REFERENCE MEASUREMENTS OF PM_{10} AND $PM_{2.5}$ PARTICULATE MATTER CONCENTRATIONS

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Abstract

To provide the reference dataset for particulate matter concentrations, a long-term campaign of continuous gravimetric measurements of PM_{10} and $PM_{2.5}$ concentrations was performed. Strict implementation of standard EN12341:2014 was fulfilled. Daily and monthly concentrations of both PM_{10} and $PM_{2.5}$ were measured with the highest possible accuracy. Ratio $PM_{2.5}/PM_{10}$ was determined and analyzed. Different distribution of particles was observed during the winter period, where most of the particulate matter originates from burning fossil fuel, and during an episode of Sahara dust, occasionally observed in spring and summer.

Keywords: PM_{10} ; $PM_{2.5}$; gravimetric measurement; Sahara dust.

1. Introduction

Air pollution by particulate matter (PM) is a global problem. Measurement techniques for PM concentrations have evolved over the past decades. Tapered element oscillating microbalance (TEOM) is one of the traditional methods [1], [2]. One of the most widely used methods is the beta attenuation mass monitor (BAM) [2]. Many governmental institutions use it because they are robust, relatively accurate, and easy to maintain. Then, laser scattering optical instruments are increasingly more popular nowadays [3], especially the low-cost variants [4]-[11]. They are less accurate but they have better time resolution and give information of several fractions of PM at once. There are also remote sensing techniques such as measurements from satellites [12]. What is common for all the abovementioned methods is significant measurement uncertainty. Thus, the reference method is necessary to verify all other measurements under different environmental conditions. The reference method for measurements of PM_{10} (all particulate matter smaller than 10 μm in diameter) and $PM_{2.5}$ (all PM smaller than 2.5 μm) concentrations is a gravimetric procedure, based on collecting the particles on filters, and weighing the filters before and after the sampling in the controlled environment. However, this method is expensive and requires a lot of manual work and it is rarely used in long-term campaigns. In this research we present a valuable asset of reference measurements of PM_{10} and $PM_{2.5}$ in Sarajevo, Bosnia Hercegovina, from 27.10.2020. till 31.5.2021.

2. The laboratory for gravimetric measurements

The laboratory for gravimetric measurements (Figure 1) is part of a larger laboratory for physical measurements, where we calibrate all instruments used in research [13]-[21]. A specific procedure for reference measurements of PM is defined in standard EN12341:2014, which is strictly implemented in our laboratory.

The following equipment was used:

- Dual channel (PM_{2.5} and PM₁₀) air sampler Gemini, Dadolab, Italy,
- Quartz filters Munktell Ahlstrom 47 mm,
- Laboratory with controlled temperature and humidity,
- Analytical balance ABT 101-5NM, Kern, Germany (Mettler Toledo XSR105DU in the final stage).

The sampling begins at 12:00 each day and ends at 11:58 the next day. Two minutes are reserved for filter exchange (automatic process). Each filter is conditioned before and after sampling using the following procedure: filters are stored in the room with a controlled temperature of $(20 \pm 1) ^\circ\text{C}$ and relative humidity $(47,5 \pm 2,5) \%$ two days. After 24 hours we take the first measurement of mass, and after 48 hours we take the second measurement. If the difference between the two measurements is not greater than $40 \mu\text{g}$, the filter is ready for sampling, otherwise, the procedure is repeated until two successive mass measurements satisfy the given criterion. The same procedure is performed after sampling. Airflow for sampling is $2.3 \text{ m}^3/\text{h}$ ($55.2 \text{ m}^3/\text{day}$).

Fig. 1. The gravimetric laboratory.

3. Results

Figure 2 shows daily average values of PM_{2.5} and PM₁₀ concentration, while Table 1 gives the monthly average values and ratio PM_{2.5}/PM₁₀ which was on average 84.4%. The primary source of air pollution in this period was the burning of fossil fuels for domestic heating and from vehicles' emissions. However, additional sampling was performed from 24.6.2021. until 26.6.2021. when Sahara dust episode was detected by satellites. Table 2 shows a very different ratio PM_{2.5}/PM₁₀ of around 30% in the case when Sahara dust was the primary source of pollution.

	Dec 2020	Jan 2021	Feb 2021	Mar 2021	Apr 2021	May 2021
PM _{2.5} ($\mu\text{g}/\text{m}^3$)	76.3	45.6	41.3	26.4	16.2	8.0
PM ₁₀ ($\mu\text{g}/\text{m}^3$)	91.3	49.1	50.4	31.1	20.7	13.1
PM _{2.5} /PM ₁₀	83.5%	92.9%	81.9%	85.0%	78.2%	61.2%

Table 1. Monthly average values of PM_{2.5} and PM₁₀.

Fig. 2. Daily average values of PM_{2.5} and PM₁₀.

Start of sampling	24.6.2021. 12:00	25.6.2021 12:00
PM _{2.5}	21.08	14.18
PM ₁₀	73.24	39.62
PM _{2.5} /PM ₁₀	28.8%	35.8%

Table 2. Sampling during the presence of Sahara dust.

Excellent accuracy of gravimetric instruments enables precise determination of PM_{2.5}/PM₁₀ ratio, which is a challenging task for all other techniques [3]. This is especially important in the atypical composition of particulate matter, such as the Sahara dust episode.

4. Conclusion

The very valuable asset of reference measurements of PM_{2.5} and PM₁₀ concentrations was produced in this research. It can be used for benchmarking all other measurement techniques, such as the research-grade equivalent methods or even the low-cost sensors. The average ratio PM_{2.5}/PM₁₀ was 84.4% during the winter period when the primary source of air pollution is the burning of fossil fuels. High daily average values up to 300 µg/m³ of PM_{2.5} were observed occasionally, which is extremely dangerous for public health. However, at the beginning of Summer, an episode of Sahara dust was detected. When the Sahara dust was the primary source of PM pollution, the ratio PM_{2.5}/PM₁₀ was only around 30% which is very interesting. This should be investigated more in future work.

5. References

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