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Original article

Nickel and chromium concentrations in Italian ryegrass exposed to ambient air in urban, suburban and rural areas

Anna Budka [a,*], Klaudia Borowiak [b], Dariusz Kayzer [a], Anetta Hanć [c], Janina Zbierska [b], Danuta Barałkiewicz [c], Agnieszka Wolna-Maruwka [d], Marta Lisiak [b]

[a] Department of Mathematical and Statistical Methods, Poznan University of Life Sciences, Wojska Polskiego 28, 60-637 Poznan, Poland
[b] Department of Ecology and Environmental Protection, Poznan University of Life Sciences, Piątkowska 94C, 60-649 Poznan, Poland
[c] Department of Trace Element Analysis by Spectroscopy Method, Adam Mickiewicz University, Umultowska 89 P, 61-614 Poznan, Poland
[d] Department of General and Environmental Microbiology Poznan University of Life Sciences, Szydłowska 50, 60-656 Poznan, Poland

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A B S T R A C T

Nickel and chromium accumulation from the air in Italian ryegrass (*Lolium multiflorum* L.) is presented in this paper. Plants were exposed at five sites varying in environmental characteristics. Four one-month series were performed during the 2011 and 2012 growing seasons. Chromium and nickel concentrations in leaves were analysed after every series and compared to control plants. The lowest levels of both trace elements were found in samples collected from control sites. Canonical variate analysis revealed differences among sites and the control, and on this basis we found the lowest values in the suburban area. The lowest trace element concentrations of Cr in leaves were observed at the beginning of the growing season and the highest from mid-June to mid-August, while Ni concentrations varied among series and years. Accumulation of both trace elements in Italian ryegrass was at a comparable level or lower than results obtained in similar investigations in other countries. Moreover, the higher concentrations of both elements were probably connected with increased traffic and elevated small industry activities in urban and rural areas.

1. Introduction

Trace elements in ambient air can come from natural or anthropogenic sources. Natural sources include volcanic eruptions, space dust, forest fires and evaporation from oceans. Anthropogenic sources however are more significant, and include industry, fertilizer production, petrochemistry power plants, transport and households (Zechmeister et al., 2003). Heavy metals occur mainly as aerosols and together with particulate matter. Particles emitted during combustion processes are mainly 0.1–0.5 μm in diameter (Fowler, 2004). Particulate matter is a mixture of small particles in the air, characterized by inhomogeneity, and the toxicity to the environment and humans is determined by its features, such as the size, number and surface area of particles, but also by their chemical composition. Trace elements can be constituents of PM 2.5 and PM 10 and may also play an important role concerning toxicity and ecotoxicity of particulate matter (Götschi et al., 2005; Klumpp and Ro-Poulsen, 2010). The most important trace elements monitored by institutions are arsenic, cadmium, lead, nickel and chromium (EEA Report, 2014).

Chromium is a rather rare element in the air in natural conditions. Its concentration in the air varies from 0.005 ng m^{-3} at the South Pole to 1000 ng m^{-3} in the city areas of the USA (Cieślak-Golonka and Bębenek, 1998). This element is mainly used in the metallurgical and chemical industries. These branches of industry have an important effect on air pollution (Kabata-Pendias and Pendias, 1999).

Nickel is also used in the galvanizing industry (Kabata-Pendias and Pendias, 1999). Alloys with copper are used for coin production and other utility products. This element is also very important for cadmium–nickel batteries (Bielański, 2002). Natural sources of nickel in the air are mainly soil dust, forest fires and sea salt. Anthropogenic sources are connected with combustion of fossil fuels and municipal waste. This element usually occurs as particles

* Corresponding author. Tel./fax: +48 61 848 7140.
E-mail address: budka@up.poznan.pl (A. Budka).

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with 0.1–0.2 μm diameter and combined with sulphureous, nitrates and chlorides. Average residence time in the atmosphere is assessed as 5–8 days (Kabata-Pendias and Pendias, 1999).

Air quality can be monitored by direct air pollution concentration measurements and plant indicators and assessed by using mathematical models. In the case of physical and chemical methods the results can be used for evaluation of risk. However, these data can only provide information about the potential effect on the environment; they cannot inform us about the real frequency and quality of this effect (Nobel, 2002). Biomonitoring can fill this gap. This method uses living organisms or their parts to provide quantitative information about environment quality (Ataabadi et al., 2010). Some particular species of higher plants are used as bioindicators in highly polluted areas, where lower plants cannot survive. These plants have revealed high potential for accumulation of trace elements occurring in aerosols in ambient air, and can also absorb elements from the soil (Mulgrew and Williams, 2000). Italian ryegrass (*Lolium multiflorum*) is becoming the most popular bioindicator plant for heavy metals in the air (Caggiano et al., 2001; De Temmerman et al., 2007; Franzaring et al., 2007; Klumpp and Ro-Poulsen, 2010). This annual plant species is characterized by high growth during the growing season, and hence has a high potential for application to absorb trace elements from the air (Hannaway et al., 1999). It is also widely used in biomonitoring programmes across Europe (Klumpp et al., 2009). The aims of the present study were as follows: (i) to compare the results of levels of nickel and chromium in ambient air in the city and surroundings areas using Italian ryegrass in Polish conditions in relation to other countries with similar investigation results and reference values; (ii) to determine if there were differences among exposure sites and series and in comparison to the control with application of canonical variate analysis.

2. Material and methods

2.1. Experimental design

The experiment was carried out in 2011 and 2012 during the growing season. The investigations schedule was provided according to the standardized method of the German Engineering Association (VDI 3957). Similar amounts of seeds (0.98 g) of *L. multiflorum* ssp. italicum var. 'Lema' were sown in 5 L pots filled with a standard mixture of soil and peat. Plants were watered with deionized water to avoid the additional application of heavy metals. Moreover, plants were fertilized (according to their needs) while growing in the greenhouse; the last fertilizing was at least one day before transport to the exposure site. Every time that plants reached 8–10 cm in height they were cut to 4 cm, and also one day before each exposure series. After six weeks of cultivation in the greenhouse conditions, pots with plants were transferred to exposure sites. Five sites were selected for the present investigations and were located in Poznan city and surrounding areas. Sites varied in air quality characteristics – there were two city sites (site no. 1 and 2), one site in a suburban area (no. 4), one site representing an agriculture area (no. 5) and one site located in a landscape park (no. 3) (Fig. 1). Plants were exposed for 28 ± 1 days. Four exposure series were carried out during the growing season in the following periods: 2011 – 16.05–12.06, 13.06–10.07, 11.07–07.08, 08.08–04.09; and in 2012 – 14.05–10.06, 11.06–08.07, 09.07–05.08, 06.08–02.09. Five pots with plants were exposed at

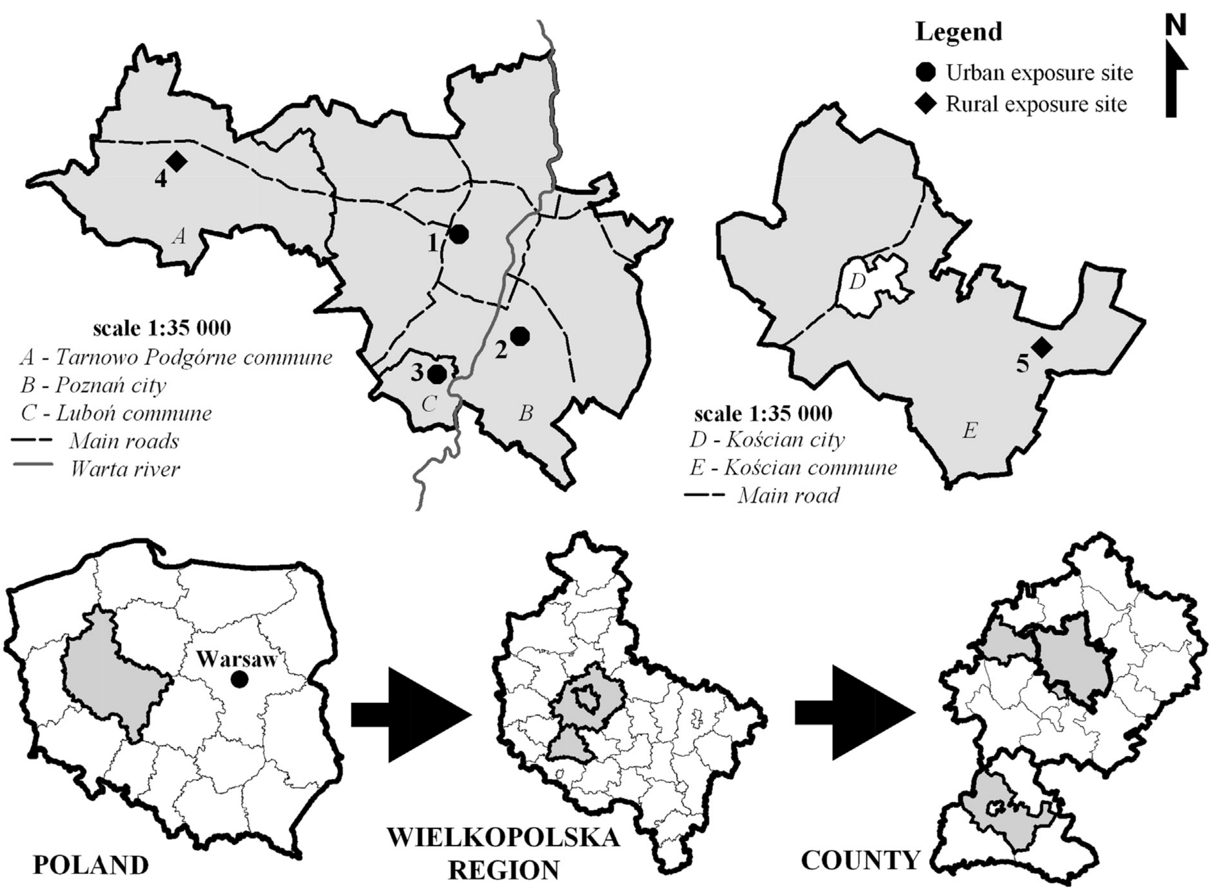

Fig. 1. Exposure sites location in Poznan city and surrounding areas (1 and 2 – urban sites, 3 – suburban site, 4 – rural site, 5 – agro-ecological park).