GRID 2024
12. INTERNATIONAL SYMPOSIUM ON GRAPHIC ENGINEERING AND DESIGN
14-16. NOVEMBER 2024

12th GRID SYMPOSIUM

The particulate matter in the working environment of the digital printing machine detected by stationary and personal methods

Savka Adamović [1], Rastko Milošević [1], Bojan Banjanin [1], Miroslav Dramićanin [2], Milana Ilić Mićunović [2], Aleksandra Mihailović [3]
[1] Faculty of Technical Sciences, Graphic Engineering and Design, Novi Sad, Serbia; [2] Faculty of Technical Sciences, Production Engineering, Novi Sad, Serbia; [3] Faculty of Technical Sciences, Fundamentals Sciences, Novi Sad, Serbia

Introduction

Particulate matter (PM) is the most significant pollutant produced by industrial activities. PM emitted during the digital printing process is potentially dangerous in the sense that it penetrates deep into the operator's lungs. To accurately assess the impact of these particles in the working environment, it's essential to determine their concentration and geometric characteristics. The analysis of PM is a complex process that requires the proposal of different analytical methods depending on the specific requirements and objectives of the research. The paper examines the similarities and differences between the concentrations of PM detected with spatial and personal sampling.

Methods

Digital printing environment

The research took place at the printing laboratory of the Department of Graphic Engineering and Design at the Faculty of Technical Sciences in Novi Sad, Serbia. PM mass concentration levels were measured near the ink jet digital printing machine, model LEC-540 (Roland, Japan).

Analysis of particulate matter

Sensor sampler

PM particle mass concentration levels were continuously monitored using an optical particle counter OPC-N2 (Alphasense, United Kingdom) sensor sampler. The sensor device is a portable and precise PM monitor known for measuring PM mass concentrations (μg/m^3) with high accuracy and real-time data collection.

Personal sampler

The EGO PLUS TT (Zambelli, Italy) personal sampler was used to collect PM particles with a diameter of less than 10 μm. The device consists of a display setting, a conical nozzle equipped with a filter, and a silicone hose. The membrane filters used were with a pore size of 0.8 μm, a diameter of 25 mm (effective diameter of 22 mm), and an effective surface of 380 mm^2. The airflow rate was 3.5 l/min. The sampling time was 30 minutes, and measurements were taken within the printing technician's breathing zone, placed on the upper part of the chest.

The mass concentration levels (quantity) of PM particles with a diameter of less than 10 μm in the indoor air near the digital printing machine were determined with standard gravimetric measurement method according to the formula (1):

$$Q_{PM} = \frac{m_2 - m_1}{V} \cdot 10^6 \quad (1)$$

where:

- Q_{PM} is the quantity of particles less than 10 μm (μg/m^3),
- m_1 and m_2 are the masses of the filter paper before and after sampling (g), respectively, and
- V is the volume of air being passed through the device for 30 min (101.6 m^3).

Results

Figure illustrates the mass concentration levels of PM_1, $PM_{2.5}$, and PM_{10} particles during 30 minutes of monitoring using a spatial sampling method with the sensor sampler, showing 8 values with a reading frequency of 4 minutes.

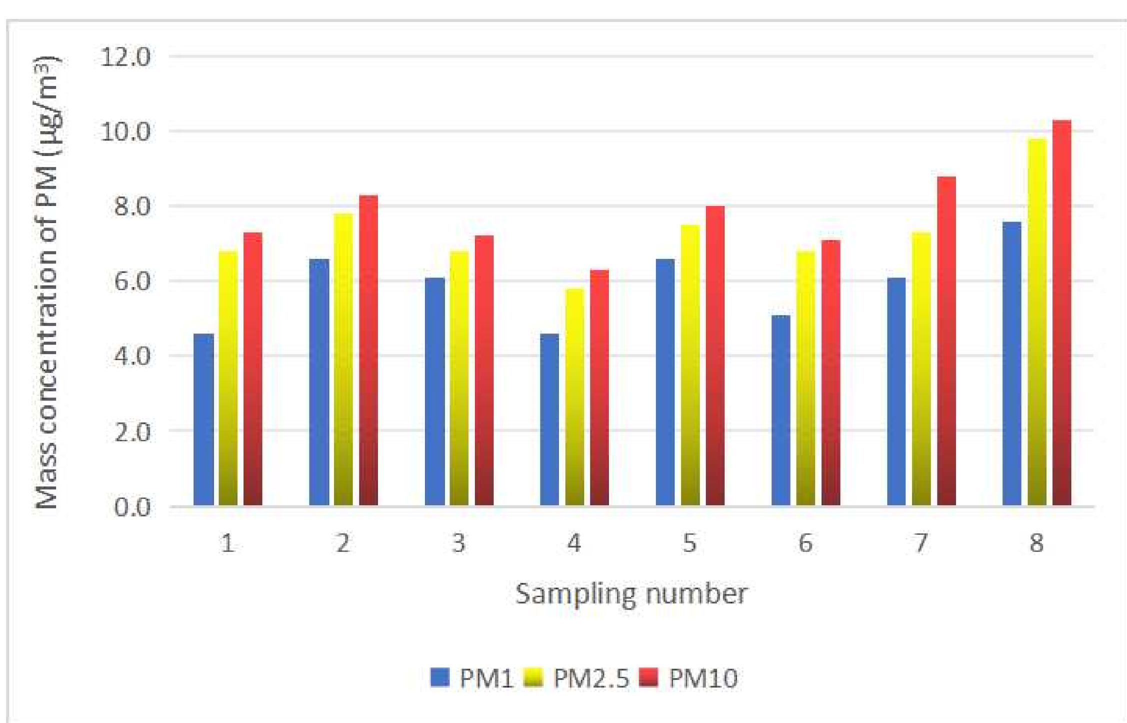

Figure 1

Concentration levels of PM_1, $PM_{2.5}$, and PM_{10} particles detected by spatial sampling with sensor sampler

The spatial sampling method detected concentrations of PM_1 particles in the range of 4.6 to 7.6 μg/m^3 for 30 minutes. The concentrations did not grow exponentially, but an increase of 39.5% increase was observed from the 1st to the 8th sampling.

Over a 30-minute monitoring period using a sensor sampler, $PM_{2.5}$ particle concentrations ranged from 5.8 to 9.8 μg/m^3. There was a 40.8% increase in concentrations from the lowest (detected in the 4th sampling) to the highest value (detected in the 8th sampling).

The mass concentrations of PM_{10} particles during the same 30-minute monitoring period ranged from 6.3 to 10.3 μg/m^3. An increase of 38.8% was observed from the lowest concentration (detected in the 4th sampling) to the highest (detected in the 8th sampling).

After using the personal sampling method, the mass of the filter paper before and after 30 minutes of sampling was 0.0254 and 0.0374 g, respectively. Based on the measured masses and the volume of air passing through the device in 30 min (formula 1), the quantity of PM particles with a diameter smaller than 10 μm was 118.11 μg/m^3.

The results indicate that the mass concentration obtained by personal sampling is 5.6 times higher (an 82% increase) than the cumulative value (21.1 μg/m^3) of PM_1, $PM_{2.5}$, and PM_{10} detectable particles with a sensor sampler.

It's important to note that spatial and personal sampling methods may not always produce comparable results. The measurements using personal samplers tend to demonstrate a higher concentration than spatial ones. This has practical implications for air quality monitoring, as it suggests that personal samplers may be more effective in detecting pollutants in certain situations. Due to their light weight, size, and the fact that they do not require calibration, passive samplers are preferred over active air pump sensor samplers.

Discussion / Conclusion

The results based on spatial sampling indicate that the detected mass concentrations decrease in the following order: $PM_{10} > PM_{2.5} > PM_1$. The concentrations of PM_{10} particles are higher than those of PM_1 particles by 15.3% to 37.0% and more than 4.2% to 17% higher than $PM_{2.5}$ particles. Additionally, concentrations of $PM_{2.5}$ particles are higher than those of PM_1 particles by 10.3% to 32.4%. Also, the cumulative value of PM_1, $PM_{2.5}$, and PM_{10} detectable particles with a sensor sampler was 82% lower than the value detected by the gravimetric analysis after the personal sampler.
In future research, the focus will be on improving methodology and incorporating new methods. For example, using scanning electron microscopy, particles can be characterized by their morphological and size distributions. Drying the filters to a constant mass will eliminate the influence of moisture, leading to more accurate results through gravimetric analysis. Analyzing and optimizing the printing process can enhance the result correlations. Identifying the best position for the devices is crucial for minimizing discrepancies between results obtained from different methods.

ACKNOWLEDGMENTS

This research has been supported by the Ministry of Science, Technological Development and Innovation (Contract No. 451-03-65/2024-03/200156) and the Faculty of Technical Sciences, University of Novi Sad through project "Scientific and Artistic Research Work of Researchers in Teaching and Associate Positions at the Faculty of Technical Sciences, University of Novi Sad" (No. 01-3394/1).