Stationary and mobile particulate matter concentration measurement in Miskolc

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Abstract. A stationary and mobile device based on a low-cost dust sensor (Plantower PMS7003) was used to study particulate matter (PM) concentration in Miskolc. The stationary device was placed at the automatic monitoring station of the National Air Quality Measurement Network (OLM) in Martintelep, Miskolc. The mobile device was used to walk 4 streets along a square route with a total length of 800 m. Measurements were made on two days (September 9 and 11) between 7am and 9am, which according to preliminary experience coincided with the morning rush hour. The access route includes the OLM monitoring station, a busy road, two bypasses, a parking lot, and a smaller roadway blocked by traffic. The measured PM1, PM2.5, PM10 concentrations of the mobile device were interpolated on a circuit-by-circuit basis in ArcGIS, and conclusions were drawn for the area. The concentration of stationary and mobile devices was compared.

Introduction

Because of its effects on human health [1] and climate [2], there are worldwide standards for particulate matter (PM) environmental concentrations [3, 4]. Compliance with the limit values is monitored based on high-quality and expensive devices. The European Union's Air Quality Directive 2008/50/EC (AQD) [5] allow to use indicative, additional measurements that meet a less strict data quality objective than accredited monitoring networks. Low-cost dust sensors may be suitable for such indicative measurements. Over the last decade, sensor-based air pollution monitoring systems have become more prominent, thanks for their low cost, small dimensions, high spatial resolution and they can provide detailed data on air pollution in cities. Due to their small size, the sensors are easy to install on fix point or mobilize, and thus become accessible to the public for air quality monitoring [6]. Most of the studies focusing on stationary networks [7, 8] or mobile sensing [9-11] but just a few with the combination of them [12, 13] measured with low-cost PM sensors. In this context, we are currently experiencing a paradigm shift in how and who observes air quality [14, 15]. This paper aims to show and analyse the measured PM1, PM2.5, PM10 concentrations of a stationary and a mobile device in a residential area.

1. Material and methods

The mobile and stationary devices are based on Raspberry Pi microcontroller and Plantower PMS7003 PM sensor as shown in Fig. 1. (a) and (b). The stationary device supplemented with a DHT22 humidity and temperature sensor. The mobile device has the BME280 sensor for the ambient parameters like humidity, temperature and pressure. To follow the position of the mobile device a NEO-6M GPS module were attached. The mobile device's time was set to the stationary device and the DS3231 internal clock helped to keep it for the whole measurement. The low-cost PM sensors reliabilities were studied before [7, 16], according to their data tables they operate with 10-15% error limit.
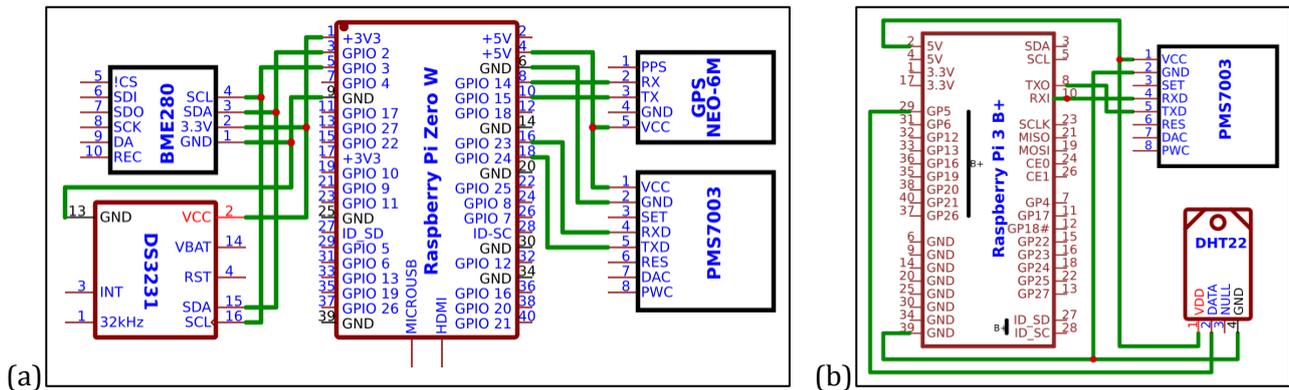

Figure 1. (a) Schematic of mobile device, (b) Schematic of stationary device

The stationary device was placed at the automatic monitoring station of the National Air Quality Measurement Network (OLM) in Martintelep, Miskolc in 4 m height. The mobile device was used to walk 4 streets along a square route with a total length of 800 m placed on a backpack in 1,6 m height. The route includes the OLM monitoring station, a busy road, two bypasses, a parking lot, and a sidewalk blocked by traffic (Fig. 2.). Measurements were made on two days (2019.09.09. and 11.) between 7am and 9am, which according to preliminary experience coincided with the morning rush hours. Each day 5 circle were made along the presented route within 40 minutes. Data were saved with continuous reading at 0.5 Hz recording time.

Figure 2. Route of the mobile device (orange square) and placement of stationary device (red circle)
1: OLM monitoring station, 2: busy road, 3: bypasses, 4: parking lot, 5: sidewalk

We saved GPS coordinates (longitude, latitude, altitude) for the measured data by the help of a mobile device, which allowed us to extend the data spatially. The process was done in ArcGIS 10.1 environment, using the spline interpolation tool (Spline with Barriers). Actually, this tool is a curve minimizing spline that uses lower degreed polynomials (usually third degree polynomials) to build up the function. This secure, that the value of the function, the first and second derivatives of it will be the same (at the measurement point). The advantage of the method is the smoothness, and the disadvantage is that it can give outlier values for the areas further away from the points [17-19].

2. Results and discussion

The average concentrations from five circles on 2019.09.09. show on Fig 3. for the three PM concentrations. The PM1, PM2.5 also PM10 concentrations are lower on the north-east (NE) side and higher on south-west (SW) part of the rout. At the NE side is an extensive green area blocked by traffic, which can reduce the PM concentrations.
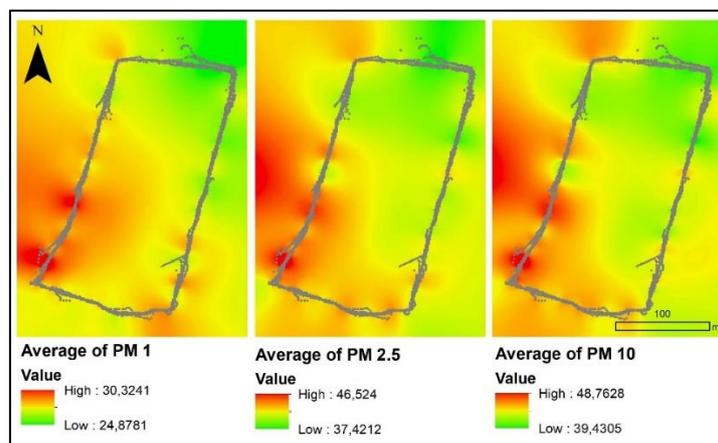

Figure 3. Average concentration maps in µg/m³ from five circles on 2019.09.09.

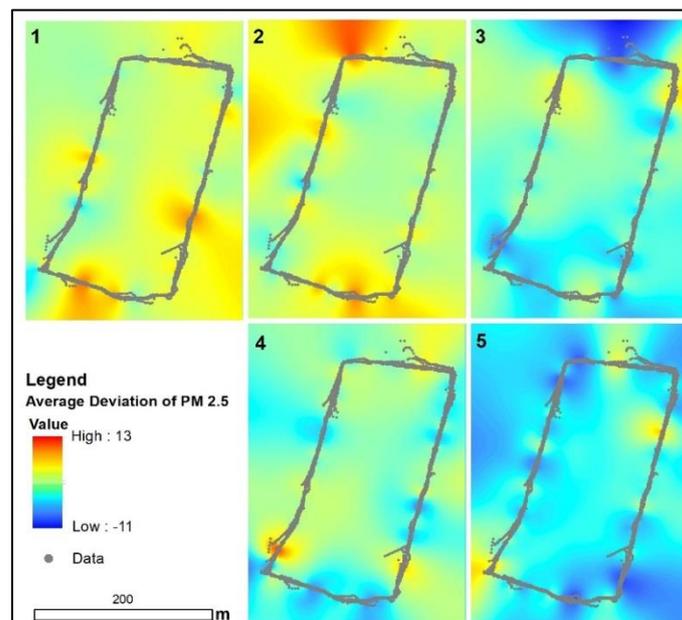*Figure 4. Average deviation maps in µg/m³ for the five circles on 2019.09.09.*

The Fig. 4. shows the average deviations of PM2.5 from circle to circle. The positive deviations show punctual but not recurrent pollution, which means that the sources of these elevated concentrations were vehicles.

The average concentrations from five circles on 2019.09.11. show on Fig 5. for the three PM concentrations. The PM1, PM2.5 also PM10 concentrations are higher on the NE side and lower on SW part of the rout.
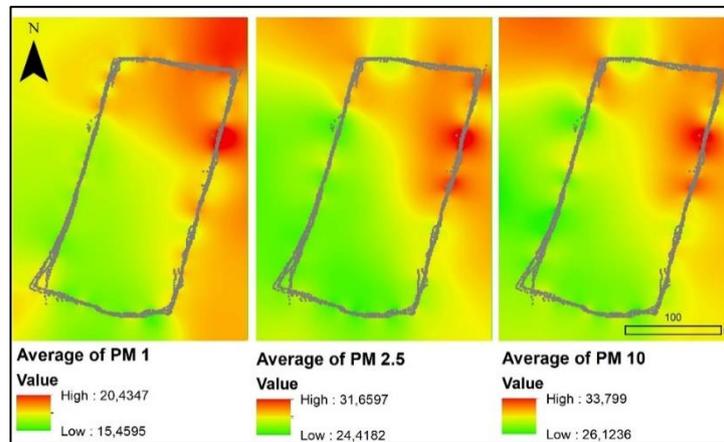

Figure 5. Average concentration maps in μg/m³ from five circles on 2019.09.11.

On this day NNE wind were observed, so the air pollutants were shifted to the south direction. That's how the mapped concentrations are in an opposite way then on 2019.09.09., then pollutants from the busy road dispersed out of the routed way. Altogether the concentration level was lower on the second measurement day, and the high values from the Fig. 5. are even lower than on Fig. 3. It's means that the NE sides concentration was not so different on these two days. The Fig. 6. shows the average deviations of PM2.5 from circle to circle. The positive deviations show punctual but not recurrent pollution, which means that the sources of these elevated concentrations were vehicles. Correlations between PM1 and PM2.5 concentrations along the routes of the two measurement days are under -0.7, between the PM10 concentrations is -0.68 (Table 1.), which confirms the differences between the average concentration maps. As Table .1 shows, the PM2.5 and PM10 concentrations on the same day correlate better than PM1-PM2.5 and even better compared to PM1-PM10 concentrations.
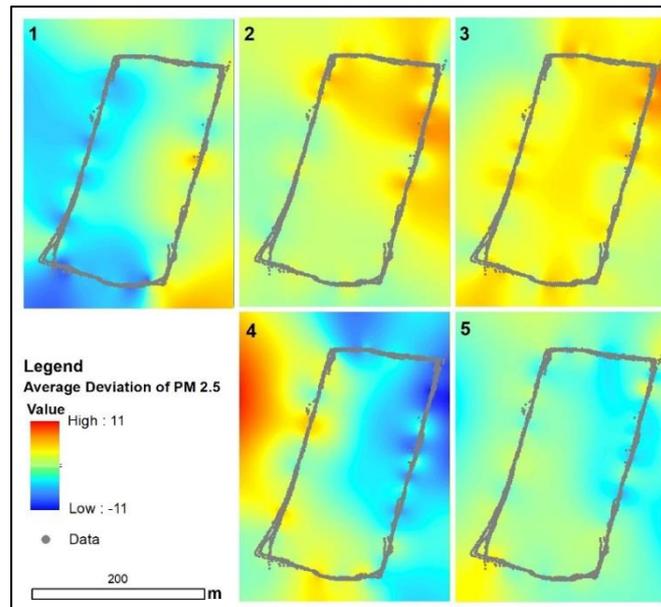
Figure 6. Average deviation maps in µg/m³ for the five circles on 2019.09.11.

From the averaged concentration maps has been collected the average PM concentrations within 10 m from the place, where the stationary device was placed, namely the OLM station. As Fig. 7. (a) shows the interpolated and averaged concentrations of the mobile device are lower on 2019.09.09. and higher on 2019.09.11. than the measured and averaged concentrations of the stationary device. Comparative measurement was made as both devices were standing on the same place.

Day		2019.09.09			2019.09.11		
PM concentration		PM1	PM2.5	PM10	PM1	PM2.5	PM10
2019.09.09	PM1	1.00	0.84	0.80	-0.79	-0.78	-0.73
	PM2.5	0.84	1.00	0.96	-0.74	-0.72	-0.70
	PM10	0.80	0.96	1.00	-0.71	-0.68	-0.68
2019.09.11	PM1	-0.79	-0.74	-0.71	1.00	0.88	0.81
	PM2.5	-0.78	-0.72	-0.68	0.88	1.00	0.96
	PM10	-0.73	-0.70	-0.68	0.81	0.96	1.00

Table 1. Correlation of averaged PM concentrations between two days

At this steady measurement the average percentage deviation was under 12%. The deviation at the OLM station on 2019.09.09. was under 15% but on 2019.09.11. was higher as Fig. 7. (b) shows.
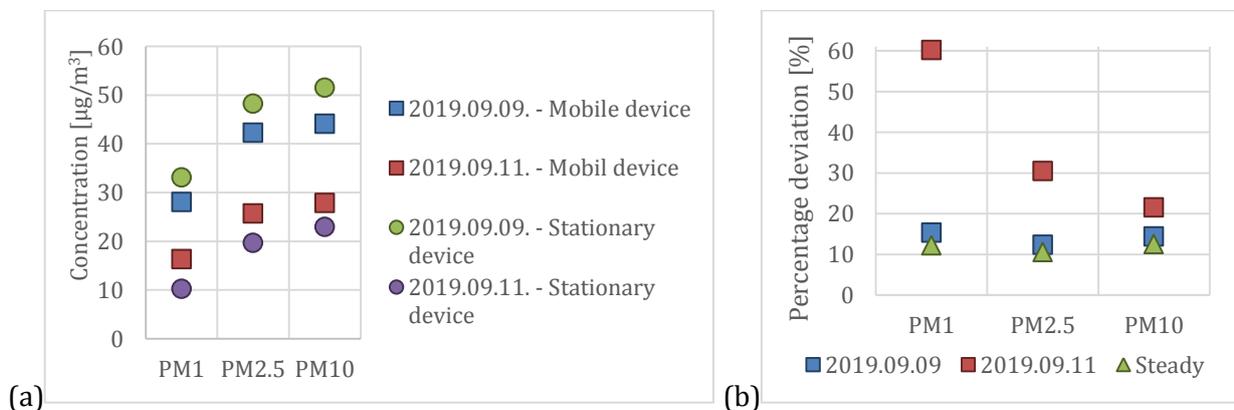

(a) (b)

Figure 7. (a) Averaged PM concentrations of mobile and stationary devices at the OLM station
(b) Percentage deviation of PM concentration of mobile and stationary devices

3. Conclusion

Stationary and mobile PM measurements were made with sensor-based devices, which represents the possibilities of a combined measurement technique. The mobile device is capable to explore an area and identify the higher concentration parts of it. If these are not recurrent and have wind dependence, we can define them as mobile sources (vehicles), if these are recurrent in case of the same wind directions, then we define them as stationary sources. Based on the result of the mobile measurements, the most stable site can be selected to measure with the stationary device. Further research will be supplemented with wind and PM data from OLM station, and measurements in different part of the day, heating and non-heating season also.

Acknowledgement

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