	88%
NOx reduction compared with 2005	45%	60%
NMVOC reduction compared with 2005	25%	45%
NH_3 reduction compared with 2005	13%	25%
$PM_{2.5}$ reduction compared with 2005	28%	58%

[1] 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. http://data.europa.eu/eli/dir/2016/2284/oj

1.5 The Medium Combustion Plant Directive[2] (MCPD), Large Combustion Plant Directive (LCPD)[3] and Industrial Emissions Directive[4] limit emissions of certain pollutants into the air from combustion plant and industry. The MCPD applies to plant of 1-50 MWth capacity, with limits varying according to fuel type and plant capacity. 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) by either 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.

1.6 Emission standards for vehicles are currently in place for light–duty (cars, vans) and heavy-duty vehicles (coaches, buses, trucks), and for non-road mobile machinery in the EU[5].

1.7 Standards relating to the ambient concentration of air pollutants and exposure in the European Union are set out in the Air Quality Directive[6] (and four Daughter Directives). The air quality standards for SO_2 imposed by the directive are summarised in Table 2.

Table 2: European Ambient Air Quality Standards

Pollutant	Concentration	Averaging period	Permitted exceedances each year
SO_2	350 µg/m^3	1 hour	24
	125 µg/m^3	24 hours	3

[2] Directive (EU) 2015/2193 of the European Parliament and of the Council of 25 November 2015 on the limitation of emissions of certain pollutants into the air from medium combustion plants

[3] 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

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

[5] https://ec.europa.eu/growth/sectors/automotive/environment-protection/emissions_en

[6] 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

2 Materials and Methods

Study Area

2.1 The study area is defined by Figure 1 and comprises the city of Deva, the Mintia-Deva Power Plant and surrounding settlements.

2.2 Deva and the Mintia-Deva power plant are situated in the Hunedoara county (South-Eastern Transylvania), on the banks of the River Mureș and located within the Mureș river valley. Land use in the study area is predominantly agricultural with the Mintea-Deva power plant being the single significant industrial installation. The power plant is 8 km from the city of Deva; its three chimneys are 220 m tall. There are hills to the north and south that rise more than 300 m above the valley floor, which may influence the dispersion of air pollutants emitted in Deva and by the Deva-Mintia power plant.

2.3 The principle source of atmospheric SO_2 within the study area is likely to be burning solid fuels, in particular coal burning for domestic heating and for electricity generation at the Mintea-Deval coal fired power plant. Emissions of SO_2 from other sources, including the transport sector, are likely to be far less significant. To put this into context, the transport sector contributed only 1% of SO_2 emitted to the atmosphere in Romania during 2012[7].

2.4 The study area contains locations sensitive to the effects of air pollution, including residential properties, schools and hospitals.

[7] European Environment Agency. 2014. Air Pollution Fact Sheet 2014, Romania

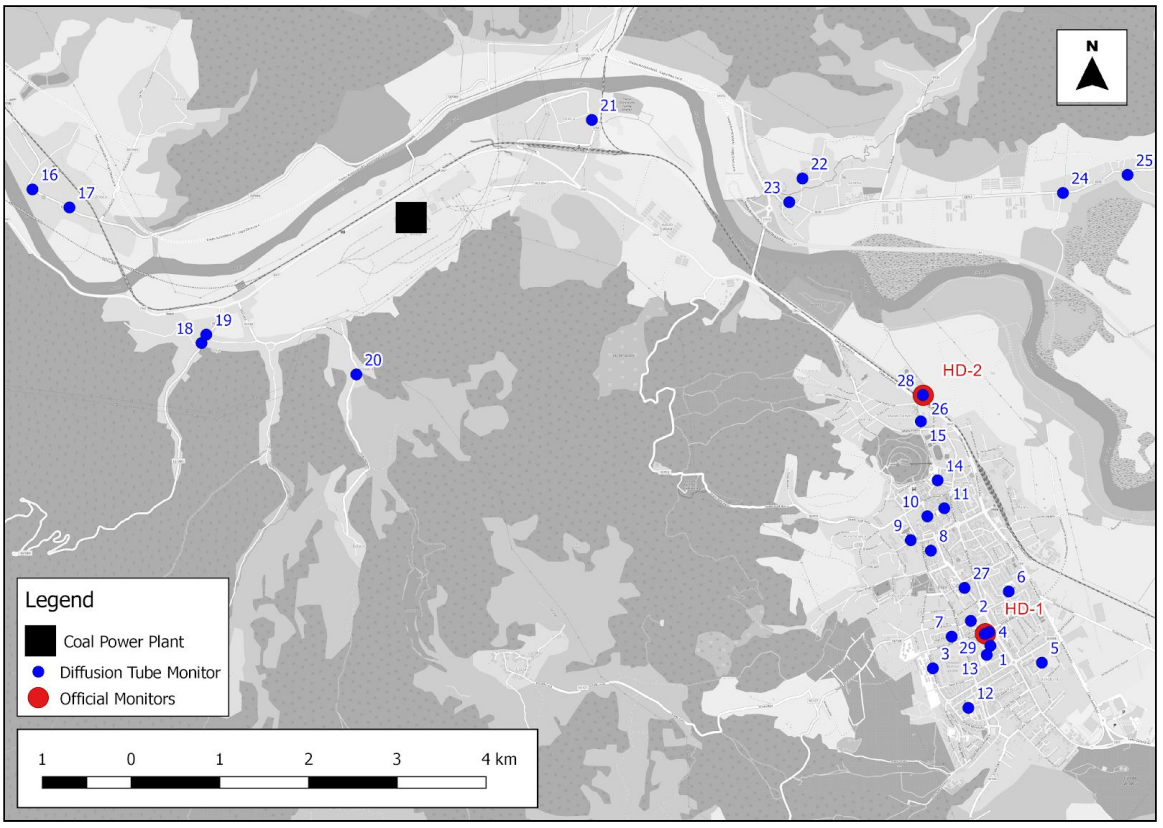

Figure 1: Monitoring Locations and The Study Area

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

Existing Monitoring Data

2.5 Two automatic air quality monitoring stations operate in Deva as part of the RNMCA. These are monitors HD-1 and HD-2 which are located on Strada Carpati in central Deva and Calea Zarandului in northern Deva respectively. Both monitors report hourly concentrations of SO_2 and other air pollutants. Data for these monitors have been downloaded from the the National Air Quality Monitoring Network website, CalitateAer[8].

Diffusion Tubes

2.6 Additional monitoring for SO_2 was undertaken by Greenpeace between November 2018 and February 2019 using diffusion tubes prepared and analysed by Gradko Ltd (UK). Twenty seven monitoring locations were selected to represent sensitive locations in the Deva area where people may be exposed to the effects of air pollution. In addition triplicate diffusion tubes were deployed in co-location with the HD-1 and HD-2 automatic monitors for data verification and bias adjustment. The locations of the diffusion tube monitors are shown in Figure 1 and are described in Table 3. Diffusion tubes were deployed for three months,

[8] http://www.calitateaer.ro/public/home-page/index.html

between 10/11/2018 and 15/12/2018 (Month 1), 15/12/2018 to 16/1/2019 (Month 2) and 16/1/2019 to 14/2/2019 (Month 3).

Table 3: Diffusion Tube Locations

Number	Location	Latitude	Longitude
1	Gradinita Nr.2 Deva	45.87018	22.90949
2	Liceul de arte Deva	45.87269	22.90664
3	Liceul Grigore Moisil Deva	45.8679	22.90113
4	Colegiul Transilvania Deva & HD1	45.87156	22.90929
5	Gradinita Tweety Deva	45.86847	22.91695
6	Scoala Andrei Saguna Deva	45.87566	22.91214
7	Liceul Teglas Gabor Deva	45.8711	22.90386
8	Gradinita Nr.7 Deva	45.87978	22.90084
9	Colegiul Regina Maria Deva	45.88084	22.89792
10	Colegiul Decebal Deva	45.88325	22.90033
11	Gradinita Nr.11 Deva	45.88406	22.90278
12	Scoala Andrei Muresanu Deva	45.86391	22.90628
13	Scoala Nr.3 Deva	45.86926	22.90895
14	Colegiul Sportiv Cetate Deva	45.88688	22.90182
15	Scoala Viile Noi Deva	45.89283	22.89939
16	Centru Social Branisca	45.91624	22.77043
17	Scoala Nicolae Tic Branisca	45.91442	22.7758
18	Scoala Vetel	45.90074	22.79497
19	Gradinita Vetel	45.90159	22.79566
20	Gradinita Herpeia	45.89757	22.81744
21	Mintia Sat	45.92325	22.85163
22	Scoala Soimus	45.91734	22.8822
23	Camin Cultural Soimus	45.91495	22.88028
24	Scoala Balata	45.91588	22.92001
25	Camin Cultural Balata	45.91771	22.92939
26	Statia	45.89549	22.89968
27	Spitalul Judetean Deva	45.87602	22.90572
28a/b/c	Triplicate co-located with HD-2	45.89549	22.89968
29a/b/c	Triplicate co-located with HD-1	45.87137	22.90869

2.7 The raw diffusion tube results have been bias corrected and annualised using data from the HD-1 and HD-2 automatic monitoring stations in Deva following the methodology set out in Appendix 1.

3 Results and Discussion

Local Air Quality Monitoring

3.1 Results of monitoring undertaken at the HD-1 and HD-2 stations during 2014-2018 are summarised in Table 4 and the monitoring locations are shown in Figure 1. These data have been collected from the National Air Quality Monitoring Network[9].

3.2 There were no recorded exceedances of the 1-hour or 24-hour standards, although data capture in 2014, 2015 and 2016 was low. In 2014, the 1-hour threshold of 350 µg/m^3 SO_2 was passed 4 times at HD-1 and 14 times at HD-2. European legislation permits 24 1-hour periods where average concentrations pass the threshold value per year, thus the standard was not exceeded.

Table 4: Summary of SO_2 Monitoring at HD-1 and HD-2

Year	Annual Mean (µg/m^3)		No. Exceedances of 1-Hour threshold (24 permitted)		No. Exceedances 24-Hour threshold (3 permitted)	
			350 µg/m^3		125 µg/m^3	
	HD-1	HD-2	HD-1	HD-2	HD-1	HD-2
2014	9.4	-*	4	14*	0	0*
2015	-*	-*	0*	0*	-*	-*
2016	9.7	-*	7	0*	0	0*
2017	9.3	11.0	0	0	0	0
2018	9.4	13.7	0	0	0	0

*Low data capture

3.3 Analysis of measured meteorological data and SO_2 concentrations for 2018 at the HD-1 and HD-2 monitoring stations reveals the relative location of pollutant sources (Figure 2). Recorded maximum wind speeds and SO_2 concentrations are lower at HD-1, in central Deva, than at HD-2, which is located on the northern edge of the city.

3.4 At HD-1, maximum SO_2 concentrations were coincident with wind speeds below 2.5 m/s, and westerly or south-westerly wind directions. In contrast, the maximum SO_2 concentrations recorded at HD-2 were coincident with wind speeds between 2.5-7.5 m/s, and westerly or north-westerly winds.

3.5 Comparison of the average diurnal, annual and weekly cycles of SO_2 concentrations at HD-1 and HD-2 are shown in Figure 3. During 2018 the annual average concentration of SO_2 was higher at HD-2 than at HD-1 during each hour of the day and each day of the week. Only the monthly averages for January and February saw concentrations at HD-1 and HD-2 converge. Concentrations of SO_2 at HD-2 did not fall below approximately 10 µg/m^3 at night.

[9] http://www.calitateaer.ro/public/home-page/?__locale=ro

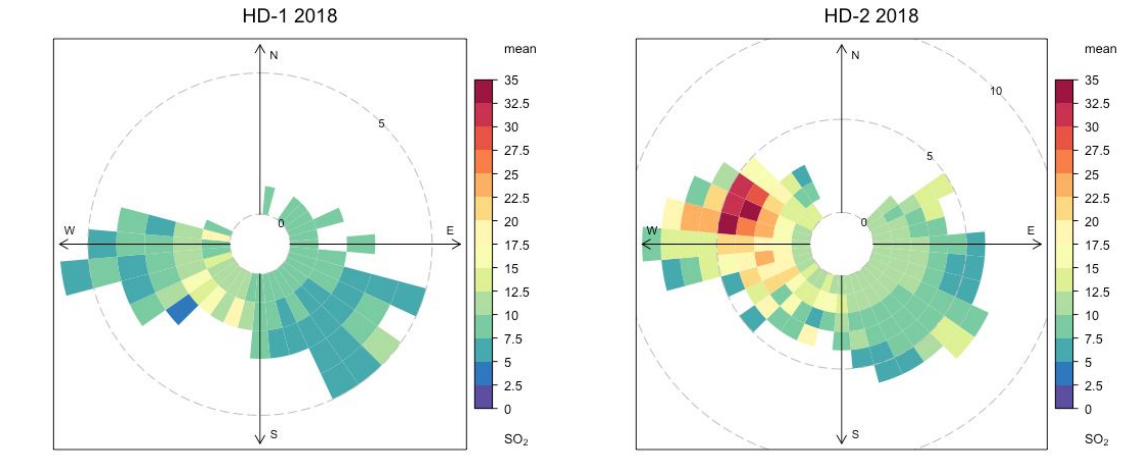

Figure 2: The concentration of SO_2 (µg/m^3) at monitors HD-1 and HD-2 split by wind direction and speed. The average concentration occurring for each wind speed (radial distance from the centre in m/s) and wind direction (degrees from North) is show. White areas correspond to wind directions or speeds not recorded at the monitoring station.

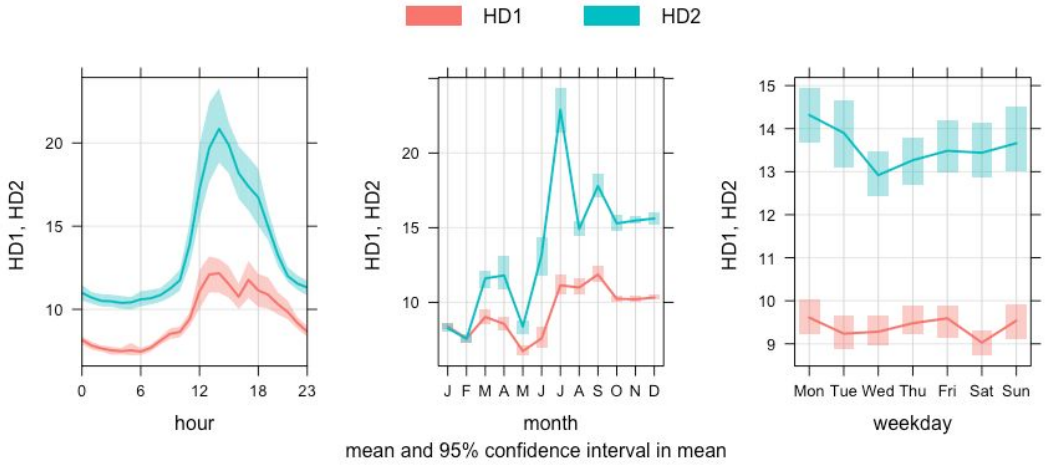

Figure 3: Concentration of SO_2 (µg/m^3) at monitors HD-1 (Red) and HD-2 (Blue) split by hour, month and week day. Plots show the average concentration during 2018 for the selected time period.

Diffusion Tube Monitoring Results

3.6 Results of the three month diffusion tube monitoring survey are summarised in Table 5 and shown in figures 4 to 6. An annual mean equivalent concentration for each diffusion tube monitoring location has been estimated for the calendar year 2018 following the method described in Appendix 1. The estimated 2018 annual mean SO_2 concentrations at each diffusion tube monitoring location are also shown in Table 5 and additionally presented in Figure 5.

3.7 Results of the diffusion tube monitoring revealed significant month on month variability. The highest monthly concentrations were recorded in month 3 (January-February 2019) at locations in the urban area of Deva (29.2 µg/m^3 at DT 9). In previous months the diffusion tube monitors located at HD-2 recorded the highest concentrations.

Table 5: Summary of SO2 Diffusion Tube Monitoring (µg/m^3)

ID	Month 1 (10/11/2018 to 15/12/2018)	Month 2 (15/12/2018 to 16/1/2019)	Month 3 (16/1/2019 to 14/2/2019)	2018 Annual Mean Equivalent
1	8.2	6.0	16.6	7.9
2	8.0	10.0	13.7	8.2
3	N/A[a]	4.5	11.2	-[b]
4	6.3	14.7	16.1	9.5
5	8.3	7.1	15.4	7.9
6	9.9	13.0	19.6	10.9
7	8.	6.6	15.3	7.8
8	9.3	8.7	22.3	10.3
9	8.8	9.0	25.2	10.9
10	10.5	10.5	21.7	10.9
11	12.9	16.0	22.2	13.2
12	N/A[a]	7.9	13.1	-[b]
13	6.0	8.1	17.2	7.9
14	11.1	13.5	20.9	11.7
15	11.9	10.4	20.7	11.1
16	N/A[a]	N/A[a]	5.2	-[b]
17	N/A[a]	N/A[a]	6.0	-[b]
18	11.2	N/A[a]	8.6	-[b]
19	N/A[a]	N/A[a]	N/A[a]	-[b]
20	N/A[a]	N/A[a]	9.7	-[b]
21	N/A[a]	N/A[a]	5.4	-[b]
22	N/A[a]	N/A[a]	5.6	-[b]
23	N/A[a]	N/A[a]	6.3	-[b]
24	N/A[a]	N/A[a]	N/A[a]	-[b]
25	8.8	N/A[a]	N/A[a]	-[b]
26	17.1	19.7	14.7	13.6
27	7.0	6.8	18.9	8.3
28a (HD-2)	-[c]	20.1	15.0	-[b]
28b (HD-2)	-[c]	12.3	13.7	-[b]
28c (HD-2)	-[c]	18.2	13.4	-[b]
29a (HD-1)	-[c]	-[c]	17.2	-[b]
29b (HD-1)	-[c]	-[c]	17.1	-[b]
29c (HD-1)	-[c]	-[c]	19.3	-[b]

[a] Measured value below the detection limit.

[b] Insufficient Data.

[c] Diffusion tube not retrieved.

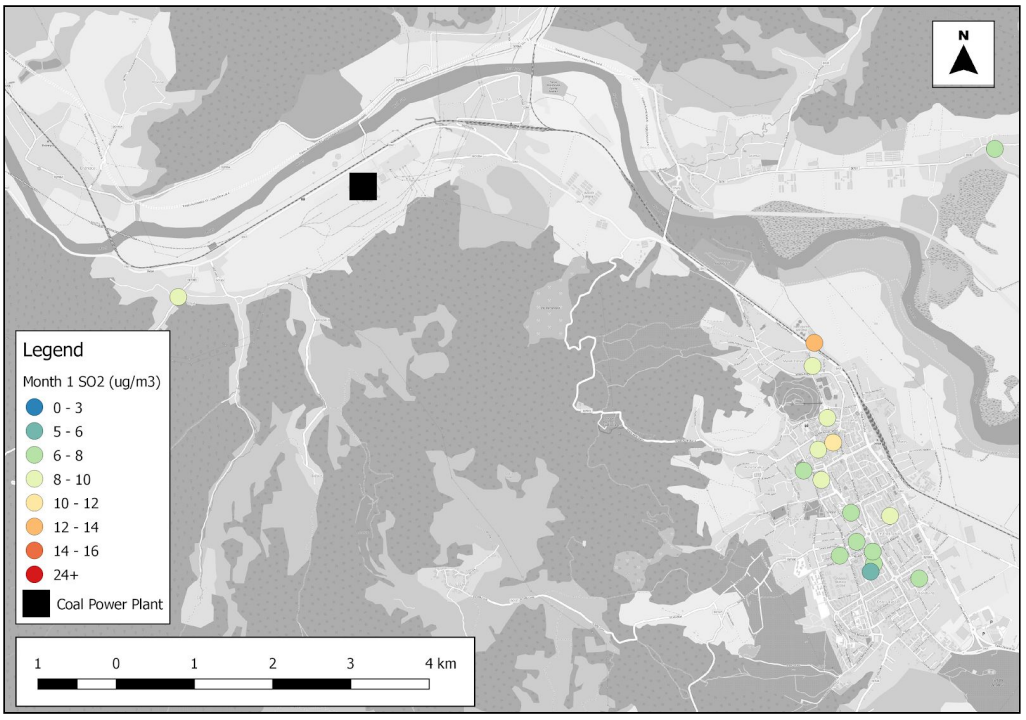

Figure 4: Month 1 (10/11/2018 to 15/12/2018) SO_2 Diffusion Tube Results (µg/m³)

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

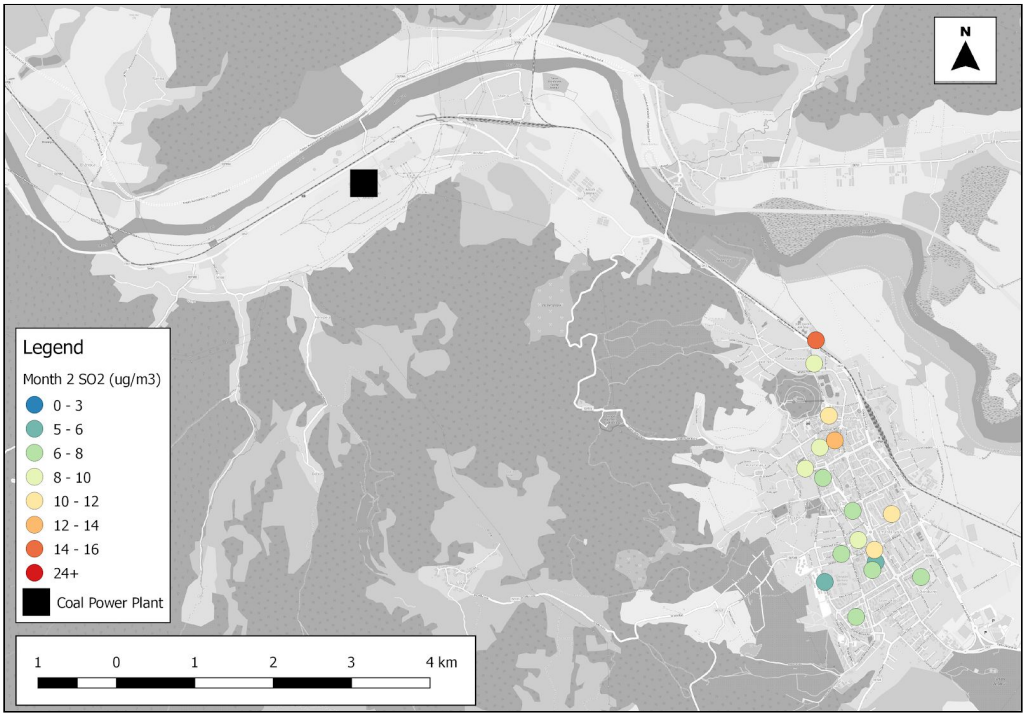

Figure 5: Month 2 (15/12/2018 to 16/1/2019) SO_2 Diffusion Tube Results (µg/m³)

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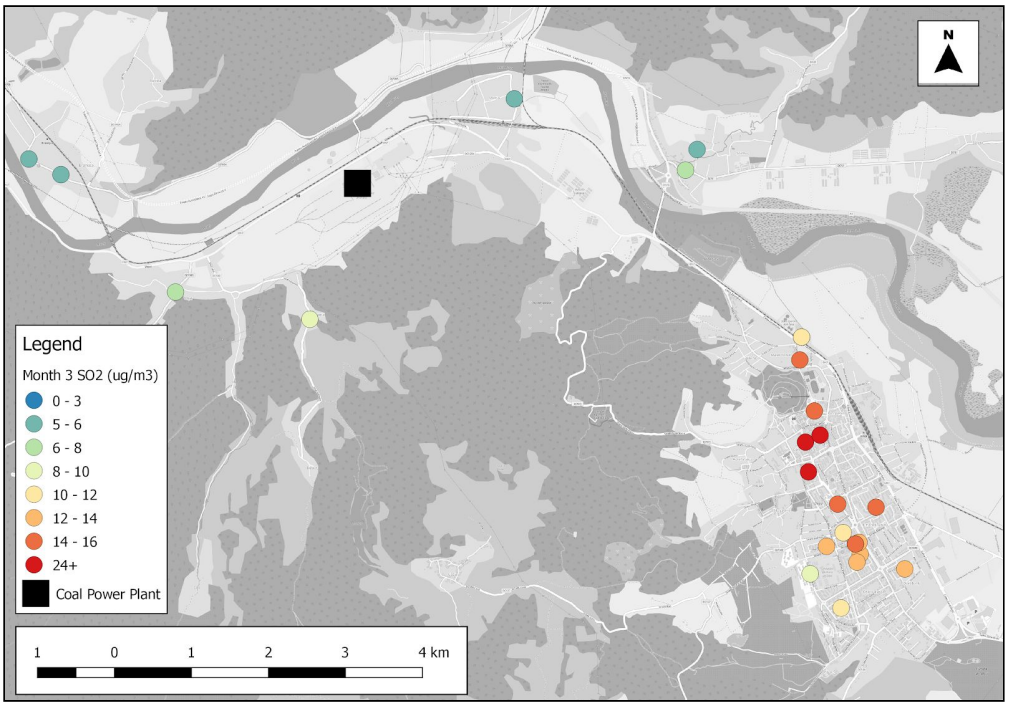

Figure 6: Month 3 (16/1/2019 to 14/2/2019) SO_2 Diffusion Tube Results (µg/m³)

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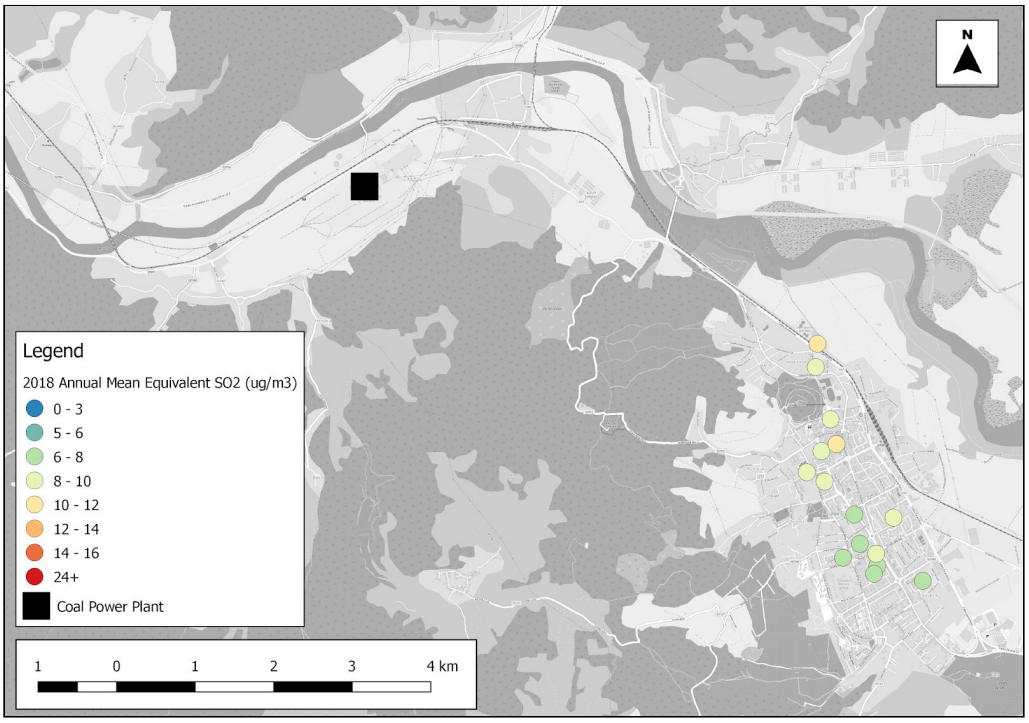

Figure 7: Annual Mean Equivalent (2018) Diffusion Tube Results for SO_2 (µg/m³)

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

4 Discussion

Comparison with Limit Values/Objectives/Guidelines

4.1 The monthly diffusion tube monitoring results cannot be directly compared to the air quality standards for SO_2, which apply over 1-hour and 24-hour averaging periods only. Hourly data is available for the HD-1 and HD-2 automatic monitoring stations, allowing comparison of those data with the standards; however no exceedances were recorded at these locations during 2014-2018 as 24 1-hour periods with average concentrations above the threshold value are permitted each year.

Source Apportionment

4.2 At HD-1, maximum SO_2 concentrations were recorded during periods with low wind speeds, below 2.5 m/s, and when the wind direction was westerly or south-westerly. This indicates that sources close to and south-west of HD-1 are principally responsible for the SO_2 emissions affecting this location. These are the denser residential areas of Deva which lie along the steep western side of the valley. The Diffusion tube monitoring results showed large month by month variability in SO_2 concentration in central Deva, possibly related to periods when meteorological conditions reduce pollutant dispersion or when rates of domestic fuel burning are higher.

4.3 At the HD-2 monitor, which is located at the northern edge of Deva and 200 m from the nearest domestic residences maximum SO_2 concentrations were recorded during periods with wind speeds between 2.5-7.5 m/s, and when the wind direction was westerly or north-westerly. This indicates that sources further from HD-2 and west-north-west of HD-2 are principally responsible for the SO_2 emissions that affect this location. The Mintia-Deval power plant lies 8 km west-north-west of HD-2 and it is likely that SO_2 emitted here is being recorded at the HD-2 monitoring station in conjunction with that from domestic properties in Viile Noi, however the contributions from local sources have not been quantified as part of this study.

4.4 During 2018, the concentrations of SO_2 were typically 4-10 µg/m^3 higher at HD-2 than at HD-1 (Figure 3). The highest values from month 1 and month 2 of the diffusion tube survey were alsoat HD-2, despite its location on the periphery of the city, where contributions to atmospheric pollution levels from domestic solid fuel burning can reasonably be anticipated to be lower. Figure 2 also reveals that the diurnal cycle of SO_2 concentrations does not fall close to zero at night, when activity from domestic or agricultural practises is at a minimum. Given its 24 hour operation, it is plausible that emissions from the Mintea-Deva power plant are contributing to measured night-time SO_2 concentrations. The night time SO_2 at HD-2 might therefore provide a first-order estimate of the SO_2 process contribution resulting from power plant emissions at that location.

4.5 Combined with the wind direction analysis presented in Figure 2, these monitoring results suggest that areas of Deva down wind of the Mintia-Deva power plant are affected by SO_2 emitted by sources further

north in the Mureș river valley. While domestic fuel burning and transport do contribute to SO_2 emissions in the region, the principal source north of Deva is the Mintia-Deva power plant.

5 Conclusions

5.1 A three-month SO_2 diffusion tube survey was undertaken at locations sensitive to the effects of air pollution in Deva and surrounding settlements between November 2018 and February 2019. Results of the diffusion tube monitoring found significant month-on-month variability which is likely the result of local weather conditions and consequent changes to domestic fuel burning. In month 1 and month 2 the highest concentrations were recorded at the site of an automatic air quality analyser on the northern edge of Deva (HD-2). In month 3, higher concentrations were recorded in urban areas of central Deva and are likely the result of domestic fuel burning and poor dispersion conditions.

5.2 Analysis of hourly monitoring data from automatic SO_2 analysers in Deva reveal that no exceedances of the SO_2 air quality standards have been recorded in the years 2014-2018. In 2014 the 1-hour threshold of 350 $\mu g/m^3$ SO_2 was passed 4 times at HD-1 and 14 times at HD-2, it is permitted for the threshold to be passed no more than 24 times per year. Averaged concentrations at the HD-2 monitor on the northern Edge of Deva are higher than those recorded at the HD-1 monitor, suggesting an important source of SO_2 pollution exists outside of the city.

5.3 Comparative analysis of wind speed and direction data suggest this source is the Mintia-Deva power plant, which is located 8 km west-north-west of the HD-2 monitor. SO_2 measurements at HD-2 remain higher than approximately 10 $\mu g/m^3$ at all times, suggesting a source that operates 24-hours per day. Further monitoring at locations both up and down wind of the Mintia-Deva power plant could be used to confirm the significance of the source.

6 Glossary

EU	European Union
µg/m³	Microgrammes per cubic metre
RNMCA	Romania National Network for Monitoring Air Quality
SO_2	Sulphur dioxide
WHO	World Health Organisation

Appendix 1: Bias adjustment and Annualisation of Results

Bias Adjustment

The SO_2 diffusion tube monitors used in this study were deployed between 10/11/2018 and 14/2/2019. Co-location of diffusion tubes with automatic monitors allow results to be corrected for bias. No co-location data is available for Month 1. Data from triplicates of diffusion tubes co-located with the HD-2 automatic monitor between 15/12/2019 to 16/1/2019 (Month 2) and 16/1/2019 to 14/2/2019 (Month 3), and a the HD-1 automatic monitor between 16/1/2019 to 14/2/2019 (Month 3) have been retrieved.

Data for the co-location periods recorded by the HD-1 and HD-2 automatic monitors have been downloaded from the National Air Quality Monitoring Network[10]. Bias adjustment factors and the data used to derive them are shown in Table A1.

These bias adjustment factors have been applied to the raw diffusion tube measurements for each month to account for uncertainty in recorded concentration.

Table A1: Derivation of Bias Adjustment Factors

Period	Automatic Monitor	A. Automatic Monitor Period Mean (µg/m^3)	B. Average of Triplicate Diffusion Tube Measurements (µg/m^3)	A/B	Bias Adjustment Factor Applied
Month 1	**HD-1**	10.18	No Data. Weighted mean of Month 2 and Month 3 applied		**4.58**
	HD-2	15.03			
Month 2	**HD-1**	11.06	No Data		**4.65**
	HD-2	16.86	3.63	4.65	
Month 3	**HD-1**	13.45	3.92	3.43	**4.55**
	HD-2	17.50	3.09	5.67	

Annualisation

Results of the 3-month diffusion tube monitoring survey are not representative of a full calendar year. Therefore, the data have been adjusted to an annual mean equivalent based on the ratio of concentrations during the 3-month monitoring period to those over the 2018 calendar year at three background sites operated as part of the National Air Quality Monitoring Network where long-term data are available.

The annual mean SO_2 concentrations and the period means for each of the automatic monitoring sites from which adjustment factors have been calculated are presented in Table A2, along with the Overall Factor.

[10] http://www.calitateaer.ro/public/home-page/?__locale=ro

The overall factor of 0.79 has been used to scale the 3-month diffusion tube data to an annual mean equivalent for 2018.

Table A2: Data used to Adjust Short-term Monitoring Data to 2018 Annual Mean Equivalent

Monitoring Site	Period Mean Concentration (µg/m^3)		Adjustment Factor	Overall Factor
	2018 Calendar year	Monitoring Period [a]		
HD-1	9.42	11.43	0.82	0.79
HD-2	13.67	16.40	0.83	
HD-3	Insufficient Data	12.47	No Used	
HD-4	9.16	9.16	0.71	
HD-5	19.73	18.73	0.78	

[a] Specifically 10/11/2018 to 14/2/2019.