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Measurement of nitrogen dioxide concentration in cold and warm seasons using a passive sampling method

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The aim of the present study was to assess distribution of nitrogen dioxide concentration in Kaunas city during cold and warm seasons. A passive sampling method was used. Nitrogen dioxide concentration was measured at 39 sampling sites in Kaunas city. The study was performed in 2010–2011. The study results showed that mean of nitrogen dioxide concentration in Kaunas city was 12.0 μg/m^3. Nitrogen dioxide concentration in cold season (winter) was 18.2 μg/m^3, in warm season (summer) 5.7 μg/m^3. The highest nitrogen dioxide concentration was obtained near street site (14.9 μg/m^3), the lowest – near regional background site (9.4 μg/m^3) and near urban background site it was 11.4 μg/m^3.

The results of the study were introduced to the ESRI Geographic Information System software ArcGIS and the extension Geostatistical Analyst was used to obtain maps of distribution of nitrogen dioxide concentration.

The lowest nitrogen dioxide pollution area was in districts which are located in the periphery of the city. The highest concentration of nitrogen dioxide was in Centras, Žaliakalnis, Šančiai, Kalniečiai, Sargėnai. It was caused by intensive traffic and unfavourable geographical position. In these districts there are more busy roads and more buildings. Centras district is located in a valley; there are unfavourable conditions for pollution dispersion.

Key words: nitrogen dioxide concentration, human health, interpolation method

INTRODUCTION

Air quality receives considerable attention from the general public and also in the political arena. This is because air pollution can cause a wide variety of health and / or environmental problems (Velders, Diederen, 2009; Pandeya et al., 2008). It is necessary to improve air quality in urban areas to protect human health and to avoid other environmental problems (Bigi, Harrison, 2010; Anttila, Tuovinen, 2010).

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Major air pollutants are produced by fuel combustion and industry processes. Road traffic is a very important source of air pollution too. Obvious products of these processes are nitrogen oxides (NOx = NO + NO_2). Nitrogen oxides are an important group of air pollutants to study because they play an important role in the chemistry of the troposphere: they condition the concentration of the OH radical, the production of acids, and it was found that nitrogen oxides are a major contributor of formation of photochemical smog and ozone in urban areas. Nitrogen oxides also participate in a chain reaction removing ozone from stratosphere. Consequently, increased ultraviolet radiation quantity reaches earth's surface (Jarquin-Lopez et al., 2009; Parra et al., 2009; Filella, Penuelas, 2006).

Large amounts of nitrogen oxides are emitted from mobile and stationary sources (Tsai et al., 2006). Motor vehicles can be the most important source of nitrogen oxides, especially in areas with few industrial sources (Tran et al., 2000).

Nitrogen dioxide (NO_2), a well-known traffic-related pollutant, is currently the biggest single cause of air quality problems in urban areas (Westmoreland et al., 2007). However, nitrogen dioxide is far more harmful with regard to toxicity than nitrogen oxide and it is a good predictor for traffic exposure (Soltic, Weilenmann, 2003; Gilbert et al., 2003).

Nitrogen dioxide pollution is higher along busy roads compared to background locations. Air pollution in city centres and districts near highways is related to traffic density of the highway, distance of the measuring site to the highway (Bogo et al., 2001; Carslow, 2005; Beckerman et al., 2008).

The aim of the present study was to assess nitrogen dioxide concentration in Kaunas city during cold and warm seasons.

MATERIALS AND METHODS

Annual and seasonal concentration of NO_2 were measured in Kaunas city (longitude 54°54' E, latitude 23°54' N), located in the centre of Lithuania, 78 meters above the sea level. The city lies in the intersection of the main roads and transport streams, in the valley of the two longest rivers of Lithuania, Nemunas and Neris. Kaunas is the second biggest city (after capital Vilnius) in Lithuania with the population around 360 000.

For determination of nitrogen dioxide concentration we used a passive sampling method and triethanolamine as an absorbent. Passive sampling method is often used for air quality monitoring purposes in remote areas. Passive samplers are simple, inexpensive, no power or pump required, and suitable for simultaneous and multipoint measurements of air pollutant. The passive sampler has an internal diameter of 25 mm and a depth of 10 mm. A disc of Whatman 1chr filter paper impregnated with triethanolamine aqueous solution is used as a collecting element. The inside of the passive sampler is protected against wind and dust deposition by a wind screen made of a polypropylene fibre material. Impregnated samplers were suspended 2.5–3.0 m above the ground level. After exposure the collecting element was treated with 2 ml of deionised water for 10 min. The extract was mixed with 2 ml of Saltzman reagent and left for 15 min. The content of nitrite ions is determined spectrophotometrically at the wavelength of 540 nm (Krochmal, Kalina, 1997; Gražulevičienė, Laurinavičienė, 2001).

Nitrogen dioxide measurements were carried out in 39 sites of Kaunas city in cold (winter) and warm (summer) seasons during 2010–2011 (Fig. 1). We used mean of 2 weeks measurements of nitrogen dioxide concentration to characterize mean of nitrogen dioxide in cold and warm seasons.

According to traffic intensity three site types were distinguished. First site type: regional background (<3 000 veh/d); second site type: urban background (3 000–10 000 veh/d); third site type: street (>10 000 veh/d).

Using the ESRI Geographic Information System software ArcGIS and the extension Geostatistical Analyst, maps of nitrogen dio-

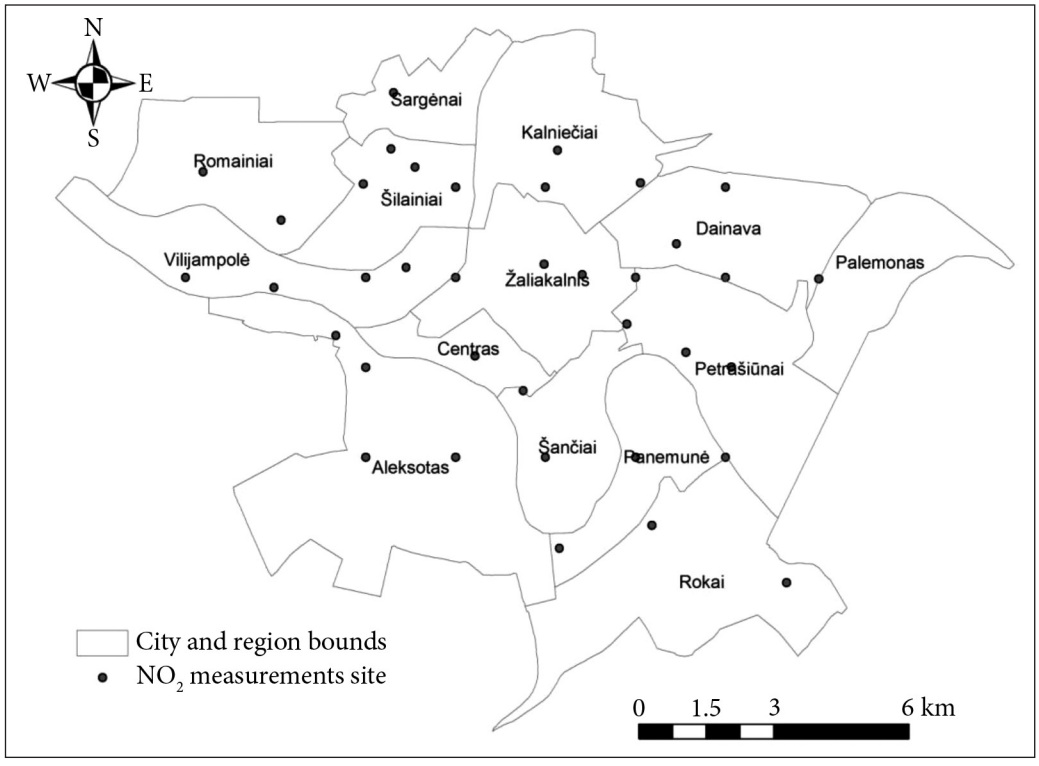

Fig. 1. Nitrogen dioxide concentration measurements sites

xide concentration distribution in Kaunas were plotted. To get a better view of the distribution of pollutant concentration, the obtained values were spatially interpolated using the Inverse Distance Weighted (IDW) method. Five areas of nitrogen dioxide pollution were classified.

Standard errors of mean were calculated using Statistica program software.

RESULTS AND DISCUSSION

Nitrogen dioxide concentration in cold and warm seasons

The average nitrogen dioxide concentration in Kaunas city was 12.0 μg/m^3 for the study period. Nitrogen dioxide concentration in cold season (winter) was 18.2 μg/m^3, in warm season (summer) 5.7 μg/m^3 (Fig. 2). Such results might

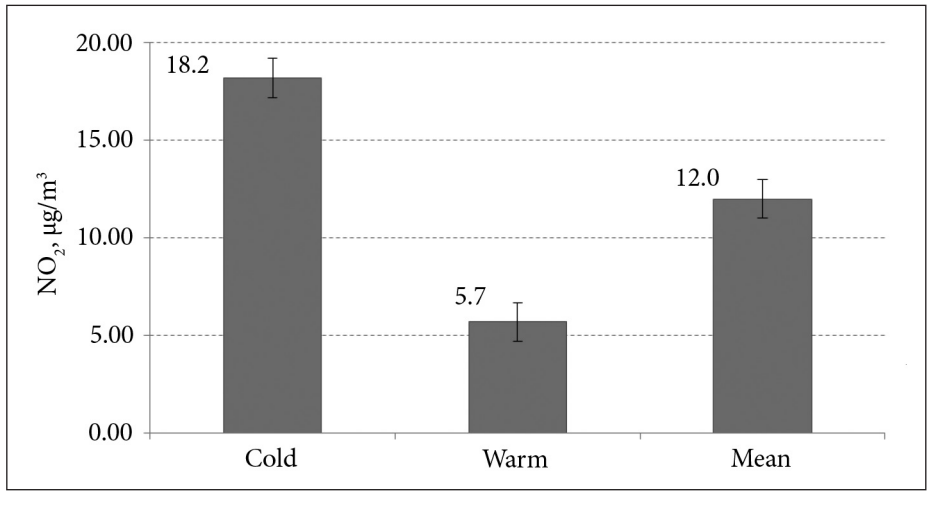

Fig. 2. Nitrogen dioxide concentration in Kaunas city

be determined by private household heating during cold season.

The highest nitrogen dioxide concentration measured with passive samplers was obtained near street site (14.9 μg/m³), the lowest – near regional background site (9.4 μg/m³) and near urban background site it was 11.4 μg/m³ (Fig. 3).

Nitrogen dioxide concentration in cold season was about 3 times higher than in warm season. This tendency was observed in all sites types. In cold season nitrogen dioxide concentration in regional background site was 15.3 μg/m³ in urban background site 17.4 μg/m³ and 22.3 μg/m³ in street site. Nitrogen dioxide concentration in warm season was 4.2 μg/m³ in regional background; 5.4 μg/m³, in urban background and 7.5 μg/m³ in street site.

Distribution of nitrogen dioxide concentration

Using Arc GIS software maps of nitrogen dioxide dispersion in Kaunas city in cold and warm seasons were plotted (Figs. 4 and 5). An Inverse Distance Weighted (IDW) technique was used creating a map. Five areas of nitrogen dioxide pollution were classified. The air pollution was higher during the cold season. The maximum NO_2 concentration was up to 30.0 μg/m³ in cold season. NO_2 concentration ranged from 4.0 to 14.0 μg/m³ in warm season.

The lowest nitrogen dioxide pollution area was in districts which are located in the periphery of the city (Fig. 4). The highest concentration of nitrogen dioxide was in Centras, Žaliakalnis, Šančiai, Kalniečiai, Sargėnai. It is caused by intensive traffic and unfavourable geographical position. In these districts there are more busy roads and more buildings. Centras district is located in a valley; there are unfavourable conditions for pollution dispersion. Similar results were reported by other authors (Costabile et al., 2006; Jo, Park, 2005). The highest concentration of nitrogen dioxide was measured at high-traffic streets, followed by industrial and downtown locations.

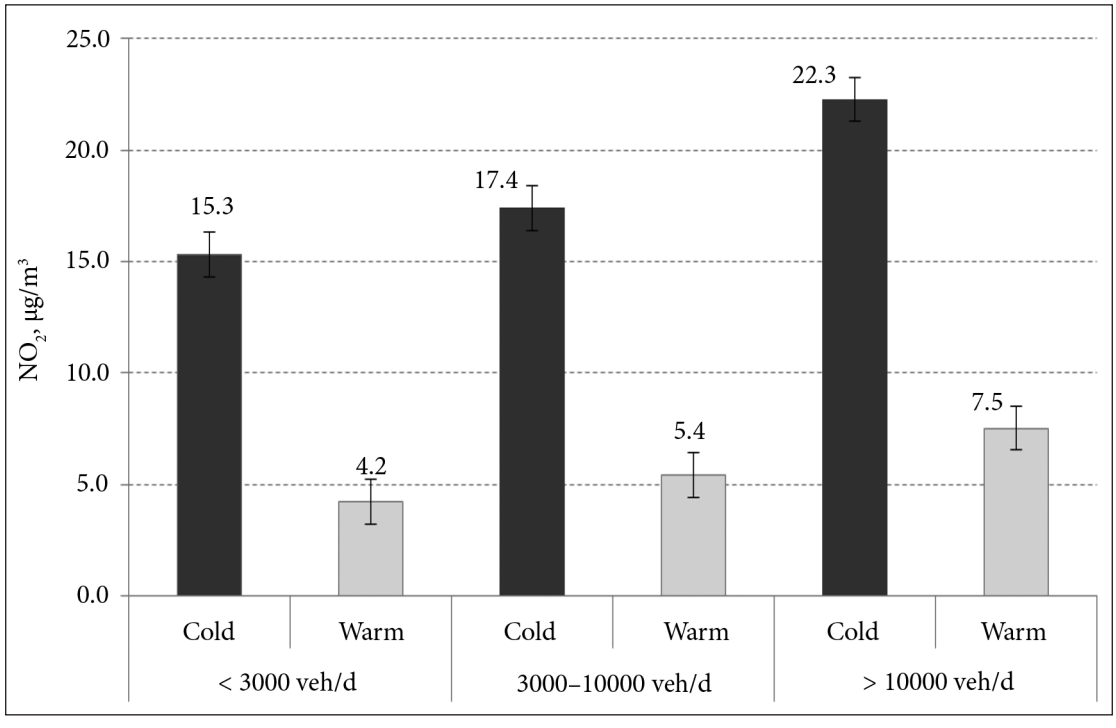

Fig. 3. Nitrogen dioxide concentration in different sites types during cold and warm seasons

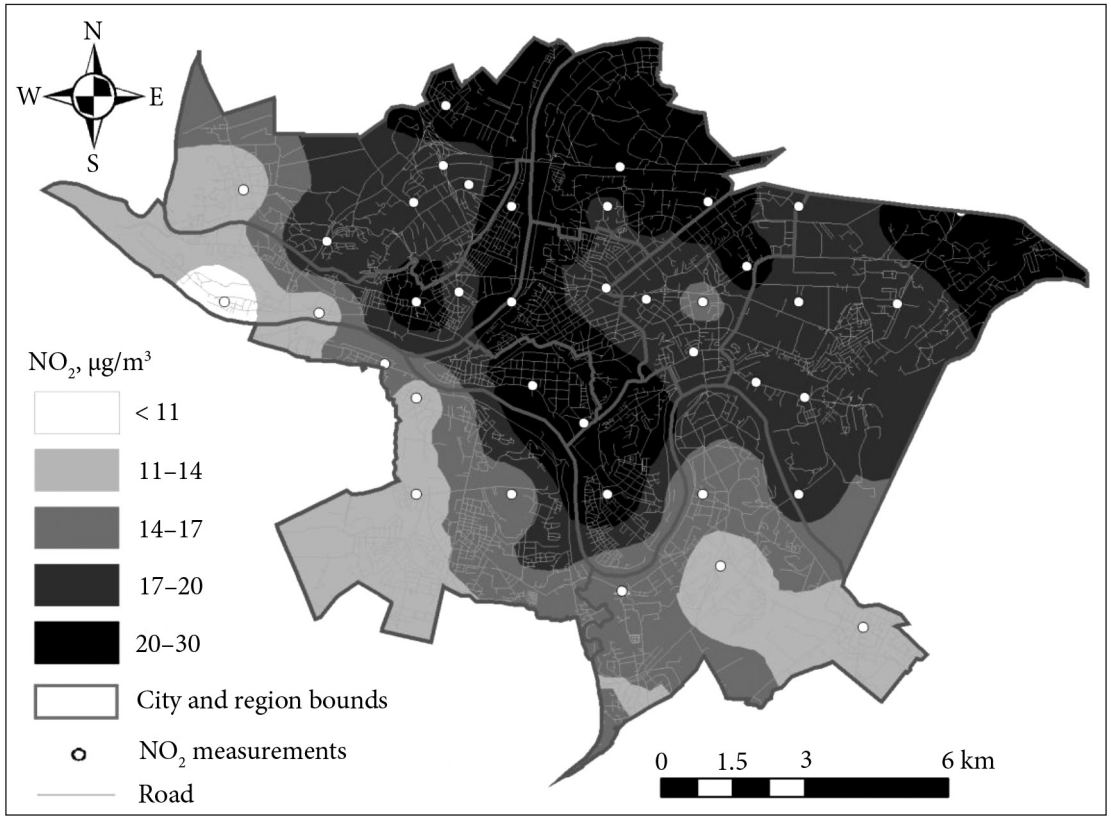

Fig. 4. Distribution of nitrogen dioxide pollution in Kaunas city in cold season

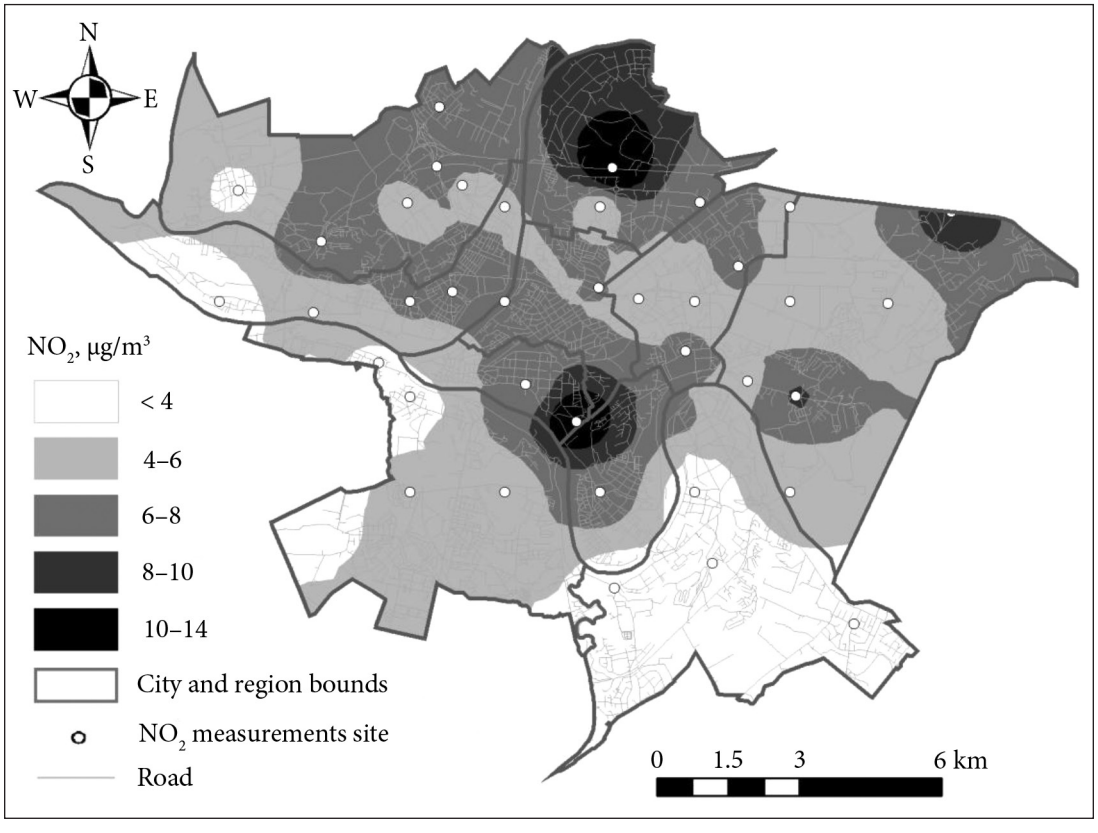

Fig. 5. Distribution of nitrogen dioxide pollution in Kaunas city in warm season

CONCLUSIONS

1. The average nitrogen dioxide concentration in Kaunas city was 12.0 μg/m^3 for the study period. Nitrogen dioxide concentration in cold season (winter) was 18.2 μg/m^3, in warm season (summer) – 5.7 μg/m^3.

2. The highest concentration of NO_2 measured with passive samplers was obtained near street site (14.9 μg/m^3), while the lowest – near regional background site (9.4 μg/m^3).

3. Interpolated results showed that the maximum NO2 concentration was up to 30.0 μg/m^3 in cold season. NO2 concentration ranged from 4.0 to 14.0 μg/m^3 in warm season.

4. The lowest nitrogen dioxide pollution area was in districts which are located in the periphery of the city. The highest concentration of nitrogen dioxide was in Centras, Žaliakalnis, Šančiai, Kalniečiai, Sargėnai.

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AZOTO DIOKSIDO KONCENTRACIJOS MATAVIMAI PASYVAUS KAUPIMO METODU ŠALTUOJU IR ŠILTUOJU SEZONAIS

Santrauka

Darbo tikslas – nustatyti azoto dioksido koncentraciją šaltuoju ir šiltuoju sezonu naudojant pasyvaus kaupimo metodą. Tyrimai buvo atlikti Kauno mieste 2010–2011 metais šaltuoju ir šiltuoju sezonais. Azoto dioksido koncentracija buvo nustatoma pasyviais kaupikliais, kurie buvo eksponuoti 39 Kauno miesto vietose. Bandiniai buvo eksponuojami 14 dienų. Tyrimų rezultatai rodo, kad vidutinė azoto dioksido koncentracija Kauno mieste buvo 12,0 μg/m^3: šaltuoju sezonu (žiemą) azoto dioksido koncentracija siekė 18,2 μg/m^3, šiltuoju (vasarą) – 5,7 μg/m^3. Aukščiausia azoto dioksido koncentracija buvo šalia intensyvių transporto srautų zonos (14,9 μg/m^3), žemiausia – šalia mažo intensyvumo transporto srautų zonos (9,4 μg/m^3); šalia vidutinio intensyvumo transporto srautų zonos azoto dioksido koncentracija siekė 11,4 μg/m^3.

Naudojant Arc GIS programinę įrangą ir atlikus azoto dioksido taršos interpoliaciją buvo sudaryti azoto dioksido taršos sklaidos žemėlapiai, kuriuose išskirtos penkios taršos zonos.

Mažiausia azoto dioksido taršos zona nustatyta rajonuose, kurie išsidėstę miesto pakraštyje. Didžiausia azoto dioksido tarša užfiksuota Centro, Žaliakalnio, Šančių, Kalniečių ir Sargėnų rajonuose – tokiai situacijai įtakos galėjo turėti tai, kad šiuose rajonuose vyrauja intensyvūs transporto srautai, taip pat nepalanki jų geografinė padėtis. Centro rajonas yra išsidėstęs slėnyje, jame daug siaurų gatvių ir pastatų, o tai pablogina teršalų sklaidą.

Raktažodžiai: azoto dioksido koncentracija, žmonių sveikata, interpoliacijos metodas