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ENVIRONMENTAL QUALITY IN FORESTS FROM BUCHAREST METROPOLITAN AREA, ROMANIA

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Abstract

The assessment of heavy metals pollution using *Xanthoria parietina* (L.) Th. Fr. as an indicator species was performed for forests from Bucharest metropolitan area. This study aims to provide original data concerning environmental quality in relation to the intensity of car traffic. Metal concentrations in *Xanthoria parietina* measured in sites adjacent to roads were compared with those measured at a distance from traffic. The results show significant correlations between the Cd and Cr concentrations and the distance from Bucharest. The Pb, Cr, Cd and Zn concentrations are insignificant correlated with the number of vehicles. Within the studied area, decreasing heavy metal concentration in *Xanthoria parietina* on sampled trees is clearly associated with increasing distance from the nearest roads. It was found that Pb and Zn concentrations are higher especially in the Pustnicul and Bolintin-Deal forests indicating that values of Pb and Zn concentrations in *Xanthoria parietina* could be used as indicators of environmental pollution for Pustnicul and Bolintin Deal forests.

Key words: atmospheric pollution, car traffic, forest, heavy metal, *Xanthoria parietina*

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1. Introduction

The assessment of environmental quality represents one of the fundamental elements of any environmental strategies (Drăgulescu et al., 2005). From all categories of bioindicators, lichens are widely used to assess the anthropogenic impact (atmospheric and water pollution, eutrophication, climate change, and forest management) on terrestrial ecosystems (Asta et al., 2002; Bartók and Kékedy, 2008; Donica, 2007; Gomoiu and Ştefănuţ, 2008; Svoboda, 2007).

The atmospheric quality in urban-industrial areas is affected by car traffic emissions, a range of industrial activities, power stations, domestic heating etc. In rural areas, emissions from small factories (mills and bakehouse), wineries, quarries, and domestic sources, contribute to atmospheric pollution. The main pollutants detected in the atmosphere from anthropogenic impact with a negative effect on lichen species are: airborne, NO_x (nitrogen oxides), SO_x (sulphur oxides) hydrocarbons, heavy metals, metalloids, persistent organic substances such as: dioxins and pesticides (Donica, 2007; Hauck, 2008).

The presence of some lichens, within polluted ecosystems and their resistance to high concentrations of heavy metals are explained by several adaptations, such as: a reduction in absorption surface, an increase in thickness of medulla and outer cortex that protects the algal cells, and an increase in rhizine density which have an important role to play in binding heavy metals to the cell walls, especially to prevent their translocation in fungal and algal cells. The capacity to accumulate a large amount of heavy metals is closely related to a large surface area (20 up to 100 times higher than the cormophytes), long generation time, ongoing metabolic activities throughout the year and a slowly growth rate. Lichens, absorb heavy metals directly from the atmosphere due to their metabolic needs; therefore, the highest values of heavy metal concentrations, were recorded in the proximity of urban-industrial areas. The sensitivity of lichens, depends on species, distance from polluted sources, heavy metal concentrations in the atmosphere, dominant wind directions, and local topography (Bartók, 1983; Donica, 2007). The diversity of lichens in air polluted areas is very low (Gomoiu and Ştefănuţ, 2008), and increases with the distance from polluted areas due to an improvement of air quality (Bartók, 1980; Bartók, 1985; Jovan and McCune, 2005; Liška and Herben, 2008).

The physical and chemical measurements provide quantitative data on the presence and level of pollutants, but do not provide an accurate picture of the extent of pollution nor offer information on its impact on organisms. The data provided by bioindicators may be used to estimate the extent of the impact on the environment and the potential threats for organisms (Kovács, 1992).

The sources that release heavy metals may be natural (volcanic activities, fire forestry, etc.) and anthropogenic, such as: industrial activities, transport, buildings, power stations, and agricultural activities, such as: fertilizer application and long-term application of wastewater in agricultural land etc. (Poikolainen, 2004; Duruibe et al., 2007; Qishlaqi and Moore, 2007).

Traffic is one of the sources of emission of heavy metals, such as: Pb, Cd, Cr, Zn, Mn, Cu, etc. Fossil fuel contains many kinds of heavy metal that will be emitted to the environment during combustion. Some heavy metals (Cd, Zn, Pb) are common components in diesel oil, tyre wear, brakes, and even in unleaded petrol. Other sources of heavy metal pollution related to vehicular traffic are greases, peeling paint and catalysts. It has been shown that heavy metal contents (Pb, Cd, Zn, etc) near to the roadside were considerably higher than in samples taken far away from the roadside (Uluozlu et al., 2007; Aslan et al., 2011).

Nowadays, tetraethyl lead is rarely used in vehicle fuel and so the traffic contribution for environmental lead pollution has decreased. But, this element is very stable and still remains present in environment (Cuny et al., 2004). In a study performed in Katni and Rewa cities from India, maximum amounts of Cr, Pb, and Zn were reported in *Pyxine cocoes* (Sw.) Nyl. and *Phaeophyscia hispidula* (Ach.) Essl. growing in the higher traffic areas (Bajpai et al., 2011). It was mentioned that the bark chemistry properties of tree trunk and also the chemical compounds of other substrata (rocks, soils, etc), have a significant impact on the element concentrations in lichen thalii (Hauck and Spribille, 2005). In a study regarding the influence of external factors on element composition in lichen thalii Hauck et al. (2006) pointed out that chlorolichens are highly toxitolerant due to the intracellular imobilization of elements.

Within Bucharest metropolitan area, the major sources of pollution are represented by industrial activities, power stations, cars, railway and air traffic, and domestic activities (Iojă, 2008).

The proposed hypothesis consist in the following assertions: (1) the heavy metal concentrations are higher in proximity of roadsides and decrease with distance from the road; (2) there is a close relation between the intensity of vehicle traffic and heavy metal concentrations. The aim of this study is to assess the use of *Xanthoria parietina* (L.) Th. Fr. as an indicator of the accumulation phenomena of heavy metals, such as: Pb, Cd, Cr, and Zn. The main objective is based on assessment of heavy metal pollution and its spatial distribution throughout the studied area.

2. Material and methods

2.1. Study area

The investigated area is a part of the Romanian Plain (South Romania). The sampling took place within the following forests from Bucharest metropolitan area: Băneasa Forest (Bucharest), Vlădiceasca Forest (Ilfov County), Snagov Forest (Ilfov County), Pustnicul Forest (Ilfov County), Goştilele Forest (Călăraşi County), Călăreţilor Forest (Călăraşi County), Râioasa Forest (Ilfov County), Bolintin-Deal Forest (Giurgiu County), Căscioarele-Malu Spart Forest (Giurgiu County), Sinteşti Forest (Giurgiu County), and Comana Forest (Giurgiu County) (Fig.1).

In the studied area, the annual average of temperature vary between 9.8°C and 11.2°C. The recorded values of air humidity vary between 75% and 80%. The annual average of precipitations are 613.1 mm (in the northern part of the studied area) and 550 mm (in the southern part of the studied area). The North-East and South-East are the prevailing winds (Iojă, 2008).

Within the studied area the sylvo-steppe is represented especially by *Quercus pubescens* Willd., *Quercus pedunculiflora* K. Koch., *Carpinus betulus* L. *Acer tataricum* L. *Carpinus orientalis* Mill., *Fraxinus ornus* L., *Ruscus aculeatus* L., etc. Oak species such as *Q. cerris* L., *Q. frainetto* Ten., *Q. pubescens, Q. robur* L. accompanied by *Carpinus betulus*, *Tilia* sp. and *Ulmus* sp. are important part of nemoral vegetation (Bălteanu et al., 2006).

The forests from Bucharest metropolitan area are managed by forestry ranges, such as: Brăneşti (units of production Pasărea, Pustnicul, and Cernica-5206.5 hectares), Bolintin (units of production Bucşani, Malu Spart, Căscioarele, Zăvoaiele Argeşului, Cotroceanca, and Grădinari-9141.4 hectares), Bucureşti (units of production Socola, Jilava, Valea Mocanului, Râioasa, Domneşti, and Băneasa-7671.1 hectares), Snagov-Scrovriştea (units of production Brânzeasca, Popeşti, Săftica, Afumaţi, Surlari-Corniş, and Balta Neagră-8316.5 hectares), Mitreni (units of production Paraschiva and Ciornuleasa-2178.5 hectares) and Lehliu (Fundulea-1667 hectares) (Iojă, 2008).

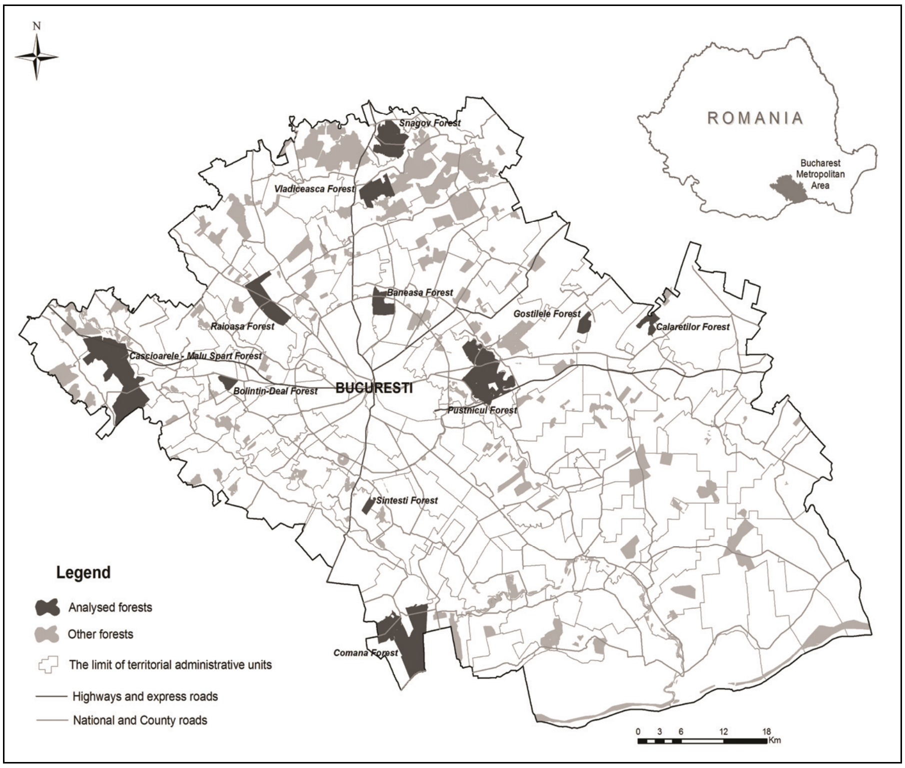

Fig. 1. Location of the studied forests in the Bucharest metropolitan area (http://www.esri.com)

2.2. Sampling design

Within Pustnicul, Bolintin-Deal, and Căscioarele-Malu Spart forests was selected only one tree situated in proximity of the roadsides (2 meters away) that go through these forests. For Goştilele, Comana, Călăreţilor, and Snagov forests was selected only one tree at the edge of each mentioned forests. The lichen thalii of *Xanthoria parietina* were collected from living tree trunks and the lignicolous substrata (dead branch fallen on the ground from the upper canopy) were collected from the ground where these have been found.

A total of 7 trees and 4 lignicolous substrata were sampled for the analysis of Pb, Cd, Cr, and Zn in the studied area. The sampled trees were selected depending on coverage degree with lichen thalii of *Xanthoria parietina*. As the coverage is higher the trees are more appropriate for lichens thalii prelevation. Also the lignicolous substrata present a high abundance of *Xanthoria parietina*. Both tree trunks and lignicolous substrata were selected depending on a high degree of *Xanthoria parietina* coverage.

2.3. Sampling procedure

The field activities were performed during June-August 2010. From each of the above mentioned forest, lichen thalli belonging to *Xanthoria parietina* species were collected for determination of heavy metal concentrations. It was observed that this species is very abundant on tree bark adjacent to the road. The samples have been collected from certain host trees rhytidoma, beginning from the base of the trunk to a height of 1.5 m, within each investigated forest. The sampled host trees, either represent alignments that follow the thoroughfare, such as: *Populus nigra* L. (Pustnicul Forest), *Populus* x *canadensis* Moench s. l. (*P. deltoides* x *P. nigra*) for Bolintin-Deal Forest, *Populus* x *canadensis* (Căscioarele-Malu Spart Forest) or are integrated parts of forestry composition, for instant: *Robinia pseudacacia* L. (Goştilele Forest), *Quercus frainetto* (Comana Forest), *Q. robur* (Călăreţilor Forest), and *P. nigra* (Snagov Forest). From Băneasa, Vlădiceasca, Sinteşti, and Râioasa forests, the samples were collected from lignicolous substrata.

The collected samples were placed in paper envelopes and then have been transported to laboratory. Whole thalli showing mature apothecia were collected from each studied forests. Thalii of *Xanthoria parietina* were collected from only one point in each investigated forest and a total of 11 samples were collected for the heavy metals analysis. One analysis for each heavy metal was performed at each investigated forest. The collection of lichen thalii from the base of the trunk up to 1.5 m is closely related to the contamination with heavy metals of the roadside soils, especially by vehicular traffic (Aslan et al., 2011). The elements are taken up from the soil by tree roots and subsequent translocation to the bark and thus, have a significant impact on element concentrations in the lichen thalii (Hauck and Spribille, 2005).

In the laboratory, the lichen samples were cleaned with tweezers to remove impurities. The mineralization of lichen samples was performed at controlled pressure and temperature with a Milestone digestor by using 6 ml HNO_3 (65%) and 1 ml H_2O_2 (35%). The heavy metals (Pb, Cd, Cr, and Zn) from collected lichen thalli were analyzed by atomic absorption spectrometry with flame and furnace atomization, using a ContrAA 700 spectrometer (Analytik Jena, DE).

2.4. The characterization of pollution sources from the studied area

Within the metropolitan area of Bucharest, environmental quality is mainly affected by industrial activities, such as: power stations (South, West, Grozăveşti, Progresul, and Titan power stations), the chemical industry (SC Rodmir Expert SRL, SC Chimester SRL, SC Chimopar SA, SC Rasin SRL, Policolor SA etc.), the metallurgical industry (SC Neferal SA, SC Doosan IMGB SA, etc.), the engineering industry (SC Urbis Armături Sanitare SA, SC Aversa SA, SC Electromontaj SA, etc.), the extractive industry (exploitation of oil from Ileana, Bolintin-Vale, Jilava, Căţelu areas, as well as gravel exploitation along Argeş, Danube, and Ialomiţa rivers), electronics and electrotechnical activities (Electromontaj SA, Electroaparataj SA), building materials (Cesarom SA, Granitul SA, SC Lasselberger SA, SC Stirom SA), etc. All the listed activities represent a high risk for the environmental health, 49 of economic business categories being subject to an integrated pollution control (Iojă, 2008).

The power stations release airborne pollutants into the atmosphere, including sedimentable particulate matter, sulphur oxides, nitrogen oxides, etc. The chemical industrial units are responsable for emissions of ammonia (NH_3), hydrochloric acid (HCl), molecular chlorine (Cl_2), nitrogen oxides, sulphur oxides, organic solvents, copper ammonia solution, etc. Airborne and sedimentable particulate matter, with a high content of heavy metals, sulphur and nitrogen oxides, and volatile organic compounds are emitted by the metallurgical and engineering industrial activities (Iojă, 2008).

The agricultural activities, affect environmental quality by mechanization, irrigation, and chemical treatment. The livestock farms (SC Agronutrisco SRL Mihăileşti, SC Golden Chicken SRL Mihăileşti, SC Comsuin SA Ulmeni, etc.), have a negative impact on the environment due to malfunction of installations, improperly treated sewage and animal waste (Iojă, 2008). Vehicle traffic, represents the main sources of Pb pollution, 95% of Pb emissions being recorded within the studied area. Also, railway and air traffic, contribute significantly to environmental pollution (Iojă, 2008).

2.5. Data analysis

Metal concentrations measured in the proximity of roads (i. e. nationals, county, forestry roads) were compared with those measured far away from any thoroughfare.

The Shapiro-Wilk test was used to show whether the data set has a normal distribution. The chosen p value is 0.05 (Mason et al., 2003). This test has shown a non-normal distribution of the collected data; therefore the correlations between heavy metal concentrations and the variables taken into account (the number of car units, the distance from Bucharest, and the distance from nearest roads) were determined using the Spearman Rank Order Correlation Coefficient (Măruşteri, 2006). The value of the non-parametric Kendall Rank Order Correlation test was used as an indicator of the strength (real significance) of the relationship between two variables (Dytham, 2011; Zar, 1998). The Kendall Rank Order Correlation test was used to showing the significance of the relationships between the elements and the variables considered within this study (number of vehicles, the distance from Bucharest, and the distance from neared roads).

The statistical analysis of collected data was performed with PAST (Hammer et al., 2001). The nomenclature used for lichens is according to Ciurchea (2004). The nomenclature of host trees is according to Ciocârlan (2009). The data regarding the heavy metal concentrations were interpreted using the intensity of car traffic, measured as a number of running car units for a 10 minute period (Donica, 2007) in the proximity of sampled trees. For the investigated forests that are not connected to roads but are surrounded by agricultural fields, the higher concentrations of heavy metals might be caused by chemical substances used as agricultural treatment. The car units were countered one-time for Pustnicul, Snagov, Bolintin-Deal, and Căscioarele-Malu Spart forests. Regarding the other investigated forests, no data was available about car traffic intensity because they either were not connected to roads or the road traffic occured rarely (exceeding 10 minutes as a reference for this study).

The Pb value of 59.83 μg/g (Table 1), is clearly an outlier; therefore this value is treated as a particular case for Pustnicul Forest. The sampling protocol was set up taking into account the intensity of vehicle traffic as one of the serious sources of atmospheric pollution. Also great importance was attributed to the distance from the road to the sampled tree trunks and to the site where lignicolous substrata were found. The map was constructed using ArcGis 9.3 (Environmental System Research Institute, Redlands, California, USA, http://www.esri.com).

3. Results and discussion

The investigated forests were classified into four groups, as follows: the Northern group (Băneasa, Vlădiceasca, and Snagov forests), the Eastern group (Pustnicul, Goştilele, and Călăreţilor forests), the Western group (Râioasa, Bolintin-Deal, and Căscioarele-Malu Spart forests), and the

Southern group (Sinteşti and Comana forests). The classification of the investigated forests into four groups allowed the assessment of heavy metal concentrations according to the distance from Bucharest along the principal roads, such as: National Road 3 (the eastern group), the county and forestry roads for the other forests (Table 2).

3.1. Relationship found for heavy metal content and the distance from Bucharest and nearest roads

Significant relationships ($r_s > 0.10$) between heavy metal concentrations (Cd and Cr) and the distance from Bucharest have been recorded (r_s = 0.54 and r_s = -0.59, respectively). The relationships between Pb and Zn concentrations and the distance from Bucharest indicate insignificant ($r_s < 0.10$) weakly positive relation ($r_s = 0.13$) and a moderate negative relation ($r_s = -0.41$), respectively. The Kendall correlation coefficient (τ) indicate significant correlations ($\tau > 0.10$) between the Cd and Cr concentrations and the distance from Bucharest (τ = 0.38 and $\tau = -0.43$) and insignificant correlations (τ < 0.10) between Pb and Zn concentrations and the distance from Bucharest ($\tau = 0.09$ and $\tau = -0.28$).

Thus, within the investigated area Cr concentrations decrease depending on the distance from Bucharest, while the Cd concentrations increase depending on the distance from the Bucharest. It has been pointed out, that car traffic is an important sources of Cr and Cd elements (Uluozlu et al., 2007; Aslan et al., 2011).

The opposite behaviour of Cd and Cr, depending on the distance from Bucharest is explained by the permanence of Cr concentrations in the proximity of the roadsides and by the dispersion of Cd concentrations over relatively large distance from the thoroughfares (Poikolainen, 2004; Bajpai et al., 2011). Moreover, it was pointed out that Cd shows highest concentrations in agricultural soils (Williamson et al., 1996), and is found as a natural element in soil and rocks (Burlacu, 2010), as well as in roadside soils (Aslan et al., 2011).

According to field observations in the studied area, most of the investigated forests are surrounded by agricultural fields. All these sources of Cd might have a synergistically impact concerning the assessment of heavy metals pollution in *Xanthoria parietina* thalii. An interesting situation was detected within the western forestry group, where Pb, Cd, and Cr concentrations are lower in comparison to the value recorded for Zn (Tables 1 and 2). Higher Zn concentration was associated with automobile tyre wear and incomplete combustion of fossil fuel (Bajpai et al., 2011).

Also, Zn is a common component in diesel oil, brakes, and even unleaded petrol (Aslan et al., 2011). The heavy metal concentrations, especially Zn concentration, recorded in Bolintin-Deal Forest are influenced by the intensity of vehicular traffic (63 car per 10 minutes) (Tables 1 and 2).

Generally, within the studied area, the Pb concentrations are increasing as a function of the distance from Bucharest (r_s = 0.13) and the Zn concentrations are decreasing as a function of the distance from Bucharest (r_s = -0.41). A significant increase in Cd concentrations with the distance from Bucharest was recorded within the northern forestry group. For Zn within the northern and eastern forestry groups the content decreased with the distance from Bucharest. No major differences regarding the Pb concentrations were recorded within the other investigated forests (Tables 1 and 2).

The correlation of heavy metals content with the distance from nearest roads was also investigated, the concentrations of Pb, Cd, Cr, and Zn showing only insignificant ($r_s < 0.10$) moderate negative relationships (r_s = -0.34; r_s = -0.25; r_s = -0.11; and r_s= -0.36). The value of the Kendall Correlation Coefficient do not indicate a strongly significant relationship ($\tau < 0.10$) between the nearest roads and the Pb, Cd, Cr, and Zn concentrations (τ = -0.23; τ = -0.16; τ = -0.11, and τ = -0.31). At the closest distance, 2 m between the road and the sampled trees, the highest concentrations of Pb and Zn were recorded within Pustnicul Forest. The Zn concentrations were higher also in lichen thalli growing on tree bark closest (2 m) to the roads in Bolintin Deal and Căscioarele-Malu Spart forests (Table 1, Table 2). For all the other forests that are located 1 km or more from the road, the heavy metal concentrations are rather low (Table 1, Table 2). As in the other study (Bajpai et al., 2011), the highest Pb and Zn concentrations were detected in roadside samples, indicating the car traffic as the major pollution source.

The high Pb concentration, recorded in Pustnicul Forest (Table 1) is related to the highest intensity of car traffic measured in Pustnicul Forest (Table 2). The value recorded to Pb in Pustnicul Forest represents a particularity for the studied area (Table 1). The increase in the distance from the sampled trees is correlated to a decrease in heavy metal concentrations. In similar studies, the heavy metal contents (Pb, Cd, Zn, etc.) were higher in the proximity of the roads than in samples taken at a distance from the roads (Uluozlu et al., 2007; Aslan et al., 2011; Bajpai et al., 2011).

3.2. The relationships between the heavy metal concentrations and the number of the vehicles within the investigated area

Within the investigated area, no significant relationships could be identified between the Pb, Cd, Cr, and Zn concentrations and the vehiculars number ($r_s < 0.10$). For Zn concentrations, the value of Spearman Coefficient indicate a positive relationships with the number of vehicles (r_s = 0.80). The obtained values of Kendall Coefficient explain also, an insignificant ($\tau < 0.10$) positive relationships (τ = 0.60) between the Zn concentrations and the number of car units.

Table 1. The spatial distribution of the heavy metal concentrations in sampled forests

Investigated forests	*Heavy metals content (μg/g)*			
	Pb	*Cd*	*Cr*	*Zn*
Băneasa Forest	0.57	0.03	14.74	37.88
Vlădiceasca Forest	3.84	0.19	7.14	7.26
Snagov Forest	3.58	0.29	10.42	6.84
Pustnicul Forest	59.83	0.10	10.31	65.88
Goştilele Forest	4.23	0.10	6.24	17.95
Călăreţilor Forest	3.20	0.13	8.07	14.50
Râioasa Forest	0.45	0.04	9.19	22.00
Bolintin-Deal Forest	1.37	0.21	11.13	69.02
Căscioarele-Malu Spart Forest	0.52	0.10	7.54	40.34
Comana Forest	0.63	0.09	9.30	21.46
Sinteşti Forest	0.81	0.12	5.73	18.79
Mean ± Standard Deviation	7.18±17.52	0.12±0.07	9.07±2.57	29.26±21.62

Table 2. The number of running vehicular units recorded in forests from the studied area

The investigated forests	*The number of running vehicular units per 10 minutes*	*The roads*	*The distance of investigated forests from Bucharest (km)*	*The distance between the nearest roads and the sampled trees (m)*
Băneasa Forest	-	Padina Street (urban road)	11	1000
Vlădiceasca Forest	1	Forestry Road	25	2
Snagov Forest	9	County Road 101 M	32	500
Pustnicul Forest	120	National Road 3	17	2
Goştilele Forest	-	County Road 402	32	350
Călăreţilor Forest	-	National Road 3	40	3000
Râioasa Forest	-	County Road 602	20	1000
Bolintin-Deal Forest	63	County Road 601	22	2
Căscioarele-Malu Spart Forest	13	County Road	40	2
Sinteşti Forest	-	County Road 401 A	15	2000
Comana Forest	-	County Road 411	32	1000

Thus, the higher concentrations of Zn were recorded especially in Pustnicul and Bolintin-Deal forests (65.88 μg/g and 69.02 μg/g) correlated to 120 and 63 vehicular units, respectively (Tables 1 and 2). The Spearman Coefficient for Cd and Cr shows a negative relationship (r_s = -0.41) and a positive relationship (r_s = 0.50), respectively with the number of car units. In the case of Cd and Cr, the Kendall Coefficient values explain insignificant ($\tau < 0.10$) relationships between these elements and the number of car units ($\tau = -0.31$ and $\tau = 0.40$). Regarding the Pb concentrations in a relation with the number of car units, a very weak relationship (r_s = 0.10) was obtained. The value of Kendall Coefficient do not indicate a correlation between the Pb concentrations and the number of recorded car units.

Within the investigated forests, the Pb, Cr, and Zn concentrations increase depending on the number of vehicles while Cd concentrations, decrease depending on the number of car units. A correlation between higher concentrations of heavy metals, such as: Pb, Cr, and Zn and car traffic has been shown (Uluozlu et al., 2007; Aslan et al., 2011; Bajpai et al., 2011).

3.3. Comparisons with other similar studies

There is a great difference between forestry ecosystems strongly affected by anthropogenic activities and those with relatively high environmental quality. In the eastern part of Bucharest both the intensity of vehicular traffic on National Road 3, Bucharest-Feteşti, and the industrial units, such as: Acumulatorul SA and SC Neferal SA, represent important sources of atmospheric pollution; the most affected by industrial emissions are Cernica, Pustnicul, Căldăraru, and Pantelimon Park forests, situated in the eastern part of Bucharest (Iojă, 2008).

In general, within both eastern and western forestry groups, the concentrations of Pb and Zn recorded near the roads from Pustnicul and Bolintin-Deal forests are the highest. With the increasing distance from the most polluted areas of Bucharest (Iojă, 2008) a decrease of Zn concentrations and an increase of Pb concentrations was noticed (Table 1, Table 2). The high level of environmental alteration associated with accumulation of Pb and Zn indicate that both Pustnicul and Bolintin-Deal forests are affected by high levels of atmospheric pollution.

The Pb is a well known tracer of leaded fuel and it has been shown that the Pb content of lichens accurately reflects the volume of the car traffic (Loppi and Frati, 2006; Donica, 2007). Nowadays, leaded fuel is not used.But, this element is very stable and still remains present in environment (Cuny et al., 2004). The harmful effects on lichen species were positively correlated to highest concentrations of heavy metal (Pb, Zn, and Fe) detected around a steelworks (Seaward, 1974). The increase in distance from pollutant sources is closely related to a decrease in the heavy metal concentrations in lichen thalli and an improvement of atmospheric quality (Nieboer et al., 1972).

The Zn concentration recorded in Băneasa Forest was much higher (37.88 μg/g) than all the other concentrations of the chemical element analysed (Table 1; Table 2). The Băneasa Forest is surrounded by roads with heavy car traffic where the main sources of Zn contamination are from manufactured materials, such as the gear box, lubricant oils etc. (Rusu et al., 2002; Lovász et al., 2005), pesticide etc. (Donica, 2007).

In Pustnicul Forest, the higher concentration of Pb might be associated with harmful effects on human health, such as neurobehavioral diseases (Velea et al., 2009). In the Brăneşti locality (Ilfov County) located near Pustnicul Forest, the high level of Pb has caused health problems in the human population, as in 2004, Ilfov Public Health Direction identified 15 patients with saturnine poisoning (Iojă, 2008). In other studies it was pointed out that the lead content in the blood of children from Pantelimon locality (situated on the eastern part of Bucharest) was significantly higher than those from Bucharest (Velea et al., 2009). In the studied area, the effects of atmospheric pollution on both human and ecosystems health are rather significant, cardiovascular and respiratory affections being reported (Iojă, 2008).

It is known that many form of anthropogenic activity, such as: industrial waste combustion, car traffic, steel works, industrial electroplating, and agricultural applications are sources of Cr contamination (Donica, 2007; Uluozlu et al., 2007; Bajpai et al., 2011). On the other hand, Cr is one of the chemical elements that is an essential nutrient for plant, animal, and human metabolism, but with a high toxicity at eleveted concentrations (Bartók et al., 1996; Uluozlu et al., 2007; Aslan et al., 2011). According to Loppi and Frati (2006) the high concentration of Cr detected in the atmosphere is associated with particulate matter and trapped soil particles. The Cr concentrations recorded in Pustnicul and Bolintin-Deal forests could be related to the intensity of vehicular traffic (Tables 2 and 3). In a study performed on atmospheric heavy metal pollution in Katni and Rewa localities (India) using *Pyxine cocoes* (Sw.) Nyl. and *Phaeophyscia hispidula* (Ach.) Essl., it was observed that the maximum amount of Cr was reported in the samples collected from roadside areas having intense car traffic activities (Bajpai et al., 2011).

Although in small amounts Cr is an essential nutrient required in plants and animals metabolism, at high level it may cause severe disorders even in humans, including lung cancer (Uluozlu et al., 2007).

Within the investigated forests from northern part of Bucharest, the influence of vehicular traffic is rather lower, mainly reflected by the Pb concentrations (Tables 1 and 2); however the concentrations that were recorded for Zn might have been caused also by the effect of agricultural practices (Williamson et al., 1996; Donica, 2007), considering that the agriculture within rural parts of metropolitan Bucharest, represents one of the most important rural activities (Pătroescu et al., 2007).

The soils contamination is considered an important factor that affects the epiphytes on the trunk surface. The chemical elements are taken up from soil borne by tree roots and deposited primarily in bark of trees and then in lichen thalii (Hauck et al., 2006). Sources of soil contamination include industrial activities, agricultural practices, urban effluent, traffic emission etc. (Aslan et al., 2011; Hauck et al., 2006; Qishlaqi and Moore, 2007).

4. Conclusions

The *Xanthoria parietina* species, is a good indicator of heavy metals accumulation due to its resistance to atmospheric pollution caused by vehicular traffic. Generally, the higher concentrations of Pb and Zn were recorded in the lichen sample collected from the roadside areas with a heavy vehicular traffic, such as: Pustnicul and Bolintin-Deal forests. Thus, within this paper, the lead and zinc were selected as heavy metals whose measured values represent a valuable indicator of environmental pollution especially for Pustnicul and Bolintin-Deal forests.

The outlier value of Pb in Pustnicul Forest is close related to a high number of car units recorded exclusively for this forest; therefore this fact brings to light a particular case for the study area. The Cd and Pb concentrations are increasing and the Cr and Zn are decreasing as a function of the distance from Bucharest. The increasing of the distance from nearest roads and sampled trees is negatively correlated with a decrease in heavy metal concentrations.

The Pb, Cr, and Zn concentrations increase with the number of vehicles and the Cd concentrations decrease with the number of vehicles. Thus, the investigated forests far from road traffic represent sites with a relatively good atmospheric quality.

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