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Repellency as a criterion for urban topsoil quality assessment

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Urban soil quality standards are very complex because of a lot of chemical, physical and biological indicators. That is why soil pollution by heavy metals prevails in the topsoil quality evaluation schemes. Soil repellence and specific surface area were examined in this study as physical indicators of urban soil quality that can be detected in composite topsoil samples, common for sanitary soil quality evaluation. It was discovered that more repellent topsoil with smaller specific surface area is typical to the topsoil from industrial and traffic environs and centrum of Šiauliai and Joniškis towns. A high percentage of repellent and consequently lower quality topsoil samples were discovered.

Key words: urban soil quality, physical properties, repellency, specific surface area, pollution

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INTRODUCTION

In 1990s the knowledge of urban soils shifted away from studies restricted to soil pollution and a reasonable number of anthropogenic urban soils were examined with pedological methods (Blume, 1989; Lehmann, Stahr, 2007; IUSS, 2006; Prokofyeva et al., 2011). The comprehensive systems of soil properties including morphological, physical, chemical and biological indicators were proposed for soil quality assessment (Blume, 1989; Ajmone-Marsan, Biasoli, 2010), but only in some evaluations they act together (Schindelbeck et al., 2008). It is assumed that the legislative soil quality standards are very complex and have hardly been defined (Karlen et al., 1997).

The most developed studies of urban soils still are the sanitary assessment issues in topsoil including only chemical characteristics. The evaluation according to the degree of chemical pollution is among the most widely applied soil quality indicators. The topsoil in Lithuania was explored properly on the total heavy metal content (Kadūnas et al., 1999). However, there is no relation between labile and total forms of heavy metals (Plyaskina, Ladonin, 2009). Hazard of migration of hardly soluble compounds to groundwater and plants is determined by physical conditions of environment, i. e. soil moisture capacity and water filtration coefficient. That is why it is necessary to estimate soil physical properties. There are seven indicators in the classical list of characteristics that distinguish urban soils from their natural counterparts: the great vertical and spatial variability, modified soil structure leading to compaction, presence of the surface crust that tends to be water repellent, modified

soil pH which is usually elevated, restricted aeration and water drainage, interrupted nutrient cycling and modified soil organism activity, presence of anthropogenic materials and other contaminants, modified soil temperature regimes (Craul, 1985).

In this study soil repellence was used as one of the physical indicators of urban soil which can be detected in composite topsoil samples, common for sanitary soil quality evaluation. The repellence reduces water permeability, soil water cleaning potential, and induces sheet erosion (Ritsema et al., 1998; Ritsema, Dekker, 2005). The soil repellence emerges because of a hydrophobic organic matter covering soil particles and aggregates. A repellent sandy soil is more common (King, 1981; Ritsema, Dekker, 2005).

An effort was made in this study to use soil samples collected for the sanitary assessment of urban soil for a more comprehensive evaluation by including two physical indicators, the specific surface area and the repellence of composite soil samples.

STUDY SITES AND METHODS

Šiauliai and Joniškis are not metropolitan areas with high population density. There were about 20 thousand citizens in Šiauliai at the beginning of the 20th century, and about 120–150 thousand citizens were living in the past 30 years (1,426 people per km^2). Joniškis had 8–11 thousand citizens at the end of the 20th century and similar population density to Šiauliai (1,194 people per km^2). The soil forming rocks in both cities are glacier tills and soils are classified to the same soil region of sandy loams and loams of Middle Lithuania. That is why the territories of the cities can be compared.

Urban soil in this study means the soil from the municipal territory. Composite soil samples were collected separately from functional zones of Šiauliai (106 samples) and Joniškis (42 samples) municipal territories.

Five functional zones were distinguished: agricultural (gardens, suburban territories), recreational (wood stands, forest parks), public-residential (tenements, schools and commercial territories), centrum (the oldest territories, build-up for more than 150 years), industrial and traffic (mill and environs of infrastructural intersections). Each zone was represented by about 20 samples of Šiauliai and 5–18 samples of Joniškis soils. There are no recreational and forest parks zones and little areas of tenements in Joniškis. Only 5 soil samples were collected from public-residential territories in Joniškis.

The great part of the composite samples was from topsoil (0–5 cm). Dust sweep from the corners of the pavements was mixed with a sample in some cases of hard paving. The sample was at least 250 ml in volume and consisted of material from more than 10 sampling points.

Soil samples were mixed and ground, sieved and tested for water drop penetration time (WDPT). The sample was identified as repellent after the 5 seconds test (Bisdom et al., 1993). More differentiated time scale fits more for soil material from a single point.

The contents of 14 chemical elements (Zn, Pb, Cu, Sn, Ag, Mo, Ni, Cr, Co, Mn, V, B, Ba, Sr) in the topsoil samples were measured by atomic optical emission spectrophotometry. Soil pollution by these chemical elements was evaluated according to the coefficients of concentration Kk and their total contamination index Z (Kadūnas et al., 1999; Taraškevičius, Zinkutė, 2003).

The specific surface area of soil was determined by the express method, using the single point approach (Puri, Murari, 1964).

RESULTS AND DISCUSSION

It was found that higher percentage of repellent topsoil with smaller specific surface area is typical to industrial and traffic environs and the centrum (older than 150-year town). Higher percentage of repellent soil samples was discovered in Joniškis (Fig. 1).

The greater difference between the repellent samples percent from highly urbanized (centrum and industrial) and moderately urbanized (agricultural and public) functional zones in Joniškis reflects the lower anthropogenic pressure in Joniškis town in comparison with Šiauliai town.

In relatively non-polluted ($Z < 16$) by harmful chemical elements samples the same proportion of hydrophilic and hydrophobic samples was found, about 50%, but most of polluted ($Z > 16$) samples (70–80%) were hydrophobic (Fig. 2).

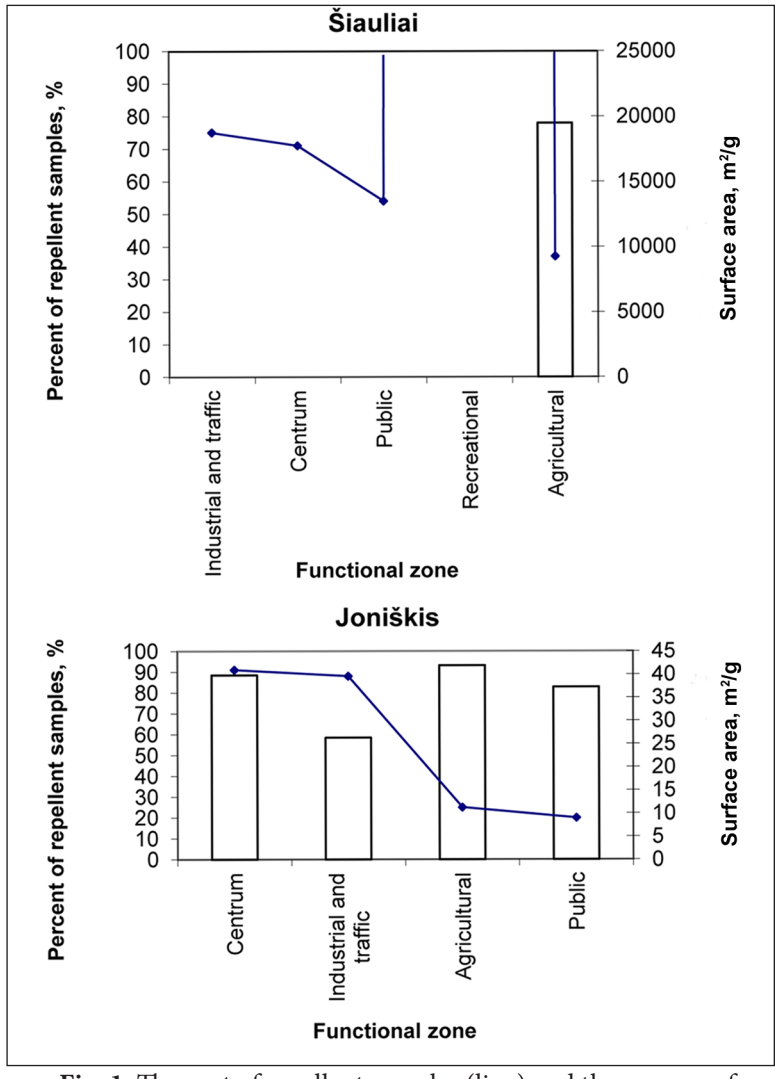

Fig. 1. The part of repellent samples (line) and the average of specific surface area (columns)
1 pav. Hidrofobiškų mėginių dalis (kreivė) ir vidutinis specifinis paviršius (stulpeliai)

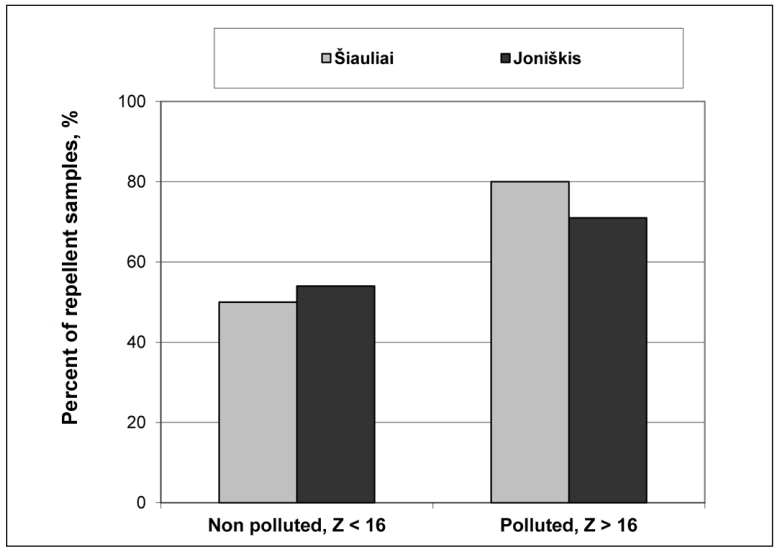

Fig. 2. The relationship between repellence and pollution
2 pav. Hidrofobiškumo sąsaja su užterštumu

According to the results, it is obvious that water repellence is more common in polluted samples and it can be used as a criterion for a more complex evaluation of the urban soil quality.

However, the value of repellence depends on the objectives of research. It must be noted that repellent soils are passive in water cleaning. In particular conditions (on slopes), if the repellent topsoil is polluted, repellence can be approached as a positive feature because repellent topsoil protects groundwater from pollution, but contaminates surface water.

Dust sweep was more repellent than samples from A and C horizons of urban soil, but the buried horizon was a little more repellent than topsoil (horizon A). After 5 seconds, water drop on Ab horizon preserved a convex form. Water drop was fully soaked to the material of Ab (buried soil organic

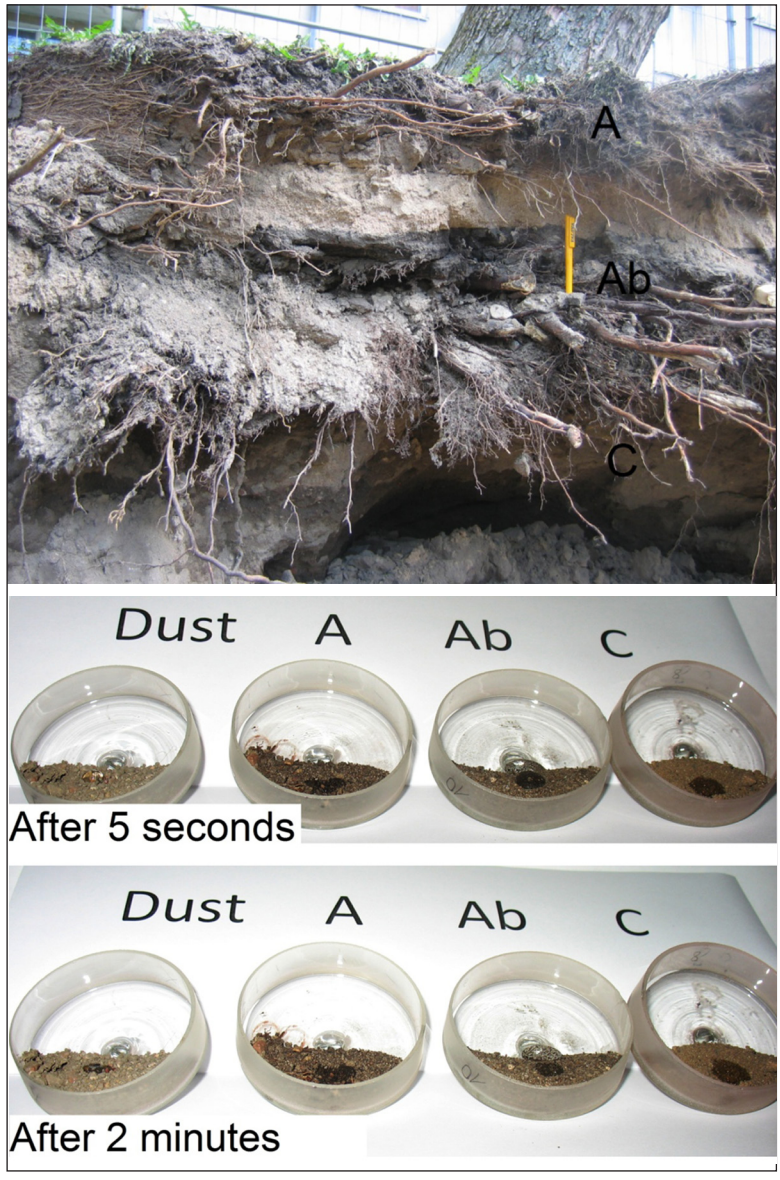

Fig. 3. Comparison of the water drop penetration test after 5 seconds and 2 minutes in dust and urban soil horizons of the profile from Vilnius, Naujamiestis region (the profile is above). The soil samples are single, neither ground nor sieved

3 pav. Vandens lašelio įsigėrimo testo rezultatų palyginimas po 5 sek. ir 2 min. dulkėse ir dirvožemio genetiniuose horizontuose Vilniaus Naujamiesčio profilyje (profilio nuotrauka viršuje). Dirvožemio mėginiai yra atsitiktiniai, nemalti ir nesijoti

horizon) only after 10 seconds (Fig. 3). It seems like aerosols are one of the main sources of urban topsoil repellence and pollution too.

Moreover, the impact of the soil organic matter content must be involved in the urban soil quality determination, because the correlation between heavy metal and soil organic matter content is reported by a lot of investigators (Ajmone-Marsan et al., 2010; Guney et al., 2010).

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HIDROFOBIŠKUMO KRITERIJAUS NAUDOJIMAS MIESTO DIRVOŽEMIO KOKYBĖS VERTINIMO SISTEMOJE

S a n t r a u k a

Nuo paskutiniojo XX a. dešimtmečio žinios apie miesto dirvožemių savybes ir funkcionavimo ypatybes įgavo mokslinį pagrindą. Sukurtos miesto dirvožemių kokybės vertinimo sistemos, kuriose naudojami fizinių-cheminių ir biologinių dirvožemio funkcijų indikatoriai.

Vis dėlto iki šiol miesto dirvožemių sanitarinės būklės vertinimo sistema evoliucionuoja tik geocheminės kokybės įvertinimo kryptimi. Darbe siūloma praplėsti miesto dirvožemių sanitarinės būklės vertinimo sistemą fiziniais parametrais, apibūdinančiais dirvožemių imlumą teršalams ir jų tolesnės migracijos geosistemoje perspektyvą.

Tyrimai buvo atlikti Šiaulių ir Joniškio miestuose. Mišrūs paviršinio dirvožemio horizonto (0–5 cm) pavyzdžiai buvo surinkti iš penkių funkcinių miesto zonų: infrastruktūros ir pramonės (1), centro (2), visuomeninės (3), rekreacinės (4) ir žemės ūkio (miesto teritorijoje esančių žemės ūkio naudmenų). Mišrieji dirvožemių pavyzdžiai sutrinti, sumaišyti ir persijoti. Atliktas vandens lašelio įsigėrimo testas, taip pat nustatytas dirvožemio dalelių paviršiaus plotas pagal Kutileką. Tuose pačiuose mėginiuose nustatytas užterštumas sunkiaisiais metalais.

Tyrimo rezultatai rodo, kad mažiausias dalelių paviršius būdingas dirvožemio paviršinio horizonto pavyzdžiams iš infrastruktūros ir pramonės bei centro funkcinių zonų. 80 % Šiauliuose ir 71 % Joniškyje užterštų mėginių buvo hidrofobiški, o mažai užterštų mėginių hidrofobiškumo tikimybė siekė 54 % (Joniškyje) ir 50 % (Šiauliuose). Daroma prielaida, kad hidrofobiškumo kriterijus yra tinkamas miesto dirvožemio kokybei vertinti, nes yra susijęs su potencialia galimybe apsaugoti pro dirvožemį besifiltruojantį vandenį nuo taršos.

Norint toliau tobulinti dirvožemio kokybės vertinimą, be fizinių indikatorių, turėtų būti nustatomi ir biologiniai, pavyzdžiui, organinės medžiagos būklė.

Raktažodžiai: miesto dirvožemiai, paviršinio horizonto kokybė, užterštumas, sunkieji metalai, fizinės savybės, hidrofobiškumas, specifinis paviršiaus plotas