CEE Bankwatch Network

Methodology for monitoring dust concentrations in ambient air and analysis of collected measurements

Monitoring device

We conduct the measurements with a GRIMM Environmental Dust Monitor 164 (EDM164). The device is a light scattering aerosol spectrometer, a recognised method for monitoring particle size distributions and particle number concentrations. It can measure the concentration of PM10, PM2.5 and PM1 particles.

The sample air is led directly into the measuring cell via the aerosol inlet or other custom-designed air inlets, e.g. for high wind speeds or overpressure. The particles in the sample air are detected by light scattering inside the measuring cell. The scattered light pulse emitted by each particle is counted, and the intensity of its scattered light signal is then classified as a certain particle size.

The dust monitor was first tested and approved in Europe for PM10 and PM2.5 as an equivalent for the reference method described in EN 12341:2014 (previously EN 14907:2005 for PM10 and EN 12341:1998 for PM2.5) and has been successfully used in EU Member States. Additionally, field tests in the US have also shown excellent accuracy in accordance with the relevant reference systems, and thus the method received the approval of the Environmental Protection Agency (EPA).

The device is equipped with a GRIMM 1146 GPS sensor to provide the exact coordinates of the monitoring location. It is also equipped with a GRIMM 158L sensor for temperature, relative humidity, barometric pressure, wind speed and wind direction to provide the basic meteorological information necessary to identify sources of dust pollution.

The dust monitor is regularly serviced by the manufacturer, GRIMM. It is also calibrated annually. The last calibration was done on 2 April 2020 and is valid until 30 April 2021[1].

Macro- and micro-siting for monitoring

When choosing the location of the sampling point, we adhere as closely as possible to the requirements of Annex III of the EU's Air Quality Directive (AQD). Our primary objective is to evaluate the impacts of coal facilities (power plants, open-pit mines and ash landfills) on human health in neighbouring settlements, so we use the articles relevant to this objective.

We conduct monitoring in the residential area nearest to the coal facilities, in an area where the highest concentrations are most likely to occur (see AQD, Annex III, Part B, Line (a)). However, we also choose a location that is representative of the whole settlement.

Although every effort is made to do so, we are not always able to place the sampling device downwind of the industrial activity as required by AQD, Annex III, Part B, Line (e). In most

[1] See a scan of the calibration certificate, 2 April 2020.

cases, in our countries of operation, coal facilities are grouped together and are located in different places around the settlement. It is also common that the most affected communities are not located downwind of industrial activities. However, when we are monitoring the contributions from a single source, we apply the siting criteria from the AQD.

Concerning the microscale siting, the monitoring device is always installed in an open space and the air flow around the inlet is always unrestricted. Depending on the conditions at the site, there is free access of air to the inlet ranging between 200 and 360 degrees. There have been a few exceptions to this, but access has never been below 180 degrees in any of our monitoring periods thus far. The inlet is always between 1.5 metres (the breathing zone) and 3 metres above the ground. It is never in the close vicinity of sources, and special attention is paid to reducing the direct impacts of automobile traffic on the air samples taken.

Comparison of the results with the limit values from the Air Quality Directive and the World Health Organisation guidelines

We have set the EDM164 to record measurements every minute, although it can be set to record them every 6 seconds if necessary. The collected data is recorded on a memory card in the device, but it is also sent in real time to an online server programmed with a dedicated software for analysing the data. The software then calculates 30-minute, 60-minute and 24-hour mean values. In addition to this, the software can flag 24-hour averages that cannot be verified because of longer interruptions in the measurements. All data can be accessed in real-time on the server, and it can also be exported for further analysis.

After we complete the monitoring cycle, which usually lasts for approximately one month, all collected data is exported and compared to the limit values from the AQD and WHO guidelines. The 24-hour mean values for PM10 are compared to the 24-hour limit value given in the AQD. Because there is not a 24-hour limit value for PM2.5 in the AQD, the results obtained are compared to the recommended ones from the WHO. We publish the results as a line chart, such as the one in Image 1. This allows for exceedances of the limit values to be easily identified.

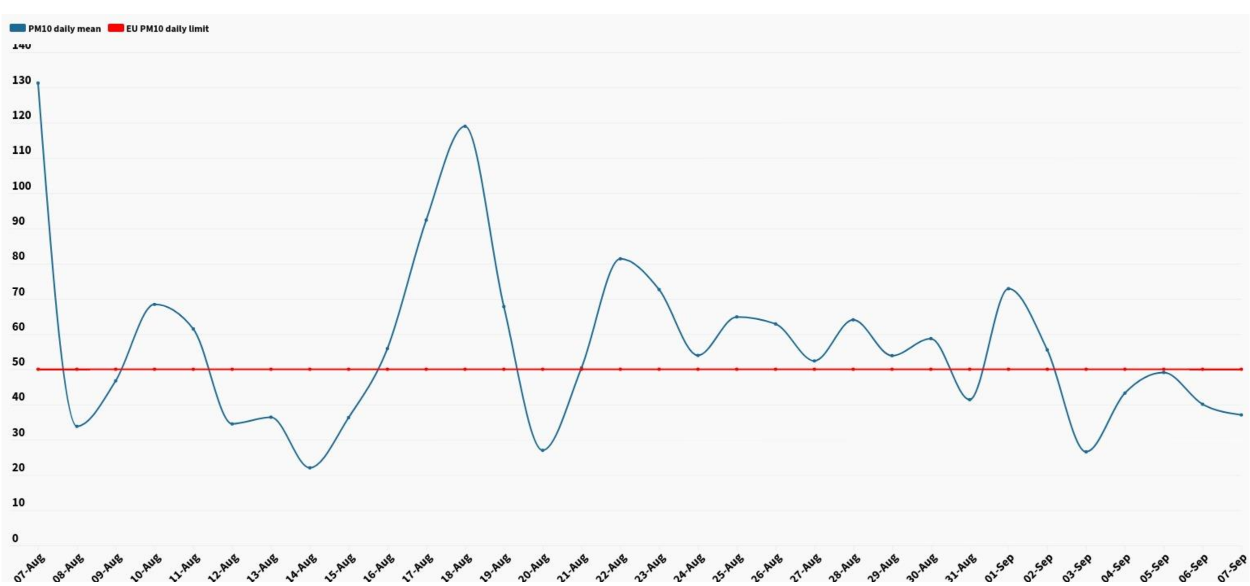

Image 1. Sample line chart with 24-hour mean values for PM10 (blue line) and the daily limit value from the AQD (red line)

Analysis of the origin of high pollution peaks using pollution wind roses

After we know which days had exceedances, we analyse the one-minute values for the days with highest values. In this way, we can identify the possible existence of high pollution peaks. These values are also presented as line charts, such as the sample in Image 2. The daily limit value is included in these charts for visual reference, but it does not apply to the short-term values.

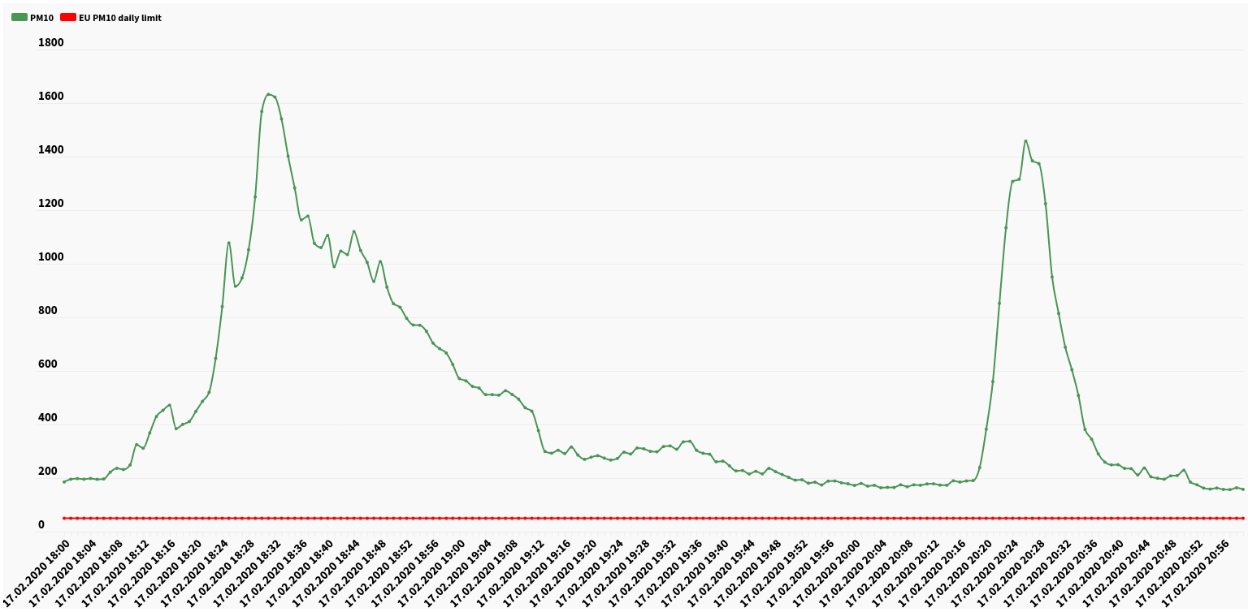

Image 2. Sample line chart with one-minute values for PM10 (green line) and the daily limit value from the AQD (red line)

By using the short-term measurements from the EDM164 and the data on wind direction from the meteorological station, it is possible to approximate the major sources of dust pollution. The measurements are plotted on a polar diagram according to the wind direction in the minute when they were recorded. When high pollution measurements are plotted multiple times in the same area of the diagram, there is a high possibility that there is a major source of pollution in that direction.

We display this data set as a pollution wind rose (Image 3). This diagram is useful for considering pollutant concentrations by wind direction, or more specifically the number of times a given dust concentration is coming from a certain direction. This type of approach can be very informative for air pollutants, as demonstrated in Henry et al. 2009.[2]

The coloured wedge segments represent the number of instances when the pollution is coming from that direction and the colours represent the different pollution concentrations in those instances as given on the scale.

[2] R. Henry, G.A. Norris, R. Vedantham, and J.R. Turner, ‘Source Region Identification Using Kernel Smoothing’, *Environmental Science & Technology* 43, 11 (2009): 4090-4097.

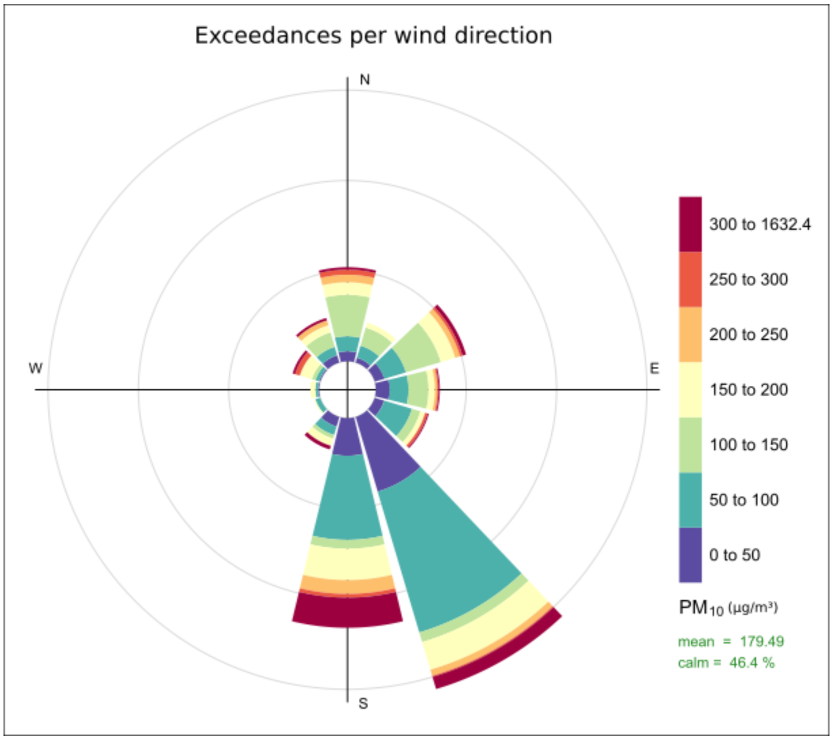

Image 3. Sample pollution wind rose for the measurements displayed in Image 2

Analysis of the potential sources' influence at a location using polar plots

When there are continuously high values of pollution at a location, identifying the direction of the short bursts of high pollution is not enough to conclude what the underlying cause of the pollution is. Wind can have different effects depending on its speed. Higher speeds can cause plumes from tall stacks to be brought down to ground-level or can increase particle suspension from facilities such as ash landfills and lignite storage, but they can also dilute the concentrations of the pollutants.

This is why the analysis of the measurements must also include a bivariate polar plot of concentrations (Image 4). This is a chart that takes into account measurements from the entire monitoring period and takes into account the variations in wind speed to provide insightful information on different sources of pollution, not just the ones that cause the pollution peaks. These plots are shown as a continuous surface, and surfaces are calculated through modelling using smoothing techniques. The idea of joint wind speed-direction dependence of concentrations has been considered before (see for example Yu et al. (2004)[3]). However, plotting the data in polar coordinates and for the purposes of source identification is first described in Carslaw et al. (2006)[4] and Westmoreland et al. (2007)[5].

[3] K. Yu, Y. Cheung, T. Cheung, and R. Henry, 'Identifying the impact of large urban airports on local air quality by nonparametric regression', *Atmospheric Environment* 38, 27 (2004): 4501-4507.
[4] D. C. Carslaw, S.D. Beevers, K. Ropkins, and M.C. Bell, 'Detecting and quantifying aircraft and other on-airport contributions to ambient nitrogen oxides in the vicinity of a large international airport', *Atmospheric Environment* 40, 28 (2006): 5424-5434.
[5] E. J.Westmoreland, N. Carslaw, D. C. Carslaw, A. Gillah, and E. Bates, 'Analysis of air quality within a street canyon using statistical and dispersion modelling techniques', *Atmospheric Environment* 41, 39 (2007): 9195–9205.

These plots have proved to be useful for quickly gaining a graphical impression of potential sources' influences at a location. This function is described in more detail in Carslaw, et al. (2006), where it is used to triangulate sources in an airport setting, and Carslaw and Beevers (2013)[6], where it is used with a clustering technique to identify features in a polar plot with similar characteristics.

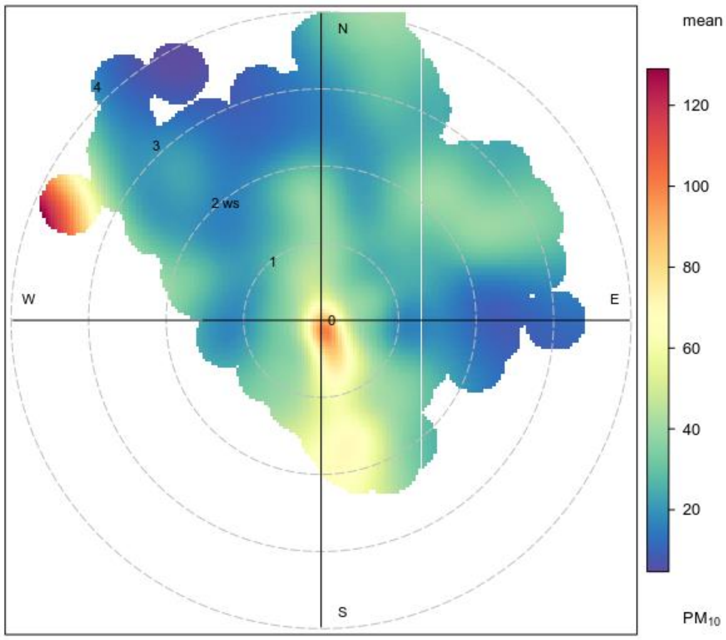

Image 4. Sample bivariate polar plot of concentrations

Analysis of the probability of sources for different pollution values using polar plots with conditional probability function

When there are different sources identified with the pollution wind rose and with the bivariate polar plot, the next step is to analyse the set of high pollution values separately from the rest of the values. For this purpose, a statistic called the conditional probability function (CPF) is introduced.

The CPF was originally used to show the wind directions that dominate a (specified) high concentration of a pollutant and showing the probability of such concentrations occurring by wind direction (Ashbaugh et al. 1985)[7]. However, these ideas can also be applied to bivariate polar plots. CPF analysis is very useful for showing which wind direction and wind speed intervals are dominated by high concentrations and give the probability of this occurring. A full

[6] D. C. Carslaw and S. D. Beevers, 'Characterising and understanding emission sources using bivariate polar plots and k-means clustering', *Environmental Modelling & Software* 40 (2013): 325–329.

[7] L. L. Ashbaugh, W. C. Malm and W. Z. Sadeh, 'A residence time probability analysis of sulfur concentrations at Grand Canyon National Park'. *Atmospheric Environment* 19, 8 (1985): 1263–1270.

explanation of the development and use of the bivariate case of the CPF can be found in Uria-Tellaetxe and Carslaw (2014)[8], where it is applied to monitoring data close to a steelworks.

For example, considering the interval between the 95th and 100th percentile of the collected measurements displays only the possible sources of the highest 5 percent of the values (Image 5). Considering the values that are in the 80th to 95th percentile interval displays values that are high enough to cause exceedances of the 24-hour values, but are not related to the high pollution peaks (Image 6). This helps to show some potentially important differences between the sources that could have been easily missed and can therefore help to build a more complete understanding of source contributions.

In the sample images, it is apparent that sources in the south are only relevant for the higher pollution values, but are completely irrelevant for the 80th to 95th percentile interval. At the same time, the sources in the north-west are the major contributor in the lower percentile interval.

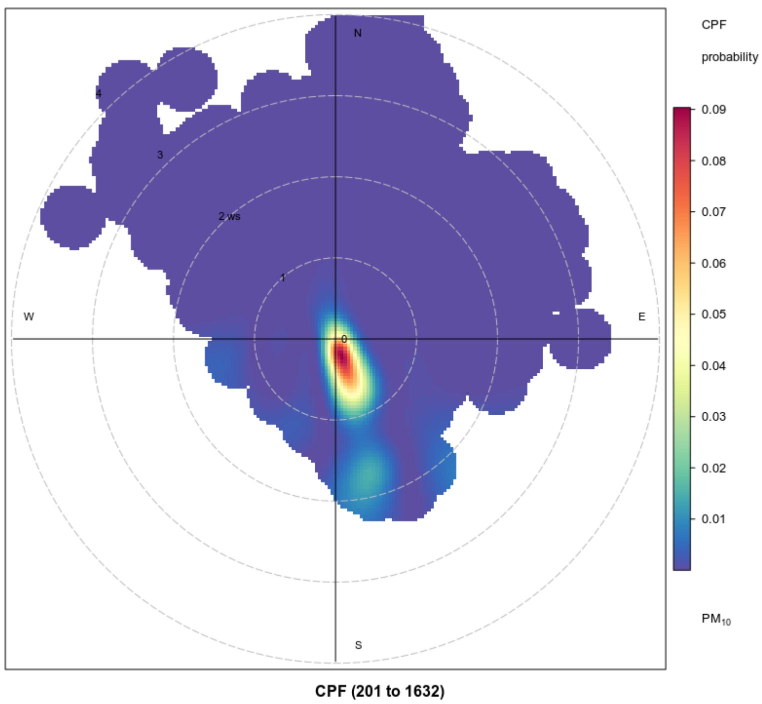

Image 5. Sample conditional bivariate probability function for the 95th to 100th percentile interval

[8] I. Uria-Tellaexte and D. C. Carslaw, ‘Conditional bivariate probability function for source identification’, *Environmental Modelling & Software* 59 (2014): 1–9.

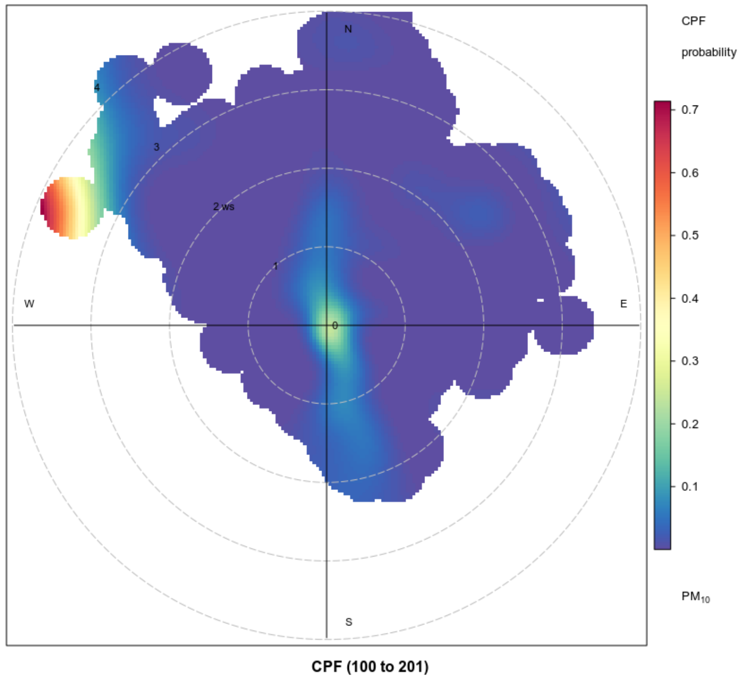

Image 6. Sample conditional bivariate probability function for the 80th to 95th percentile interval

Analysis of the differences between daytime and night-time pollution values using polar plots

Another useful analysis in our work is looking into distinctions between daytime and night-time. This is particularly useful if in the previous steps there is an obvious pattern of high pollution peaks occurring during a certain time of the day.

The previously mentioned bivariate polar plot of concentrations can be used here, to separately display the possible sources during day and night (Image 7).

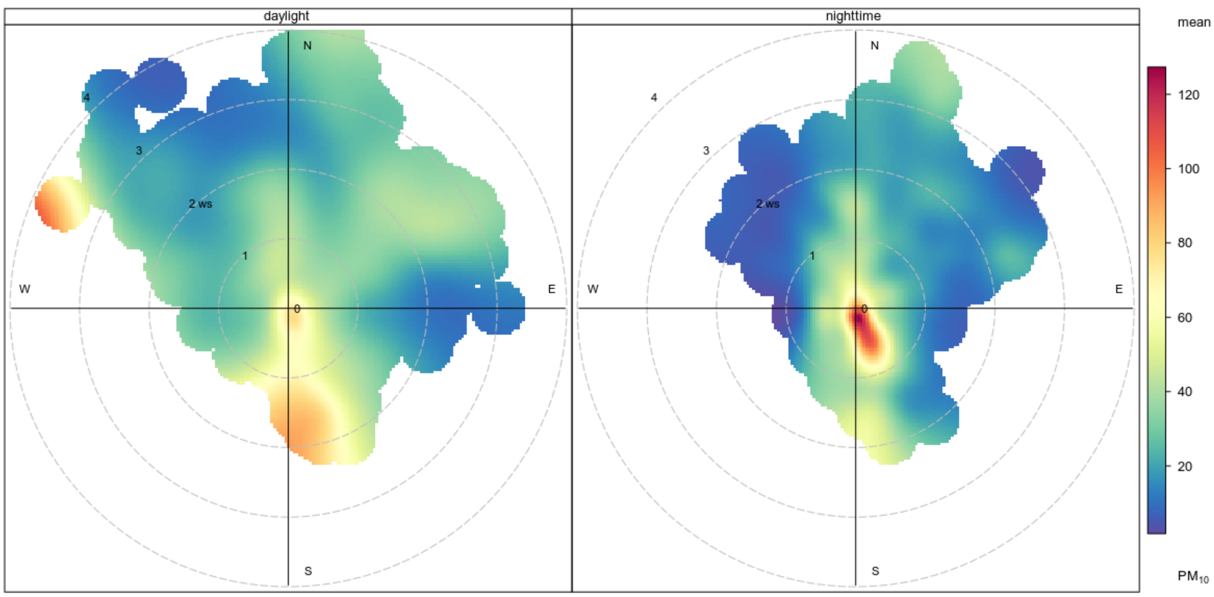

Image 7. Sample bivariate polar plot of concentrations for the daytime values (left) and night-time values (right)