Aplinkos tyrimai, inžinerija ir vadyba, 2009. Nr. 3(49), P. 21-28 *ISSN 1392-1649*
Environmental Research, Engineering and Management, 2009. No. 3(49), P. 21-28

Ground-level Ozone Air Pollution in Vilnius City

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(received in July, 2009; accepted in September, 2009)

This study aspires to assess distribution of the ground-level ozone concentration in Vilnius city. A portable Aeroqual series 300 ozone monitor has been used for measuring purposes. Sampling was carried out in Vilnius city during four seasons in the period of 2006-2007.

Results of this study have revealed that annual mean of ground-level ozone concentration in Vilnius city was 30.3 μgm^{-3}. The highest ground-level ozone concentration was in Viršuliškiai district (43.1 μgm^{-3}), the lowest - at a highway of Eišiškės (17.9 μgm^{-3}).

The highest average seasonal concentration was determined in summer (49.6 μgm^{-3}) and the lowest - in autumn (16.9 μgm^{-3}). The ground-level ozone concentration has also a clear diurnal cycle - with higher values in the day-time and notably lower values at night. A minimal ground-level ozone concentration was at 06 am (4.0 μgm^{-3}), the maximal one - at 01 pm (87.0 μgm^{-3}).

During the measurement period the concentration of ground-level ozone in Vilnius has never exceeded the stated value (120.0 μgm^{-3}).

Meteorological conditions are known to influence the formation and dispersion of ground-level ozone. The results of this work show that the ground-level ozone concentration noticeably correlates with the temperature (r=0.554 p= 0.000) and the wind speed (r= -0.785 p= 0.000).

Keywords: *air pollution, ground-level ozone concentration, seasonal and diurnal variation of ground-level ozone concentration, meteorological parameters.*

1. Introduction

Ground-level ozone air pollution is of great concern because of its adverse effects on human health and ecosystems (Poupkou et al. 2008, Cristofanelli & Bonasoni 2009). Ground-level ozone is not emitted directly into the atmosphere. It results from photochemical reactions between oxides of nitrogen (NO_x) and volatile organic compounds (VOCs) in the presence of sunlight (Pudasainee et al. 2006, Vingarzan & Taylor 2003, Clapp & Lenkin 2001, Sillman 1999). Emissions of NO_x are produced primarily in motor vehicle engines, power plants, industrial boilers and at burning of fossil fuels. Main sources of VOCs emissions are motor vehicle emissions, gasoline vapors, chemical solvents (Parra et al. 2009, Westmoreland et al. 2007).

Big concentrations of ground-level ozone become a greater and greater problem each year because it constitutes the main part of photochemical smog. Photochemical ground-level ozone formation depends on a number of natural and anthropogenic factors. Typical summer fair weather conditions are responsible for an increase in ground-level ozone production (Jacob & Winner 2009). The most efficient ozone formation reactions are driven by solar radiation and its precursors (Chudzynski et al. 2001). Meteorological parameters (temperature, wind speed and direction, solar radiation, humidity) highly influence the formation and dispersion of pollutants, the concentration varying widely from region to region, with the time of year, and the time of day (Hunova et al. 2004).

This study intends to assess the ground-level ozone concentration in Vilnius city. To determine the ground-level ozone concentration a portable Aeroqual series 300 ozone monitor has been used. The latter has been of great assistance in estimating the concentration of ground-level ozone in places where there are no permanent measurements: close to streets, in catchment areas, also in resorts, in relatively clean places and suburbs.

2. Methods

Ground-level ozone concentration measurements were carried out in Vilnius city. A portable Aeroqual series 300 ozone monitor was used (Fig. 1).

Fig. 1. *Ground-level ozone concentration measurement Aeroqual series 300 ozone monitor*

An Aeroqual series 300 ozone monitor is constructed to measure low and high ozone levels. Its low concentration ozone head measures the ozone concentration from 0.000 to 0.500 ppm, and a high concentration ozone head measures the ozone concentration from 0.50 to 20.00 ppm. Accuracy of a low concentration ozone head is +/- 0.010 ppm (from 0 to 0.100 ppm); +/- 10% (0.100 to 0.500 ppm), while that of a high concentration ozone head is +/- 10% (from 0.20 to 2.00 ppm); +/- 15% (from 2.00 to 20.00 ppm), the measurement units being either ppm or mg/m^3. The operating temperature range is from -5°C to 50°C, relative humidity limits are 5% and 95%. A sensor type - gas sensitive semiconductor (GSS) is described in (www. ozoneapplications).

Sampling was carried out during four seasons in the period of 2006-2007. 15 measurement places were selected in the whole city (Table 1, Fig. 2). In each measurement place the ground-level ozone concentration was measured three times at noon (at 12 am-01 pm) and in the evening (at 05-06 pm).

Table 1. *Measurement places of the ground-level ozone concentration*

No.	Measurement place	Description of measurement place
1.	Crossroad of Kareivių and Kalvarijų str.	Intensive traffic
2.	Sapieginės pinewood	Recreation zone
3.	Geležinkelio str.	Intensive traffic
4.	City hall	Lots of people and vehicles, valley
5.	Dariaus and Girėno str.	Residential district, many vehicles
6.	New Vilnia	Suburb area, many people, intensive traffic, hill
7.	Cathedral square	Many people and vehicles, valley
8.	Sausio 13 th str.	Residential district, intensive traffic
9.	Supermarket "Akropolis"	Many people, intensive traffic, many vehicles, hill
10.	Savanorių av.	Residential district, intensive traffic, stationary air pollution source „Vilniaus energija"
11.	Sereikiškių park	Recreation zone, valley
12.	Arsenalo str.	Many people , hill
13.	Tauras hill	Residential district, hill
14.	Viršuliškių str.	Residential district, intensive traffic
15.	Eišiškių highway	Suburb area, housing, many vehicles

According to the measured concentration the average seasonal and annual concentration of ground-level ozone in Vilnius city was calculated.

To assess the relation to the meteorological parameters, the correlation coefficients between the ground-level ozone concentration and meteorological variables (temperature and wind speed) were calculated. Meteorological data were obtained from a meteorological station (www.meteo.lt).

3. Results

3.1. Seasonal variation of the ground-level ozone concentration

Study results show that the annual mean ground-level ozone concentration in Vilnius city was 30.3 μgm^{-3}. Distribution of the ground level ozone concentration in the whole city is presented in Fig.3. The highest ground level ozone concentration was in Viršuliškiai district (43.1 μgm^{-3}) and Lazdynai district near Television Tower (42.4 μgm^{-3}). The lowest ground-level ozone concentration was at the highway of Eišiškės (17.9 μgm^{-3}).

Fig. 2. *Measurement places of the ground-level ozone concentration in Vilnius*

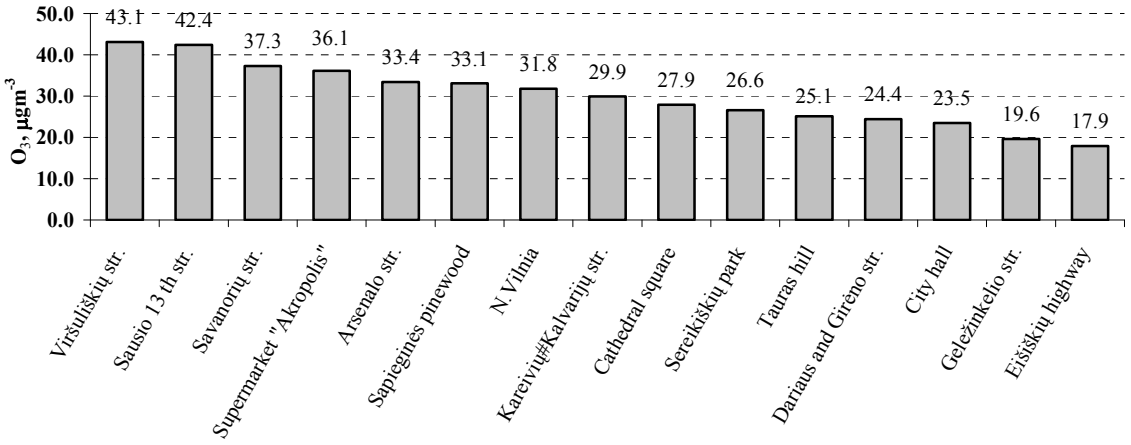


Fig. 3. *Annual mean of the ground-level ozone concentration in Vilnius*

Meteorological conditions and anthropogenic exhaustion made a basic impact on seasonal distribution of the concentration of ground-level ozone. The highest mean seasonal concentration was found in summer (49.6 µgm^{-3}, Fig.4) and the lowest – in autumn (16.9 µgm^{-3}). In winter season the ozone concentration was 23.6 µgm^{-3}, in spring – 31.1 µgm^{-3}.

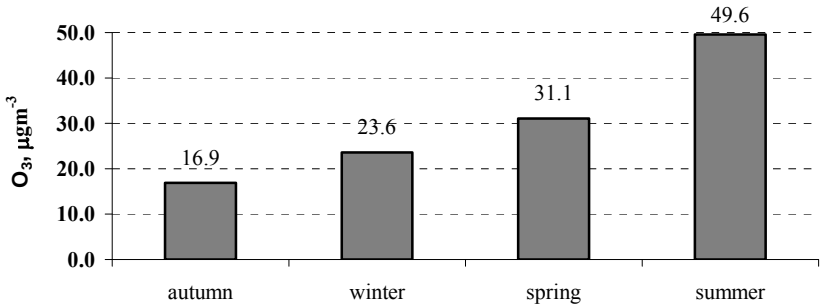


Fig. 4. Seasonal distribution of the ground-level ozone concentration in Vilnius

In autumn season the highest ground-level ozone concentration was determined at Viršuliškių street (25.0 µgm^{-3}, Fig. 5), the lowest at the highway of Eišiškės (8.0 µgm^{-3}).

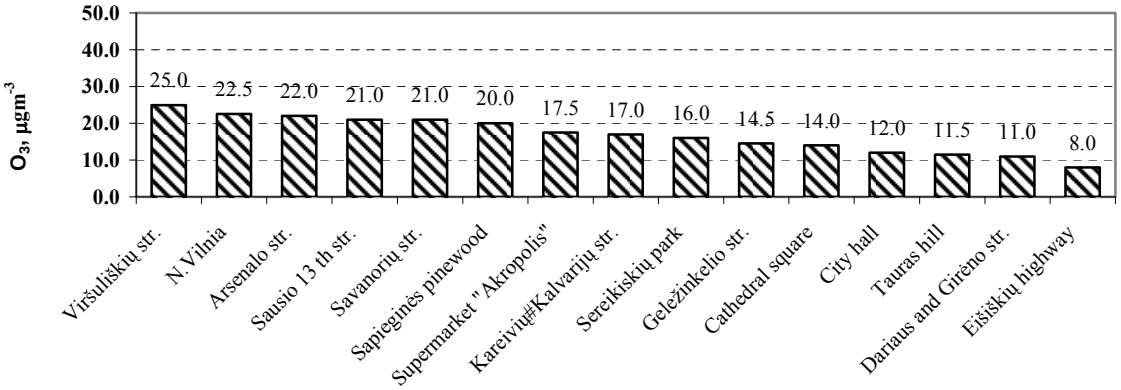


Fig. 5. Ground-level ozone concentration in autumn season in Vilnius

In winter season the highest ground-level ozone concentration was at Sausio 13th str., Savanorių av. and Arsenalo str.(29.5 µgm^{-3}, Fig. 6) the lowest at Dariaus and Girėno str. and Geležinkelio str. (15.5 µgm^{-3}). The situation in autumn and winter seasons was similar.

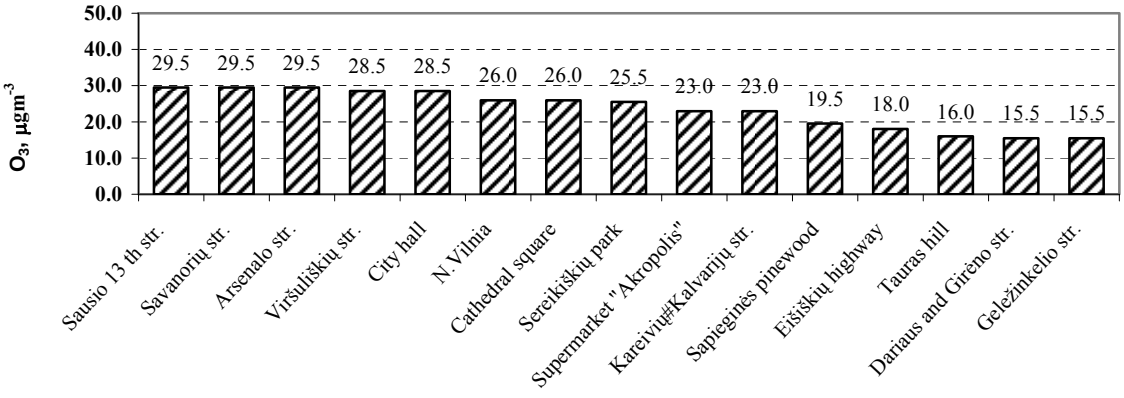


Fig. 6. Ground-level ozone concentration in winter season in Vilnius

In spring season the ground-level ozone concentration was considerably higher than in autumn and winter seasons. The highest ground-level ozone concentration was at supermarket “Akropolis” (47.0 µgm^{-3}, Fig. 7) the lowest - at the highway of Eišiškės (16,. µgm^{-3}).

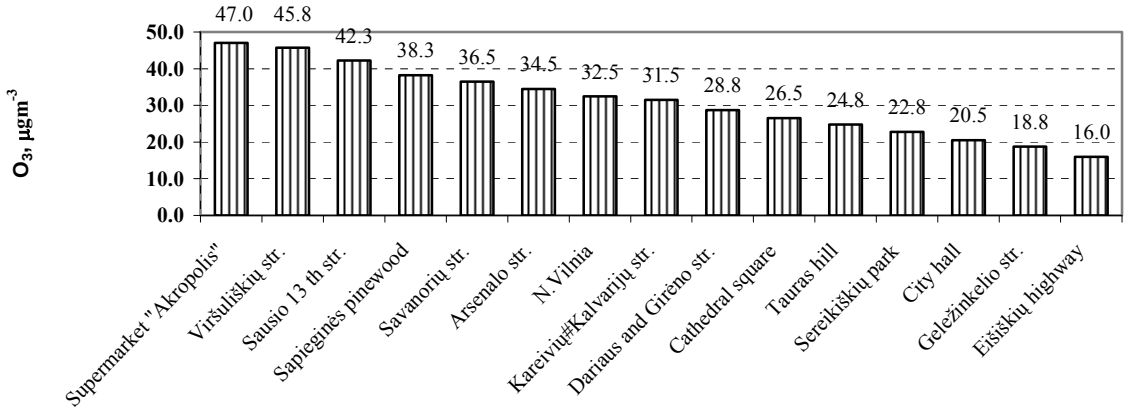


Fig. 7. *Ground-level ozone concentration in spring season in Vilnius*

In summer the ground-level ozone concentration was the highest compared to the other seasons. The highest ground-level ozone concentration was determined at Sausio 13th str.and Viršuliškių str. (77.0 and 73.0 µgm^{-3}, Fig. 8) the lowest at the highway of Eišiškės and Geležinkelio str. (29.5 µgm^{-3}).

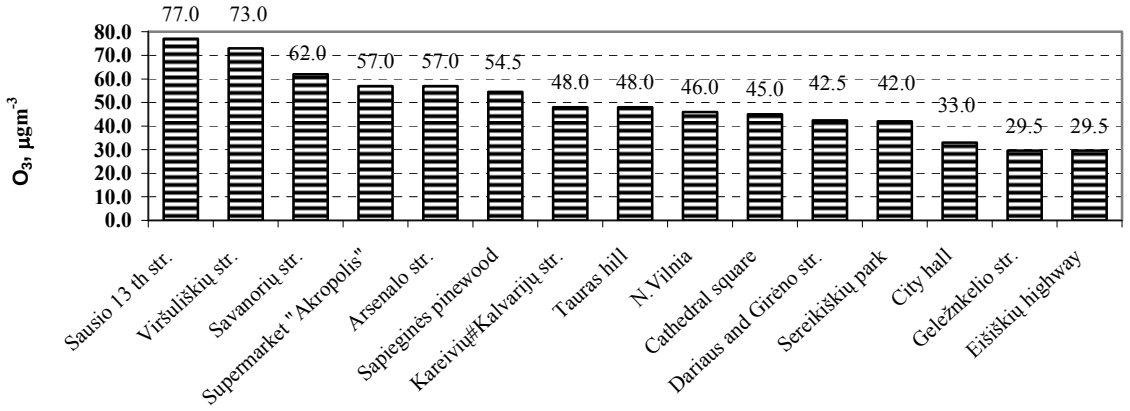


Fig. 8. *Ground-level ozone concentration in summer season in Vilnius*

Variation in the seasonal ground-level ozone concentration in each measurement place is presented in Fig.9. This Figure shows that the highest ground-level ozone concentration were at Sausio 13th Viršuliškių streets, supermarket "Akropolis" and Savanorių avenue in all seasons.

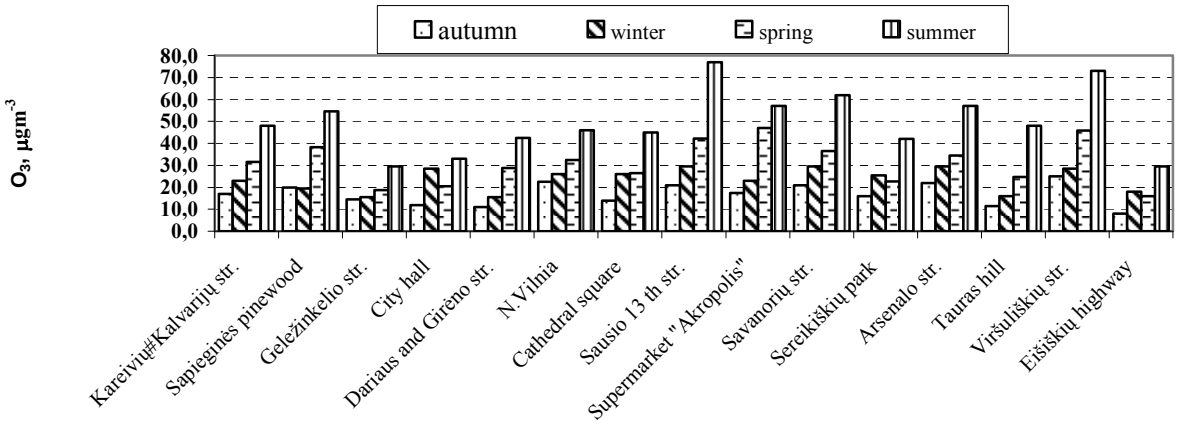


Fig. 9. *Seasonal variation in the ground-level ozone concentration in Vilnius*

3.2. Diurnal variation in the ground-level ozone concentration

To determine diurnal variation in the ground-level ozone concentration, measurements were made each hour from 06 am to 09 pm (Fig. 10).

The minimal ground-level ozone concentration was at 06 am (4.0 μgm^{-3}), the maximal at 01 pm (87.0 μgm^{-3}). Fig. 10 shows that two peaks of the ground-level ozone concentration are clearly expressed. The first peak of the ground-level ozone concentration was formed from 12 am to 01 pm, the second - at 05 pm.

In the measurement period the concentration of ground-level ozone had not exceeded the stated value (120.0 μgm^{-3}).

3.3. Ground-level ozone concentration relationship with meteorological parameters

To assess the relation with meteorological parameters the correlation coefficients between the ground-level ozone concentration and meteorological variables (temperature and wind speed) have been calculated.

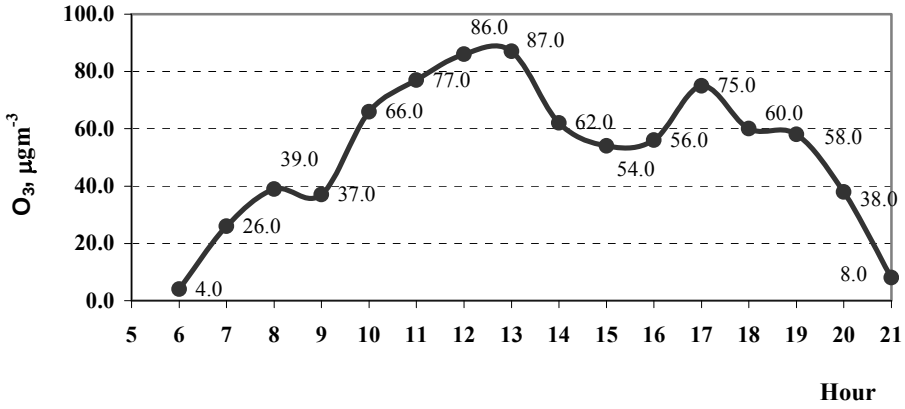
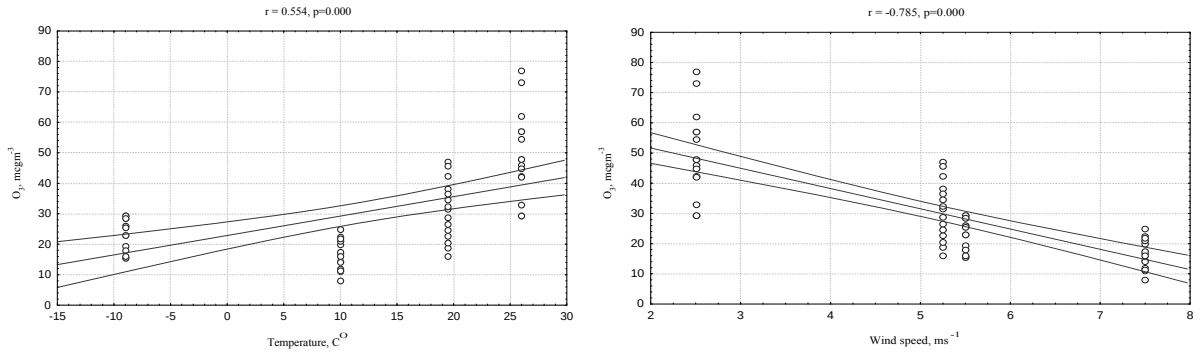


Fig. 10. Diurnal variation in the ground-level ozone concentration



a) b)

Fig. 11. Correlation between the ground-level ozone concentration and meteorological variables: a) correlation between the ground-level ozone concentration and temperature; b) correlation between the ground-level ozone concentration and wind speed

Results of this research have revealed that the ground-level ozone concentration is markedly correlated with the temperature (r= 0.554 p= 0.000, Fig. 11 a). The ground-level ozone concentration is also strongly correlated with the wind speed (r= -0.785 p= 0.000, Fig. 11 b).

4. Conclusions

Ground-level ozone is known as a product of complex photochemical processes involving nitrogen oxides (NO_x) and volatile organic compounds (VOCs) as main precursors. Main sources of nitrogen oxides and volatile organic compounds in urban areas are transport and industrial activities (Cristofanelli & Bonasoni, 2009). In polluted urban areas high ground-level ozone levels are frequently reported. Results of this study show the same situation i.e. that the highest ground-level ozone concentration is in urban residential districts close to supermarkets (with intensive traffic at a supermarket „Akropolis) and around the stationary pollution sources (“Vilniaus

energija“, Fig. 2). Similar results are reported by other authors (Tressol et al. 2008, Pace et al. 2005).

The ground-level ozone concentration is characterized by the specific seasonal variation. The highest ground-level ozone concentration is spring and summer seasons (Jacob and Winner, 2009). In this case the highest seasonal ground-level ozone concentration was determined during the summer season, too (49,. μgm^{-3}, Fig. 3). These results are similar to those of other authors (Sanz et al. 2007).

The ground-level ozone concentration has also a clear diurnal cycle, with higher values in the day-time and notably lower values at night (Millan et al. 2000). This study has also revealed that at the day-time the ground-level ozone concentration values were considerably higher than at an early morning or evening (Fig. 9). Lee et al. also reported that ozone concentration gradually increased after the sunrise and decreased in the evening (Lee et al. 2008).

The ground-level ozone concentration depends on meteorological conditions (temperature, solar radiation, wind speed and direction). Olszyna et al. have demonstrated that ozone concentration correlate reasonably well with the temperature (Olszyna et al. 1997). We have also found a significant positive correlation between the ground-level ozone concentration and temperature (r= 0.554 p= 0.000, Fig. 11 a). The other authors have reported an inverse correlation between the wind speed and ozone concentration (Luria et al. 2008). Our results present the same relationship (r= -0.785 p= 0.000, Fig. 11 b).

Acknowledgement

Many thanks to Laura Buce who assisted in the field sampling and otherwise contributed to this work.

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www.ozoneapplications.com/ozone monitors

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Oro tarša priežemio ozonu Vilniaus mieste

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(gauta 2009 m. liepos mėn.; atiduota spaudai 2009 m. rugsėjo mėn.)

Darbo tikslas – nustatyti oro taršą priežemio ozonu Vilniaus mieste. Priežemio ozono koncentracija buvo matuojama naudojant „Aeroqual Series 300" ozono kontrolės prietaisą. 2006 – 2007 m. Vilniaus mieste buvo atlikti sezoniniai priežemio ozono koncentracijos matavimo tyrimai. Gauti matavimų rezultatai buvo naudojami apskaičiuoti vidutinę sezoninę ir vidutinę metinę priežemio ozono koncentraciją Vilniaus mieste.

Tyrimų rezultatai parodė, kad vidutinė metinė priežemio ozono koncentracija Vilniuje buvo 30,3 μgm^{-3}. Didžiausia vidutinė metinė priežemio ozono koncentracija nustatyta Viršuliškių g. (43,1 $\mu g/m^3$), mažiausia – Naujininkuose prie Eišiškių plento (17,9 $\mu g/m^3$).

Vidutinė sezoninė priežemio ozono koncentracija svyravo nuo 16,9 μgm^{-3} rudenį iki 49,6 μgm^{-3} vasarą. Priežemio ozono koncentracija pasižymi aiškia kaita paros metu, didesnės reikšmės fiksuojamos dieną, mažesnės – naktį. Mažiausia priežemio ozono koncnetracija buvo nustatyta 6:00 val. ryto (4,0 μgm^{-3}), didžiausia – 13:00 val. dienos (87,0 μgm^{-3}).

Priežemio ozono koncnetracija nei vienoje tyrimo vietoje neviršijo nustatytos ribinės vertės (120,0 μgm^{-3}).

Žinoma, kad meteorologinės sąlygos turi įtakos ozono susidarymui ir sklaidai. Gauti rezultatai parodė, kad yra ryšys tarp priežemio ozono koncentracijos ir temperatūros ($r = 0,554$, $p = 0,000$) bei tarp priežemio ozono koncentracijos ir vėjo greičio ($r = -0,785$ $p = 0,000$).