Accumulation of Heavy Metals in the Urban Soils of Natural Monument “Bunardzhik” (Plovdiv, Bulgaria)

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Abstract. Progressing urbanization makes soils structurally altered and that results in their degradation, so we aimed to analyze the content of some heavy metals in urban soils of the park zone of Natural monument “Bunardzhik”, situated in the real center of the city of Plovdiv (Bulgaria). Soil samples were collected from the surface layers of urban soils located to the Western and Eastern park zones of the Bunardzhik Hill, according to transects starting from the main communication routes. Soil content of As, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Se, Sr, V, U, Zn was determined by inductively coupled plasma–mass spectrometry (ICP–MS). The content of V, Mn, Cr, Cu, Zn and Pb is noticeably reduced in the Western park zone (p<0.05), leaving from the route and reaching the middle of the park zone. Urban soils from the Eastern park zone are more polluted and there no significant decreases in their content with increasing the distance from the main road artery have been found. All studied heavy metals and toxic elements could be arranged as follows: Mn (436 mg/kg) > Zn (81 mg/kg) > V (40 mg/kg) > Pb (39.7 mg/kg) > Sr (38.3 mg/kg) > Cu (31.3 mg/kg) > Cr (23.7 mg/kg) > Ni (22.0 mg/kg) > As (3.3 mg/kg) > U (1.9 mg/kg) > Cd (0.36 mg/kg) in the Western park zone and Mn (552 mg/kg) > Zn (84 mg/kg) > V (62 mg/kg) > Pb (52.3 mg/kg) > Cr (36.3 mg/kg) > Sr (33.7 mg/kg) > Cu (28.7 mg/kg) > Ni (28.3 mg/kg) > As (6.0 mg/kg) > U (3.1 mg/kg) > Se (1.6 mg/kg) > Cd (0.55 mg/kg) > Hg (0.23 mg/kg) in the Eastern park zone, respectively. The results obtained for the two studied park zones allow for their use for recreational purposes but some exceedance of the precautionary limits should be adressed.

Key words: urban soils, heavy metals, toxic elements, pollution.

Introduction

Heavy metals are natural constituents of the Earth’s crust. Anthropogenic activities have drastically disturbed the biochemical and geochemical cycles of some heavy metals. Therefore, the assessment of the environmental risk due to soil pollution is of particular importance for agricultural and urban areas, where heavy metals, which are potentially harmful to human health, persist in soils for a very long time.

Contamination of soil surface layers with heavy metals is mainly associated with urban areas which are intensively managed by humans (WALCZAK et al., 2011). Heavy metals in urban soils may come from...
various human activities, such as industrial and energy production, construction, vehicle exhaust, waste disposal, as well as coal and fuel combustion (Komai, 1981; Ikeda & Yoda, 1982; Ritter & Rinefiend, 1983; Chon et al., 1995; Wong & Mak, 1997; Martin et al., 1998; Li et al., 2001). These activities send heavy metals into the air and the metals subsequently are deposited into urban soil as the metal containing dust falls. Sakagami et al. (1982) reported that there was a close relationship between heavy metal concentrations in soils and those in the dust falls.

Human health in towns and cities is strongly dependent on the status of urban soils (Simpson, 1996). Strong compaction, contamination by wastes and atmospheric depositions, loss of organic matter, changes in soil reaction, structural degradation and infection by pathogenic microorganisms are only few of the many adverse processes that affect and modify the ecological functions of soils in urban areas (Bullock & Gregory, 1991; Jim, 1993; Beyer et al., 1995; Blum, 1998). Heavy metals in the soils can also generate airborne particles and dusts, which may affect the air environmental quality (Chen et al., 1997; Bandhu et al., 2000; Cyrys et al., 2003; Gray et al., 2003). In contrast to agricultural soils, urban soils, especially in parks and residential areas which are not used for food crops, may also have a direct influence on public health since it can be easily transferred into human bodies (De Miguel et al., 2007; Mielke et al., 1999; Madrid et al., 2002). In particular, the ingestion of dust and soil has been widely regarded as one of the key pathways by which children are exposed to the heavy metals and metalloids from paint, leaded gasoline, vehicles and local industry (Meyer et al., 1999; Rasmusen et al., 2001).

Previous studies indicated that the extent of heavy metal pollution in urban areas varied across time (Pfeiffer et al., 1991) and location (Albasel & Cottenie, 1985), and that increased levels of heavy metals in urban soil was related to the intensity of human activities and traffic volume (Zheng et al., 2002). The investigation of soil heavy metal concentrations in parks and green areas in Seville, Spain, indicated that the concentrations of Pb, Zn and particularly Cu in the soil often exceeded the acceptable limits for residential, recreational and institutional sites (Madrid et al., 2002). The study of large parks in Stara Zagora (Bulgaria) reveals technogenic loads on soils with heavy metals on the bases of technogenic coefficients and coefficient of abnormality but without risks for ecosystems (Petkov et al., 2010). Links between soil pollution with heavy metals and age of the park are determined also (Li et al., 2001; Hou et al., 2015; Kachova & Atanassova, 2017). Recent research in some of the oldest urban parks of Sofia revealed that lead was imported to the soils mainly with dust particles (particulate matter) and accumulated in the surface layers of soil from urban parks (Kachova & Atanassova, 2017). The data on the chemical variability in the total Cu and Cd concentrations confirmed that Cd and Pb are inferred as markers of anthropogenic pollution, Cu contents are attributed to litho(pedo)genic sources, while Zn is both of anthropogenic and litho(pedo)genic origin.

However, differences among cities including population density and industrial activities could have a large impact on the findings of individual studies. Moreover, little information is available on heavy metal concentrations in soils of urban parks located in older cities with large populations.

The aim of this study is to identify the soil environment in terms of the content of selected heavy metals, as well as to identify some of physical and chemical properties of urban soils of Natural monument “Bunardzhik” (Plovdiv, Bulgaria). By analysing the spatial distribution of heavy metal concentrations in relation to the correlations among these elements and
distance from the routes, it may be possible to assess the contamination of the soils, the potential hazardous risk both for human health and for protected area.

Materials and Methods

Study area and sampling sites description

Plovdiv (42°9’N, 24°45’E) is situated in south-central part of Bulgaria, in the southern part of the Plain of Plovdiv, on the two banks of the Maritsa River. It is the second-largest city after the capital Sofia with a population of over 347,000 inhabitants (NSI, 2018). Inside the city proper are six syenite hills (including Bunardzhik Hill), several industrial zones, densely populated central area, some moderately populated areas around it, wide network of busy streets and train tracks, big parks and other green yards. Air quality in Plovdiv is quite worsened due to the motor vehicle emissions and residential heating, then the industrial sector, which has a minor impact (Atanassov et al., 2006; Petrova, 2011; Petrova et al., 2013; 2014a; b; 2015; Riosv, 2017).

The climate is temperate with mild influence from the Mediterranean Sea and a large temperature range between summers and winters. The average annual temperature is 12.3 °C with maximum in July (32.3 °C) and minimum in January (6.5 °C). The average relative humidity is 73%. It is highest in December (86%) and lowest in August (62%). The total precipitation is 540 mm – the wettest months of the year are May and June with an average precipitation of 66.2 mm, while the driest is August with an average of 31 mm. Gentle winds with speed of up to 1 m s−1 represent 95% of all winds during the year. The prevailing wind direction is from west, rarely from east. Mists are common in the cooler months, especially along the banks of the Maritsa River. On average there are 33 days with mist during the year (National Institute of Meteorology and Hydrology, 2018).

Bunardzhik Hill, also known as the Hill of the Liberators, has an outstanding value in the urban ecosystem as one of the major city-forming factors and it is: i) symbol of the city of Plovdiv; ii) basic element of his identity; iii) unique geomorphological entity; iii) habitat of rare and protected plant species. Functionally, the territory of the hill is assigned to the green system of the city for wide public use according to the General Plan of the Territory of Plovdiv (2007) and the Program for development, maintenance and protection of urban green system (2013). In 1990 Bunardzhik Hill was declared for a Monument of garden-park art, and in 1995 the Ministry of Environment and Waters declared it as a Natural monument (Ordinance RD-466/22.12.1995, MOEW) according to Protected Areas Act (1996) in Bulgaria. The natural character of the territory (including ecosystems and the landscape as a whole) is significantly influenced by the human factor, with most of the habitats characterized by a low degree of naturalness (Management Plan of Natural Monument “Bunardzhik”, 2017).

Bunardzhik Hill is situated in the real center of Plovdiv, Bulgaria, along the two of the main road arteries in Plovdiv (Ruski Blvd. and Vassil Aprilov Blvd.) (Fig. 1). Its territory covers an area of 22 ha and is divided to the four functional zones (Table 1) according to the Management Plan of Natural Monument “Bunardzhik” (2017).

Soil sampling

As the park zone is the most influenced area, both from the traffic emissions and from anthropogenic pressure, this study focused on the park soils’ investigation. Soil samples are taken in June 2017 from the Eastern and the Western park zones of the hill. These two park zones abut upon Ruski Blvd. and Vassil Aprilov Blvd., respectively, so soil sampling was made along a pollution gradient using the transect method (Fig. 1). Transects started from the road and were directed towards the hill in order to allow the effect of traffic on soil properties be assessed. Soil samples were collected at the 7.5 m, 25 m, and 50 m distance from the route (Table 2) on the
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depth of 0-20 cm (ISO 10381). Each sample was formed by 5 subsamples. The topsoil horizon was chosen for the analysis because it undergoes the biggest impact of versatile origin – mechanical, physical, chemical and biological. The preparation of soil samples for analysis was carried out, according to ISO 11464.

Soil analyses
Soil pH was measured using pHotoFlex Set, 2512000, WTW-Germany (ISO 10390), and the soil conductivity was measured using Multiset, F340, WTW-Germany (ISO 11265). Soil texture (pipette method by Wigner), humus content (by Turin) has been analyzed in the Laboratory of the Department of Agroecology and Environmental Protection, Agricultural University of Plovdiv.

Total soil content of As, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Se, Sr, V, U, Zn was determined by inductively coupled plasma-mass spectrometry (ICP-MS) (Agilent 7700). ICP-MS system was calibrated with international standards. Quality control was performed using the standard reference plant material (NCS DC73348): the percent recovery ranged from 91 to 99%, depending on each analyzed element. The extraction of trace elements and analyzes have been made in the Laboratory of Analytical chemistry and Computer chemistry of the University of Plovdiv “Paisii Hilendarski”.

Statistical evaluation
Raw data from all analyses were processed using statistical software package Statistica 7.0. for Windows (Stat Soft Inc., 2004). Multi ANOVA (MANOVA) and Student/Fisher test were used for testing the differences of elemental concentrations, both between the soils samples from different road distance and also between the studied sampling sites (p<0.05). Relationships between the contents of individual elements in collected soil samples were tested using Pearson correlation coefficients (p<0.05). A cluster analysis was used for grouping the studied chemical elements on the basis of their content in studied urban soils from both park zones (Complete linkage, 1-Pearson r).

Results and Discussion
General characteristic of the soils in the studied park zones

Urban soils are composed largely of a mixture of materials differing from those in adjacent agricultural and forest areas, and transformed deeply by human activity through mixing, importing and exporting material, and by contamination (Craul, 1992). Thus human activities modify urban soils thereby setting off anthropogenic lithogenesis and pedogenesis, particularly by imposing very rapid transformation cycles (Blume, 1996; De Kimpe & Morel, 2000).

Based on their genesis, the soils in the Plovdiv area are classified as Fluvisol according to the FAO World Reference Base for Soil Resources (2014). Due to the prolonged human presence on the studied territory (more than 8000 years) and the increasing rate of urbanization in the last decades, soils properties are significantly influenced and now it is more appropriate to discuss them as Technosols and Anthrosol.

Soils in the low and relatively flattened peripheral zones of the Bunardzhik Hill are heterogeneous. They typically have a profile that is disturbed as a result of constructions, ameliorative and reinforcing activities. The terrain surface is typically artificially modeled in terms of alignment, inclination and exposure so as to form a kind of landscape for public service (Fig. 2).

Physical and chemical characteristics of studied urban soils from two park zones of the Natural Monument “Bunardzhik”

The pH values of the studied soil samples from the surface layer (0-20 cm) varied between 6.22 and 6.98 (from light acidic to neutral) in the Western park zone and between 5.87 and 6.22 (from medium acidic to light acidic) in the Eastern park zone (Table 3). Urban soils from the parks of the city of Sofia also showed slightly acidic
to neutral reaction (KACHOVA & ATANASSOVA, 2017). DOICHINOVA & ZHIYANSKI (2013) reported similar pH values of urban soils from park zone in Sandanski (Bulgaria). They confirmed that pH in topsoil horizon was greater and tended to decrease in deeper layers which was found as a diagnostic feature for urbanized soils by GENCHEVA (2000). Studies in different environments (agricultural, urban and transition land-use zones) demonstrate that in the acid soils, heavy metals are more mobile than in the alkaline one, and the alkaline environment better sustains metals (KAZLAUSKAITE-JADZEVIČĖA et al., 2014).

In an urban environment soil organic matter (SOM) has manifold functions and it is with considerable ecological significance. In the present study, we found that soil organic matter varied between 1.55% (WPZ-50) and 3.41% (EPZ-7.5) (Table 3). So, the studied soils could be characterized as relatively fertile and able to meet the needs of plants. Higher values were measured close to the road and tended to decrease to the inner of two park zones (p<0.05). Urban soils of studied parks in Sofia were characterized by significantly higher soil organic matter content – from 5.4% to 8.3% (KACHOVA & ATANASSOVA, 2017), but our findings were close to data from DOICHINOVA & ZHIYANSKI (2013) concerning the SOM content of urban soils from park zone in Sandanski (Bulgaria). As many authors have shown, soil organic matter may be affected by mixing of carbonaceous material like debris, ash, slag, garbage and sewage sludge, as well as from deposition of airborne particles (SCHLEUSS et al., 1998; BEYER et al., 2001). Therefore, the transformed chemistry and structure of soils may lead to serious disturbances in their biological activity and impoverishment of vegetation cover (MIRELES et al., 2012; Hu et al., 2013).

Soil texture of urban soils from Bunardzhik Hill varied from light sandy to sandy loam (Table 3). The light soil texture respectively, with the higher sand content, could be related to a potentially higher soil vulnerability to processes of degradation in the presence of pollution, which is characteristic of the urban environment (WU, 2014; MAO et al., 2014). We found that the soils from the Western park zone were with smaller clay fraction than soils from the Eastern park zone (p<0.05) (Table 3). As the both studied park soils originated from the same rocks, the variations in the soil texture could be due to the different type of evolution processes, managed by different exposure.

Content of heavy metals and toxic elements in the studied park soils from Natural Monument “Bunardzhik”

In urban areas, a wide range of substances being produced through combustion of fuels, industrial processes, road de-icing, and abrasion of vehicle exploitation materials (mainly tyres) are emitted to the environment. These are toxic gases and dust enriched with heavy metals. Such contamination undergoes deposition and penetrates into soils, damaging the main soil properties (SHANG et al., 2012; MCBRIDE et al., 2014).

The highest content of all the studied heavy metals and toxic elements was found in the sampling plots, situated along the route arteries – at 7.5 meters (Fig. 3 and Fig. 4). This content differed significantly with the concentrations of the same elements measured at the distance of 25 meters and 50 meters (p<0.05). So, the traffic inputs could be considered as the leading factor for soil contamination in the periphery of park zones. Our previous studies in Plovdiv revealed that the content of some trace elements in soils along the road network was in direct relationships both with the distance from road and the road location itself according to the wind rose (PETROVA et al., 2018). This situation reflected also on the soil microbial community structure, leading not only to the damages in the physico-chemical properties of soils but to the decrease into their quality and functions.

As a whole, park soils in the east side of Natural Monument “Bunardzhik” are more
contaminated then the park soils from the west side. Exceptions were found only for Cu and Sr (Fig. 3 and Fig 4). Heavy metals (mainly Cu, Pb, Zn, Cd, Ni, V) are derived by many anthropogenic processes and activities, such as domestic activities, residential heating, petrol and diesel vehicles (JOHNSON et al., 2011). Copper (Cu) is yet another lithogenous trace element found in soil, but the increased levels of it, as they are observed in the topsoil, can be put down on anthropogenic activity. Strontium (Sr) is usually linked to carbonaceous soil material of large scale broken rock, and so in this case, as its content do not vary very much (38 mg/kg average in soils from Western park zone and 34 mg/kg average in those from Eastern park zone). Soil content of Hg and Se in the Western park zone is under the detection limit of 0.1 mg/kg but in soils from the other park these elements are more abundant (p<0.001) (Fig. 3 and Fig. 4). Compared to data from park zones in Sofia, the studied urban soils from Plovdiv (Bunardzhik Hill) have about 40% lower content of Cu, but are significantly more polluted with Pb (up to 3 fold), Cd (up to 2 fold) and Zn (up to 2 fold) (KACHOVA & ATANASSOVA, 2017).

Table 1. Functional zoning of the Bunardzhik Hill’s area.

<table>
<thead>
<tr>
<th>Zone</th>
<th>Area, ha</th>
<th>%</th>
<th>Functional purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Park zone (Zone 1)</td>
<td>4.55</td>
<td>20.5</td>
<td>Recreation, public services, sports and cultural events</td>
</tr>
<tr>
<td>Forest park zone</td>
<td>10.81</td>
<td>49</td>
<td>Recreation in semi-natural (forest-park) natural environment, conservation of plant and animal species and typical landscapes</td>
</tr>
<tr>
<td>High zone (Zone 3)</td>
<td>5.61</td>
<td>25.5</td>
<td>Maintaining natural vegetation and endangered, rare and endemic species</td>
</tr>
<tr>
<td>Memorial zone (Zone 4)</td>
<td>1.07</td>
<td>5.0</td>
<td>Preservation of the memorials</td>
</tr>
<tr>
<td>Total:</td>
<td>22.04</td>
<td>100</td>
<td>-</td>
</tr>
</tbody>
</table>

Fig. 1. Functional zoning of Natural Monument “Bunardzhik” and sampling plots location.
Table 2. Sampling plots description.

<table>
<thead>
<tr>
<th>Park zone</th>
<th>Along Boulevard</th>
<th>Distance from the road</th>
<th>Soil sample symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western park zone</td>
<td>Vassil Aprilov</td>
<td>7.5 m</td>
<td>WPZ-7.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25 m</td>
<td>WPZ-25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50 m</td>
<td>WPZ-50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.5 m</td>
<td>EPZ-7.5</td>
</tr>
<tr>
<td>Eastern park zone</td>
<td>Ruski</td>
<td>25 m</td>
<td>EPZ-25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50 m</td>
<td>EPZ-50</td>
</tr>
</tbody>
</table>

Fig. 2. Landscape in Western park zone (A) and Eastern park zone (B).

Table 3. Physical and chemical characteristics of studied urban soils from two park zones.

<table>
<thead>
<tr>
<th>Soil sample</th>
<th>pH</th>
<th>Organic C, %</th>
<th>SOM, %</th>
<th>Soil texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>WPZ-7.5</td>
<td>6.41</td>
<td>1.75</td>
<td>3.02</td>
<td>Sandy soil</td>
</tr>
<tr>
<td>WPZ-25</td>
<td>6.98</td>
<td>1.35</td>
<td>2.33</td>
<td></td>
</tr>
<tr>
<td>WPZ-50</td>
<td>6.22</td>
<td>0.90</td>
<td>1.55</td>
<td></td>
</tr>
<tr>
<td>EPZ-7.5</td>
<td>5.87</td>
<td>1.98</td>
<td>3.41</td>
<td>Sandy loam soil</td>
</tr>
<tr>
<td>EPZ-25</td>
<td>5.90</td>
<td>1.81</td>
<td>3.11</td>
<td></td>
</tr>
<tr>
<td>EPZ-50</td>
<td>6.22</td>
<td>1.28</td>
<td>2.21</td>
<td></td>
</tr>
</tbody>
</table>

Fig 2. Content of heavy metals and toxic elements in soils from Western park zone of Natural Monument “Bunardzhik” (mg/kg, logarithmic scale).

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Fig 3. Content of heavy metals and toxic elements in soils from Eastern park zone of Natural Monument “Bunardzhik” (mg/kg, logarithmic scale).

Fig 4. Comparison of our results with the precautionary limits (Regulation Norm №3/2008) about Cd, Pb and Zn content in soils of Natural Monument “Bunardzhik”.

A comparison has been made with the national precautionary limits and threshold values accepted in Bulgarian standards for soils from public areas (Regulation Norm №3, 2008). Although our results are quite below the maximal limits some problems were found with the precautionary values (Fig. 4). Lead in soils from the Eastern park zone exceeds these values up to 170% at distance of 7.5 m, and to a lesser extend at 25 m and 50 m, while in soils from Western park zone an increment of 155% have been found only at 7.5 m distance from road (p<0.05). Cadmium content in Western park zone is below the limits but the closest sampling plot to the road in Eastern park zone was contaminated up to 125% above the precautionary values (p<0.05). Zink content in both sampling plots at 7.5 m distance was found to be 1% below the precautionary limits so some attention should be paid. Our findings are in good agreement with the statement of KACHOVA & ATANASSOVA (2017) that Cd and Pb are inferred as markers of variables. Anthropogenic pollution, Cu contents are attributed to litho(pedo)genic sources, while Zn is both of anthropogenic and litho(pedo)genic origin.

These results give us a reason to assume that in the area of our research, these
elements have a common origin, namely as waste products from road transport. This includes both exhausted gases and waste products from brake systems, tire wear, etc. A number of publications indicate that Fe is emitted from vehicle braking systems, Pb and Cd - from the exhaust gases, V from different metal composites (MAHER et al., 2008). Cr and V are considered indicative of vehicle emissions (GARTY et al., 1996) and partly associated with tire and brake abrasion, as we have shown in our previous studies (PETROVA, 2011; PETROVA et al., 2013; PETROVA et al., 2014a, b; PETROVA et al., 2015). So, the significant correlation with the elevated content of other studied elements in soil samples from 7.5 m distance from road lets to conclude that the traffic is the main emitter of toxic substances in the central city part of Plovdiv.

The results achieved in the cluster analysis of soil contamination showed some different relationships between heavy metals and toxic elements in the two investigated park zones (Fig. 5). Two main groups have been formed in the Western park zone, first of which included 10 of studied elements, and the second – only two (Mn and Sr) (Fig. 5A). According to BURAU & ZASOSKI (2002), it is possible to explain a stronger relationship between lithogenous elements as strontium (Sr) and manganese (Mn). When regarding the other elements, the strongest accumulation associations were formed by As-Cr-Cu, Cd-Pb-Zn and Fe-Ni-V, among which a strong linear interdependence is observed and it could be related to the pollution levels in the city. The weakest genetic links of these metals connect them with uranium (U) that is found in their cluster. Two main groups were observed in the cluster analysis of soils from Eastern park zone too (Fig. 5B), but they significantly differ from data obtained by the Western park zone. Similar accumulation tendency was found only for associations Cd-Pb-Zn and Fe-Ni (p<0.05).

![Cluster analysis of heavy metals and toxic elements in soils from Western park zone (A) and Eastern park zone (B) of Natural Monument “Bunardzhik”.](image)

Fig 5. Cluster analysis of heavy metals and toxic elements in soils from Western park zone (A) and Eastern park zone (B) of Natural Monument “Bunardzhik”.

Our previous studies have shown significant differences in the trace elements content both in some herbs (PETROVA et al., 2013, 2014a) and in the leaves of some ornamental trees, growing in these two park zones (PETROVA et al., 2014b). For example, average Pb content in tree leaves from the Western park zone was 6.7 mg/kg while in the Eastern park zone was 8.9 mg/kg, average content of Cu was 9.1 mg/kg and 12.4 mg/kg, respectively, while average content of Ni was 2.2 mg/kg and 3.0 mg/kg, respectively (PETROVA et al., 2014b). Thereby, some activities in collecting and removing
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the fallen autumn leaves in park zones could be recommended as a practical measure for limiting the entry of pollutants in urban soils by the decomposition of organic matter.

Conclusions
The studied soils from the Eastern and Western park areas of the Natural monument “Bunardzhik” have different characteristics that are probably due to the complex impact of natural and anthropogenic factors. In the soils from the western side of the hill, the content of vanadium, manganese, chromium, copper, zinc and lead is noticeably reduced, leaving from Vassil Aprilov Blvd. and reaching the middle of the park zone. In the soils on the eastern side of the hill, as a whole, higher amounts of the majority of the studied elements are reported, and there is a lack of significant decreases in their content, increasing the distance from the main road artery - Ruski Blvd.

Based on the results obtained, all studied heavy metals and toxic elements could be arranged as follows: Mn (436 mg/kg) > Zn (81 mg/kg) > V (40 mg/kg) > Pb (39.7 mg/kg) > Sr (38.3 mg/kg) > Cu (31.3 mg/kg) > Cr (23.7 mg/kg) > Ni (22.0 mg/kg) > As (3.3 mg/kg) > U (1.9 mg/kg) > Cd (0.36 mg/kg) in the Western park zone and Mn (552 mg/kg) > Zn (84 mg/kg) > V (62 mg/kg) > Pb (52.3 mg/kg) > Cr (36.3 mg/kg) > Sr (33.7 mg/kg) > Cu (28.7 mg/kg) > Ni (28.3 mg/kg) > As (6.0 mg/kg) > U (3.1 mg/kg) > Se (1.6 mg/kg) > Cd (0.55 mg/kg) > Hg (0.23 mg/kg) in the Eastern park zone, respectively.

The comparison with the normative base showed that the precautionary limits of zinc, cadmium and lead in the roadside sections of the Eastern and Western Park zone and of lead in the middle part of the Eastern park zone of Natural monument “Bunardzhik” were exceeded. The main source of these pollutants is urban traffic, and a possible reason for the higher concentrations in the Eastern park zone is the lack of wind, dust recirculation, canyon street effect, etc.

Elevated concentrations of heavy metals in the topsoil negatively affect soil biota and plant biodiversity and conditions are created for disturbances in mineral nutrition, changes of metabolic and physiological processes in green plants. The deteriorated status of green systems directly reflects on the quality of the city environment, and especially of the protected area Natural monument “Bunardzhik”. Some adequate measure for future prevention of soil pollution should be implemented, i.e. removing of the fallen tree leaves in the autumn season, traffic optimization and restriction, etc.

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