The determination of particulate matter pollution in Kaunas city

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Abstract. Particulate matter pollution is a major environmental issue in a large number of cities causing adverse effects on human health. It is a mixture of solid, liquid or solid and liquid particles suspended in the air, which vary in size and composition. The aim of this study was to determine and evaluate the concentration of particular matter (PM_{10}), which is 10 micrometres or less in diameter, in Kaunas city, Lithuania. The measurements were carried out in 35 sites of Kaunas city. We used a real-time dust monitor (CEL - 712 Pro MicroDust, Casella) with an ambient air pump.

The results of the study showed that the concentration of PM_{10} in high traffic intensity sites (more than 10,000 vehicles/day) ranged from 22.4 to 32.3 μg/m^3 with the average value of 26.3 μg/m^3, while in low traffic intensity sites (less than 3,000 vehicles/day) PM_{10} values varied from 15.3 to 20.8 μg/m^3 with the average value of 17.8 μg/m^3. We compared the concentrations of PM_{10} in areas of multi-storey buildings blocks and individual houses blocks. It was found that the average concentration of PM_{10} was higher in areas with multi-storey buildings 24.2 μg/m^3, while in areas with individual houses - 19.2 μg/m^3.

Keywords: Particulate matter, air pollution, traffic, measurements

1. Introduction

According to the epidemiological studies both long-term and short-term effects of particulate matter are dangerous to human health. Exposure to particulate matter is associated with an increased risk of lung cancer, mortality from heart disease depending on the individual sensitivity and the duration of exposure.

One of the main objectives of European Union environmental policy is to achieve acceptable air quality levels, which have no adverse effects on human health and do not pose a threat to the environment. Road transport and industry are major sources of air pollution in many cities in Europe and the world. Particulate matter is a significant indicator of environmental quality, which emissions pose the greatest risk to human health.

The highest particulate matter smaller than 10μm (PM_{10}) concentrations both in urban and rural areas are observed during the cold season (January - March and October - December). During this period 63-100 % of daily limit values are exceeded. A significant influence on the increase in particulate matter concentrations during cold season has domestic heating with solid fuel. Particulate matter emissions from transport can be emitted directly from vehicle exhaust and can be formed by attrition of brake linings and other vehicle parts (Amato *et al*., 2009). Particulate matter is of various size dust, soot, ash and aerosols. Particulates are divided into organic, inorganic and mixed. Organic particles are naturally occurred by metabolic processes. Inorganic particles are the result of anthropogenic pollution (coarse dusts, aerosols, soot, ash and heavy metals). Mixed particles are compounds of organic and inorganic particles. Particulate matter ability to penetrate into the respiratory system is a main factor having the highest adverse impact on human health (Londahl *et al*., 2006). Some studies have shown that even a very small number of particles entering the lung alveoli may adversely affect the human health. The increase of PM_{10} concentration in 10 μg/m^3 increases the risk of total mortality, mortality due to cardiovascular diseases and respiratory disorders by 0.6 %, 0.9 % and 1.3 %, respectively. A study from Sydney (Australia) assessed a significant relationship between the respiratory disease and dust storms. PM_{10} concentration often reaches and exceeds the value of 400 μg/m^3 during dust storms. No significant difference in cytotoxicity of particulate matter between the dust event days and normal days, when the concentrations are much lower, was determined (Marzouni *et al*., 2016). Particles containing more toxic heavy metals have a relatively high toxicity and are more dangerous to human health. Particles absorb chemical and biological contaminants such as heavy metals (cadmium, lead, mercury) and in the form of fine particulate matter they penetrate into the human body (Cheung *et al*., 2011; Tsyro 2005; Aziakpono O.M., 2013). Long-term effects of particulate matter can lead to diseases, such as atherosclerosis, bronchial asthma, obstructive bronchitis, emphysema, as well as adverse birth outcomes. The particles can cause skin, eye and lung irritation and inflammatory reactions. The most sensitive and vulnerable population groups to the effects of particulate matter are children, elderly suffering from bronchitis, asthma, and chronic illnesses (Guaita *et al*., 2011; Li Z *et al*., 2015). According to the World Health Organization (WHO), air pollution of particulate matter (PM_{10}) has a significant impact on the increased incidence of respiratory and cardiovascular diseases. European Environment Agency reports that air pollution of particulate matter has the greatest impact on human health.

2. Methods

The study was conducted in Kaunas city. The measurements were carried out in spring season in 2016. We selected 35 measurement sites of PM_{10} concentration across the city (Figure 1). Measurement sites were selected in different areas of the city, according to the residential dwelling structure (individual houses or multi-storey houses) and traffic intensity: 1) high traffic intensity streets (> 10,000 vehicles per day); 2) low traffic intensity streets (< 3000 vehicles per day). Two measurements were performed in each site with the duration of 60 minutes and air flow of 16.7 lt/min. The measurements were carried out in 1.5 meter height. Optical method based on light scattering technology was used for the measurements of particulate matter concentration in Kaunas city. A real-time dust monitor (CEL - 712 Pro MicroDust, Casella), particulate matter (PM_{10}) cyclone and Zambelli adjustable air pressure pump were used in this study.

3. Results

3.1. Variation of PM_{10} concentration in Kaunas city districts

There was observed a high variation of PM_{10} concentrations between different districts of the city. Sources of air pollution of PM_{10} have a significant effect on the distribution of particulate matter concentration. The average PM_{10} concentration in ten districts of Kaunas city was 25.8 μg/m^3. The lowest concentrations of PM_{10} were measured in Eiguliai (21.5 μg/m^3) and Žaliakalnis (19.2 μg/m^3) districts. The highest levels of PM_{10} were determined in Vilijampolė (30.7 μg/m^3) and Dainava (30.0 μg/m^3) districts (Figure 2). The lowest PM_{10} concentrations were found in areas with lower traffic intensity and smaller building density. The eastern part of Vilijampolė district is in urban background area compared with more polluted western part, therefore minimum and maximum concentration of PM_{10} differ by 3.4 times.

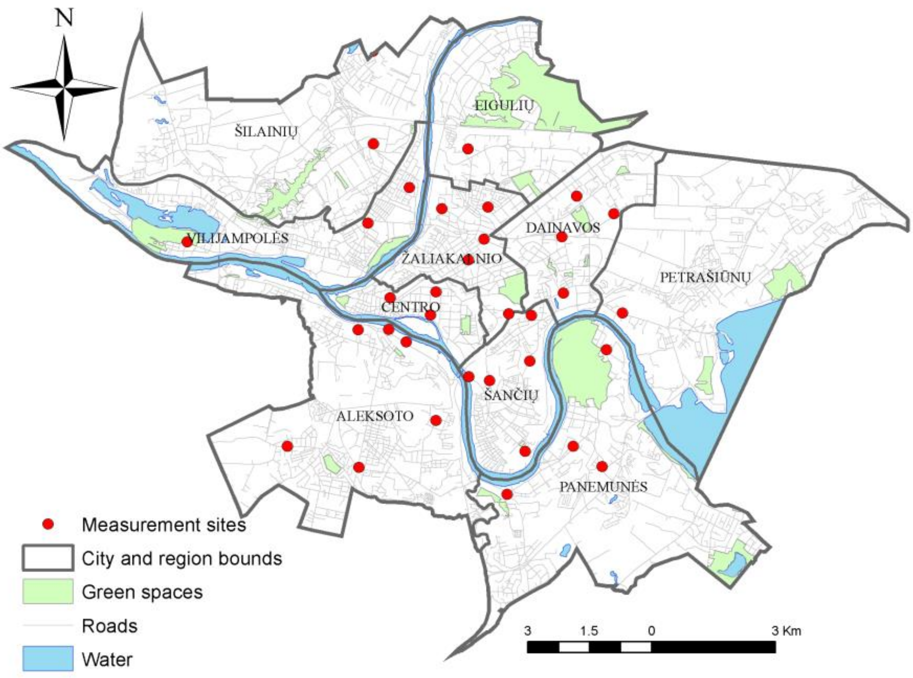

Figure 1. The measurement sites of PM_{10} concentration in Kaunas city

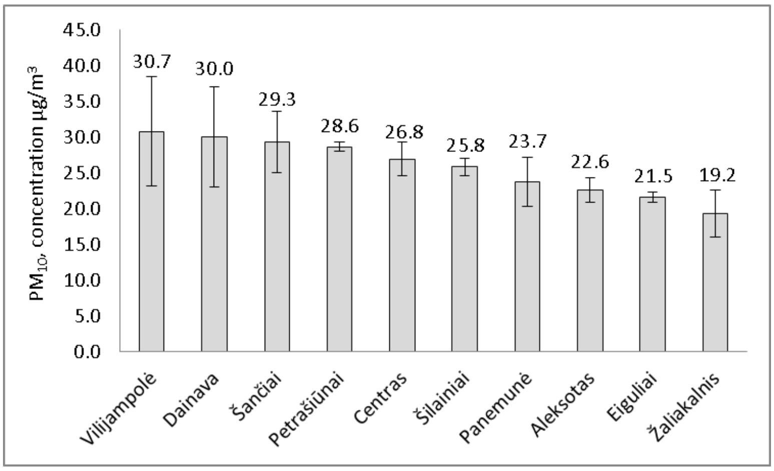

Figure 2. The concentration of PM_{10} in Kaunas city districts

Table 1. The concentration of PM_{10} depending on traffic intensity

Traffic intensity	Mean PM_{10} concentration, µg/m^3	Minimum value, µg/m^3	Maximum value, µg/m^3	Standard error of mean
High traffic intensity (> 10,000 vehicles/day)	26.3	22.4	32.3	1.04
Low traffic intensity (< 3,000 vehicles/day)	17.8	15.3	20.8	0.82

3.2. The concentration of PM_{10} depending on traffic intensity

There was found statistically significant difference between high traffic intensity sites and low traffic intensity sites ($p < 0.05$). The average concentration of PM_{10} in high traffic intensity sites with more than 10,000 vehicles per day was 26.3 µg/m^3, while in low traffic intensity sites with less than 3,000 vehicles per day – 17.8 µg/m^3 (Table 1).

Road transport is a major source of particulate matter pollution. Particulate matter is not only emitted directly from the vehicle exhaust, but also includes particles from wear on road and dust from road surfaces. The risk to human health is higher in urban areas with higher traffic intensity.

The concentration of PM_{10} in high traffic intensity sites (> 10,000 vehicles/day) ranged from 22.4 µg/m^3 to 32.3 µg/m^3. The lowest concentration was measured in Tvirtovės avenue (22.4 µg/m^3) and Taikos Avenue (23,2µg / m^3). The highest concentration was observed in Baršausko Street (32.3 µg/m^3) and Pramonės Street (28.8 µg/m^3).

The concentration of PM_{10} in low traffic intensity sites (< 3,000 vehicles/day) ranged from 15.3 µg/m^3 to 20.8 µg/m^3 (Fig. 3.5). The lowest concentration of PM was determined in Vytautas Street (15.3 µg/m^3) and

Romuvos Street (15.8 µg/m^3). The highest concentration of PM_{10} was measured in Smetona avenue (20.8 µg/m^3) and Vaidotas Street (20.5 µg/m^3).

3.3. The variation of PM_{10} concentration depending on type of residence place

The average PM_{10} concentration in sites of multi-storey houses was higher compared with individual houses sites, 24.2 µg/m^3 and 19.2 µg/m^3, respectively (Table 2). There was no statistically significant difference between these two types of sites ($p > 0.05$). There is higher population density in sites with multi-storey houses compared with individual houses sites, resulting in a greater number of vehicles and traffic intensity. Blocks of multi-storey houses are often located near intensive traffic streets for the convenient access and this also leads to higher PM_{10} concentrations.

Table 2. The concentration of PM_{10} in multi-storey houses and individual houses sites

Site type	Mean PM_{10} concentration, μg/m^3	Minimum value, μg/m^3	Maximum value, μg/m^3	Standard error of mean
Multi-storey houses	24.2	22.0	27.5	1.65
Individual houses	19.2	12.8	23.2	1.94

4. Conclusions

The aim of this study was to determine PM_{10} concentration depending on different traffic intensity and type of residence place in Kaunas city. PM_{10} concentrations differed statistically significant between sites with different traffic intensity, while the difference between measurement sites of multi-storey houses and individual houses was not statistically

significant. The highest PM_{10} values were measured in sites with high traffic intensity and building density, where the amount of green spaces was small – Vilijampolė, Dainava and Šančiai districts. The least polluted districts in Kaunas city were Žaliakalnis, Eiguliai and Aleksotas. The level of PM_{10} was higher in sites with multi-storey houses than in sites with individual houses.

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