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THE EFFECT OF HEAVY METALS ON MITE COMMUNITIES (ACARI: GAMASINA) FROM URBAN PARKS - BUCHAREST, ROMANIA

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Abstract

This paper presents the effect of heavy metal soil pollutants (Pb, Cd, Cu, Zn) on soil mite communities in three urban parks within Bucharest, Romania: Cişmigiu, Unirea and Izvor. For each park, the investigations were based on three transects that were established in relation to the nearest source of air pollution i.e. heavy traffic from the main boulevards. The study was carried out in 2007. 405 soil samples were collected, comprising 14 species of Gamasina. The highest numerical density was recorded in Unirea Park and the lowest in Cişmigiu Park. With reference to measured concentration of heavy metals from soil samples, the concentrations in Cişmigiu Park exceeded the reference permissible values and alert limits (according to National and European legislation) in all three transects. In Unirea Park, these limits were exceeded for Pb concentration in all three transects and for Zn concentration in one of them, transect 3. In Izvor, Pb, Cu and Zn concentrations exceed the reference permissible values and alert limit in transect 2. According to the multivariate analysis, the abundance of mite species was significantly related to humidity, pH, Cd and Cu concentration. pH and soil moisture content were significantly correlated with mite species abundance, the correlation being positive for soil moisture and negative for pH. This analysis indicated a significant negative effect of Cd concentration and a significant positive effect of Cu concentration on mite species abundance.

Key words: mites, pollutant, population, urban

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1. Introduction

According to the European Environment Agency, although the distribution of soil pollution sources across economic sectors differs from country to country, industrial activities are responsible for over 60% of Europe's soil pollution (the oil sector accounts for 14% of this total). The most common harmful contaminants are heavy metals (37%) and mineral oils (33%) (EPA, 2009). Not only are humans and plants affected, but also the soil (Balaban et al., 2018; Li et al., 2017). Increasing recognition of problems of soil degradation identified soil fauna research as a priority in soil quality assessments. Most invertebrates have life cycles that are highly dependent on their immediate environment, interacting with soil in several different ways. To be able to evaluate their role and function, it is important to use methodologies that highlight either the number of species present or the processes and roles that they play in the soil environment (Parissi et al., 2005; Ruf, 1998; Rusek and Marshall, 2000).

The effects of heavy metal pollution on the community structure of soil arthropods have been demonstrated by many researchers (Cortet et al., 1999; Gillet and Ponge, 2002; Haimi and Mätäsniemi, 2002; Migliorini et al., 2004; Pouyat et al., 1994; Van Straalen et al., 2001; Zvereva and Kozlov, 2010).

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Among soil invertebrates, mites are considered very sensitive to heavy metal contamination. They have high species diversity and are abundant in the forest soil, especially in the organic layer, where they contribute to litter decomposition (Gwiazdowicz et al., 2011; Monroy et al., 2011; Russell and Alberti, 1998; Walter and Proctor, 1999). Therefore, any disturbances in the density and species composition of mites under the influence of heavy metals affect the rate of soil organic-matter transformation and soil fertility (Bengtsson and Tranvik, 1989; Filser et al., 2008; Haimi and Mätäsniemi, 2012; Russell and Alberti, 1998; Seniczak, 1995; Seniczak et al., 2002; Skubała and Kafel, 2004). This is the reason that mites are considered as precious bioindicators for soil quality (Beaulieu and Weeks 2007; Coja and Bruckner, 2006; Koehler, 1999; Nahmani et al., 2006; Ruf, 1998).

In Romania just a few studies regarding the influence of heavy metals on mites have been developed (Manu et al., 2017; Teodosiu and Castells, 2017). In 1984, Georgescu studied the influence of heavy metals (Cu, Cd, Zn, Mo, Fe, Mn) on Gamasina mites from the Zlatna industrial area. The study signalled a decrease in the species diversity, especially in the deeper soil layers, but an increasing density of the most active and parasitic species. Another study revealed influences of some air pollutants (SO_2, NH_3, HCl) on mite diversity the Neamţ district (Călugăr et al., 1983).

In Europe, the impact of heavy metals (from different sources e.g. metallurgical plants and dumps, air pollution, experimental studies with contaminated soils) on mite diversity, species structure and dynamics was studied by many specialists (Bengtsson and Tranvik, 1989; Janssen et al., 1990; Russell and Alberti, 1998; Salminen et al., 2002; Seniczak and Seniczak 2002; Seniczak et al., 1998, 2002; Siepel, 1995; Zaitsev et al., 2001).

The soil mite communities from urban ecosystems have been studied in Poland and Germany. These studies revealed a characteristic structure and dynamics for these invertebrates, correlated with vegetation and other environmental factors (type of soil, humidity, pH) (Kropczynska et al., 2002; Niedbała et al., 1982; 1990; Weigmann, 1995).

Other studies of soil mite communities in urban parks within Bucharest demonstrated that the complex soil-vegetation-abiotic factors influenced community structure, but these studies did not consider the concentration of heavy metals in urban soils (Honciuc and Manu, 2010; Manu, 2008; Manu and Honciuc, 2010; Vasiliu-Oromulu et al., 2011). In this paper we examine the effect of soil pollutants (Pb, Cd, Cu, Zn) on soil mite communities from three parks, taking into account two other abiotic parameters: soil acidity and soil water content. At the same time, the present study seeks to test the following hypothesis: did the heavy metal pollutants from different transect (with the nearest source of air pollution being the intense traffic on the main boulevards) influence the mite community structure?

2. Case studies

2.1. Study area

The study was carried out in 2007 in three parks within the central area of Bucharest city: Cişmigiu Park (N=44^{0}25,56.6$^{"}$; E=26^{0}05,27.5$^{"}$), Unirea Park (N=44^{0}25.5,56.6$^{"}$; E=26^{0}08,09.9$^{"}$) and Izvor Park (N=44^{0}25,56.4$^{"}$; E=26^{0}05,27.8$^{"}$). In these parks, the native vegetation has almost disappeared, being replaced by trees brought from Europe, China, Japan and America. The dominant autochthonous and European planted species are presented in Table 1. Some natural plant species remained, reflecting the modified conditions of an urban ecosystem. Car pollution is likely to increase atmospheric NOx and deposition levels greatly resulting in both higher fertility and reduced pH in urban areas. Other characteristics of urban parks are dryness and increased temperature (Stevens et al., 2004). Plant species (trees, shrubs and herbaceous) have a varied distribution in the three investigated parks (Onete and Paucă-Comănescu, 2008).

2.2. Soil analysis

The soil from the urban parks was mostly sandy, with a low content of organic matter (the litter-decomposition layer is very thin and often the humus layer is missing). A thin litter-decomposition and humus layers were identified only in Cişmigiu Park, where the vegetation is better represented.

Within each park, the soil samples were collected from three transects (T1- near and parallel to the most major adjacent road, T2- near and parallel to another side of the studied area and T3 - in the middle of the studied area). The transect length varied between 74 - 390 meters and the width about 5 meters. Transects were selected taking account of their variation in distance to the nearest air pollution source i.e. the intense traffic on main boulevards (Fig. 1).

In order to measure the soil moisture content (%), four samples per transect and per season were collected. The volume of each sample was 98.12 cm^3. In total, 36 soil samples/ park were collected and soil moisture content were analyzed using the gravimetric method, while the soil pollutants were measured using an atomic absorption spectrophotometer. The concentrations of heavy metals are indicated in gkg^{-1}. Following 180 measurements, a mean of the results was derived (with standard deviation= SD), representing the values for each studied transect in each year.

2.3. Mite analysis

Gamasina mites were collected using a MacFadyen soil corer to 10 cm depth. In total 405 samples were collected. In each urban park, five samples per transect were collected with three replicates in each of three seasons: spring, summer and autumn. Extraction was performed with a modified

Berlese-Tullgren extractor, in ethyl alcohol, by 90 %, for ten days, in natural light. Mites were sorted from the samples under a Zeiss binocular microscope and then clarified in lactic acid. The mites were identified to the genus and species level using the Zeiss microscope and the key for Gamasina identification (Ghiliarov and Bregetova, 1977; Gwiazdowicz, 2007; Hyatt, 1980; Karg, 1993; Masan, 2003; Masan and Fenda, 2004; Masan, 2007; Masan and Halliday, 2010). All identified specimens were preserved in ethyl alcohol and stored in the collection of the Institute of Biology.

2.4. Statistical analysis

To test the effect of soil moisture content, pH, Cu, Pb, Cd, Cu, and Zn concentration on soil mite communities we used a generalized linear model (GLM) approach (abundance: Poisson errors and log link function).

Table 1. Characterization of investigated parks within Bucharest

Characteristics	***Cişmigiu***	***Unirea***	***Izvor***
Vegetation (dominant species)	Herbaceous: *Cynodon dactylon* (L.) Pers.; *Dactylis glomerata* L., *Elymus repens* (L.) Gould.; *Lolium perenne* L.; *Agrostis stolonifera* L.; *Atriplex patula* L.; *Lamium amplexicaule* L.; *Taraxacum officinale* Weber ex. Wiggers; *Trifolium hybridum* L.; *Trifolium pratense* L.; *Trifolium repens* L. Shrub: *Sambucus nigra* L., *Thuja orientalis* L., *Hedera helix* L., *Spiraea alba* Duroi; *Syringa vulgaris* L.; *Buxus sempervirens* L.; *Corylus avellana* L; *Forsythia europaea* Degen. et Bald; Tree: *Acer platanoides* L.; *Acer pseudoplatanus* L.; *Aesculus hippocastanum* L.; *Tilia cordata* Miller; *Gleditsia triacanthos* L.	Herbaceous: *Dactylis glomerata* L., *Poa pratensis* L.; *Polygonum aviculare* L.; *Cynodon dactylon* (L.) Pers.; *Trifolium repens* L., *Capsella bursa-pastoris* (L.) Medik Shrub: *Forsythia europaea* Degen. et Bald; *Rosa canina* L., *Spiraea alba* Duroi; *Tamarix tetrandra* Pallas ex. Bierb. Tree: *Quercus rubra* L., *Tilia cordata* Miller; *Rhus hirta* (L.) Sudworth	Herbaceous: *Cynodon dactylon* (L.) Pers.; *Dactylis glomerata* L., *Elymus repens* (L.) Gould.; *Lolium perenne* L.; *Plantago lanceolata* L.; *Polygonum aviculare* L.; *Taraxacum officinale* Weber ex. Wiggers; *Trifolium hybridum* L.; *Trifolium pratense* L.; *Trifolium repens* L. Shrub: *Forsythia europaea* Degen. et Bald; *Ligustrum vulgare* L., *Spiraea alba* Duroi. Tree: *Platanus hispanica* Miller ex. Muench.; *Populus nigra* L. cv. *italica* Moench.; *Populus tremula* L.; *Quercus rubra* L.; *Tilia cordata* Miller; *Tilia platyphyllos* Scop.
Geographical coordinates:	N=44^{0}25'56.6"; E=26^{0}05'27.5"	N=44^{0}25.5'56.6"; E=26^{0}08'09.9"	N=44^{0}25'56.4"; E=26^{0}05'27.8"
Area (ha)	15.41	2.34	14.03
Coverage:	91%	66.8%	61%
Canopy:	39.4%	15,9%	4.3%
Type of soil:	Sandy, with a thin layer of litter-fermentation and humus layers	Sandy	Sandy
pH:	7.15	7.45	6.73
Soil moisture content (%)	10.78	12.36	9.88

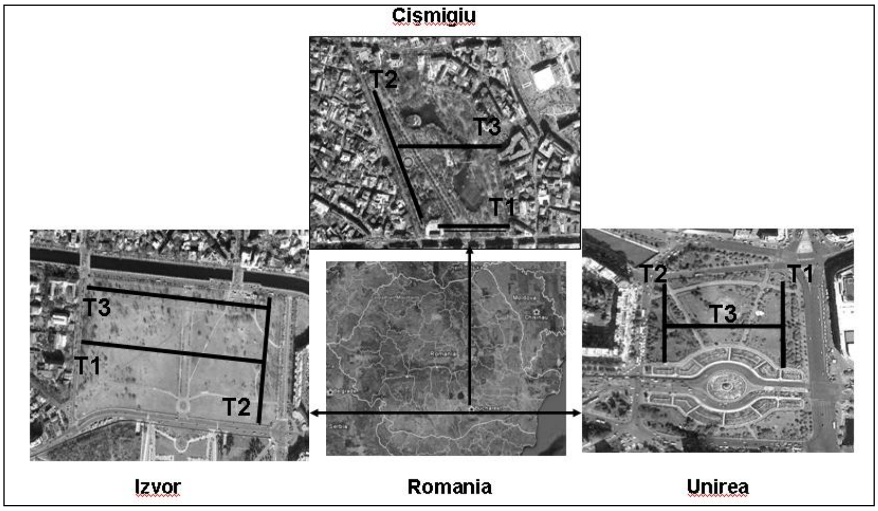

Fig. 1. Investigated transects (T1, T2, T3) from three parks in Bucharest

We used canonical correspondence analysis (CCA) to investigate the associations between mite communities and environmental variables (Legendre and Legendre, 2000; Ter Braak and Verdonschot, 1995). We used the forward selection procedure with Monte Carlo simulations (199 permutations) to constrain the final model to include only those environmental variables significant at $p < 0.05$. CCA was carried out using the vegan package in R version 1.8.1 (R Development Core Team, 2003) whereas GLM was performed using SPSS version 17.0 (SPSS Inc., 1999).

3. Results and discussion

Among the abiotic factors, the highest mean soil moisture content was recorded in Unirea and the lowest in Izvor. Examining the individual transects, the highest value was recorded in T1 from Unirea and the lowest in T1 from Izvor (Table 2).

The average values of soil pH varied from 7.15 in Cişmigiu to 7.45 in Unirea and 6.73 in Izvor (Onete and Paucă Comănescu, 2008; Manu and Honciuc, 2010). At the transect level, in all three parks the lowest pH values were recorded for T1 whilst the higher pH values were found for T2. The presence of tree layers near the main boulevards and the associated intense traffic could determine this pattern in soil acidity (Table 3).

Romanian law (O.G. no 756/1997) defines values for pollutants that are regular occurring within the environment (termed "reference values") and values that require intervention as they reflect a seriously polluted situation (termed "alert values"). Limit of alert is represented by the pollutant concentrations on which the competent authorities are alerted, concerning a potential impact on the environment, which requests an additional monitoring and/or measures to reduce their concentrations. Limit of intervention is represented by the pollutant concentrations on which the competent authorities shall establish risk assessment studies and measures for reducing pollutant concentrations. These regulations regarding soil pollution refers both to use sensitive and less sensitive to the land, identified as follows: sensitive usage of the land (residential, recreational areas, agricultural fields, protected areas, areas with sanitary restrictions regime); less sensible usage of the land (industrial and commercial areas). These terms are used subsequently within this paper.

Analysis of heavy metals from soil revealed that in all parks the mean concentrations of Pb, Cu and Zn exceed the reference values and, in the case of Pb within Cişmigiu, even exceed the value set according to Romanian law no.756/03.11.1997 requiring an environmental alert (Table 4). Examining the results for individual transects, the concentrations of Pb exceeded reference values in nearly all transects (except Izvor - T1 and T3) and the limit requiring an environmental alert in all parks (Cişmigiu - T1 and T2; Unirea - T3, Izvor – T2). Similar results were noted for Cu, but with a few exceptions, where the concentrations were lower than reference values (Izvor - T1, T3) and the corresponding limits requiring an environmental alert (Cişmigiu-T1). For Zn all measurements were also higher than the reference values, but in Unirea (T1, T2) and Izvor (T1, T3) the concentrations were lower. Only in the case of Cd did the concentrations not exceed the legal limits according to Romanian and European laws (Table 4).

Fourteen species of Gamasina mites were identified, with 110 individuals. The highest number of species and abundance were recorded in Unirea Park, followed by Izvor and the lowest values were obtained in Cişmigiu Park. When considering individual transects in both Cişmigiu and Izvor, a high species diversity and abundance were obtained in T1 and T2, and the lowest in T3. This trend is in contrast to that observed for soil water content, which increased in Cişmigiu and Izvor according to the range: T1<T2<T3. In Unirea, on T3 was identified the highest parameters and on T2 the lowest (Table 5).

Table 2. The average (±SD) of the relative soil moisture content (%) of soil in parks within central Bucharest for investigated transects

Transects	***Cişmigiu***	***Unirea***	***Izvor***
T1	9.6 (±1.5)	13.72 (± 0.7)	9.27 (± 2.1)
T2	10.73 (± 1.2)	11.38 (± 1.94)	10.1 (± 1.3)
T3	12.01 (± 0.9)	12 (± 1.2)	10.27 (± 1.4)
Average	10.78 (± 1.32)	12.36 (± 1.27)	9.88 (± 1.92)

Table 3. The average (±SD) of the pH of soil in central parks from Bucharest for investigated transects

Transects	***Cişmigiu***	***Unirea***	***Izvor***
T1	7.08 (±1.42)	7.12 (± 0.65)	6.25 (± 1.92)
T2	7.29 (± 1.17)	7.85 (± 1.25)	7.34 (± 1.27)
T3	7.13 (± 0.85)	7.38 (± 1.17)	6.58 (± 1.54)
Average	7.15 (± 1.63)	7.45 (± 1.24)	6.73 (± 1.92)

Table 4. Accepted soil limits on heavy metals, according to European and Romanian laws (European Directive 86/278/EEC; and Waters, Forests and Environmental Protection Ministry Order no.756/03.11.1997) and concentrations of heavy metals (gkg^{-1}) from soils in parks of central Bucharest for investigated transects (T1, T2, T3)

Limits	***Pb***	***Cd***	***Cu***	***Zn***
86/278/EEC				
Limits	50-300	1-3	50-140	150-300
M.O. 756/03.11.1997				
Reference	20	1	20	100
Limit of alert-sensible	50	3	100	300
Limit of alert-less sensible	250	5	250	700
Limit of intervention- sensible	100	5	200	600
Limit of intervention- less sensible	1000	10	500	1500
Cişmigiu				
T 1	124.30	0.22	133.50	232.62
T 2	71.60	0.80	72.00	191.50
T 3	47.72	0.55	29.95	162.45
Average	81.20 (SD= ± 3.4)	0.53 (SD= ± 1.3)	68.5 (SD= ± 4.5)	195.53 (SD= ± 7.2)
Unirea				
T 1	30.16	0.43	22.13	76.80
T 2	29.10	0.44	21.16	72.93
T 3	75.53	0.57	85.76	174.16
Average	44.93 (SD= ± 2.4)	0.48 (SD= ± 0.7)	49.68 (SD= ± 6.2)	107.63 (SD= ± 11.5)
Izvor				
T 1	17.54	0.59	14.24	69.95
T 2	87.86	0.69	80.61	182.88
T 3	15.41	0.48	12.79	67.69
Average	38.94 (SD= ± 5.3)	0.58 (SD= ± 1.3)	35.88 (SD= ± 4.7)	106.84 (SD= ± 12.4)

Table 5. The abundance of mites (Acari: Gamasina) found in transects from the parks of Bucharest

Species	***Cişmigiu***			***Unirea***			***Izvor***		
	T1	***T2***	***T3***	***T1***	***T2***	***T3***	***T1***	***T2***	***T3***
Alliphis siculus (Oudemans, 1905)						2			
Amblyseius meridionalis (Berlese, 1914)							4		
*Ameroseius fimentorum (*Karg, 1971)						4			
Asca bicornis (Caneastrini and Fanzago, 1887)				2		16			
Crassicheles concentricus (Oudemans, 1904)						4			
Dendrolaelaps sp.						2			
Hypoaspis aculeifer (Caneastrini, 1883)		10				2	6	6	
Hypoaspis praesternalis (Willmann, 1949)						6	4		4
Lysigamasus neoruncatellus (Schweizer 1961)				2					
Pachylaelaps furcifer (Oudemans, 1903)								6	
Rhodacarellus perspicuus (Halaskova, 1958)	8	2							
Rhodacarellus silesiacus (Willmann, 1935)	8		2		2		2	2	
Veigaia exigua (Berlese, 1914)							2		
Veigaia nemorensis (Koch,1938)								2	
Total number of individuals	16	12	2	4	2	36	18	16	4

From among the parameters analyzed with GLM (generalized linear modelling) the significant variables were soil moisture content, pH, Cd, Cu and mite abundances (Table 6). The soil moisture content and pH were significantly correlated with mite species abundance, the correlation being positive for soil moisture content and negative for pH.

GLM indicated a significant negative effect of Cd concentration and a significant positive effect of Cu concentration on mite species abundance. The population parameter varied significantly, the highest value being met in Unirea Park and the lowest in Cişmigiu Park (Table 5). No significant difference between mites species abundance was found between transects within each park (Table 6).

The forward selection procedure with Monte Carlo simulations (199 permutations) resulted in the retention of six environmental variables (Table 7). In the multivariate analysis the abundance of mite species was significantly related to sites, transect, season, soil moisture content Cd and Cu concentration (Table 7).

Table 6. Parameter estimate (β), standard error (SE), Wald Chi-square statistic (Wald χ^2), degree of freedom (df) and significance level (P) obtained for the parameters investigated by generalized linear models in relation to abundance of mite species (The significant parameters (α = 0.05) are in bold)

Parameter	***β***	***SE***	***Wald χ^2***	***Df***	***P***
(Intercept)	6.171	2.721	5.143	1	0.023
Soil moisture content	0.031	0.016	3.72	1	**0.054**
pH	-0.755	0.358	4.45	1	**0.035**
Pb	0.000022	0.008	0	1	0.998
Cd	-3.089	0.971	10.126	1	**0.001**
Cu	0.015	0.006	6.058	1	**0.014**
Zn	-0.002	0.004	0.254	1	0.614
Park					
Cişmigiu	-1.394	0.3945	12.48	1	**0.001**
Izvor	0				
Unirea	0				
Transect					
Transect 1	-0.017	0.2695	0.004	1	0.949
Transect 2	-0.465	0.2555	3.31	1	0.069
Transect 3	0				

Table 7. Results of forward selection procedure with Monte Carlo simulations (199 permutations): degree of freedom (df), chi square (chi sq), F- statistics (F) and significance level (P).

Variables	***Df***	***Chi sq***	***F***	***P***
Sites	2	0.0399	5.7769	**0.005**
Transect	2	0.0087	1.2654	**0.005**
Season	2	0.0072	1.0468	**0.005**
Soil moisture content	1	0.004	1.1575	**0.05**
Cd	1	0.0061	1.7622	**0.01**
Cu	1	0.0034	0.9725	**0.05**
Pb	1	0.0018	0.5204	0.44
Zn	1	0.0009	0.2707	0.9

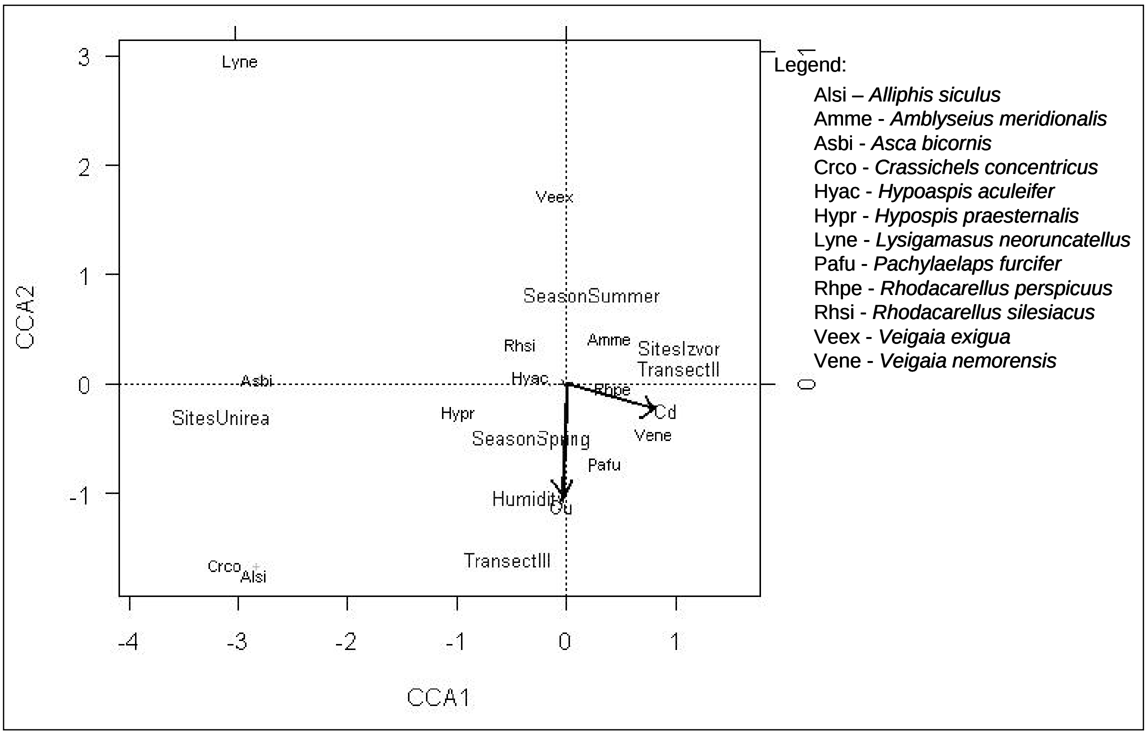

Fig. 2. Canonical correspondence analysis bi-plot on mite species abundance. Length and direction of arrows indicate the relative importance and direction of change in the environmental variables

The association of these significant environmental variables with mite abundance is depicted in a CCA ordination diagram (Fig. 3). The two eigenvalues were 0.035 and 0.012, indicating that the first axis explained 51.73 % of the variability and the second 17.3 % of the variability. The Unirea site was significantly correlated with the first axis (-0.95). In addition Cd concentration was also significantly associated with the first axis (0.27). The second axis was significantly correlated with T3 (-0.48) and Cu concentration (-0.34). Species ordinated close to the vectors have strong relationships with them. Species located near the origin do not show a strong relationship to any of the variables and are found at average value in relation to the environmental variables. *Asca bicornis* was associated with the Unirea site and two other species (*Veigaia nemorensis* and *Rhodacarellus perspicuus*) were associated with relative Cd concentration. *Pachylaelaps furcifer* was highly associated both with T3 and with Cu concentration. These Gamasina species mentioned above which are influenced by the pollutants could be successfully used as bioindicators for soil quality.

The CCA ordination indicated that the presence of some species limited to a single transect and a single park nonetheless resulted in a significant correlation between the abundance of soil mites and transects (e.g. *Amblyseius meridionalis* for Izvor Park-T2; *Crasicheles concentricus* and *Alliphis siculus* for Unirea Park- T3 (Fig. 2).

For soil acidity and soil moisture content, the lowest values of both parameters were recorded in Izvor, compared with medium values from Cişmigiu and the highest values from Unirea parks. The physical, chemical, and biological properties of urban soils are modified by significant site disturbance in creating and using their urban infrastructure. The soil in Bucharest city is sandy, and poorly covered by litter-fermentation and humus layers. Researchers have observed that soil biological properties in urban environments also differ from those in other managed and natural systems, finding that soil decomposition is reduced by 25% and microbial biomass by 50% in urban soils compared to rural soils (Coleman et al., 2004; Gillet and Ponge, 2002; McDonnel et al., 1997; Vilisics et al., 2007). Construction of the infrastructure for a park often involves topsoil replacement, leading to reduced soil organic matter. Removal of grass clippings, tree leaves, and other organic debris can further reduce inputs to the soil organic-matter pool; while organic additions such as top soil replacement, mulch, root turnover, microbial and earthworm activity, grass clippings, and leaf litter left on site help to build soil organic matter (Craul, 1999; Jones and Leather, 2012; Scharenbroch et al., 2005).

The highest number of species and abundances were obtained at Unirea Park (38.18% of the total number of individuals recorded), followed by Izvor Park (34.54%) and Cişmigiu (27.27%). The positive correlations obtained between soil moisture content and mite abundance, demonstrated that this abiotic factor provides a favourable habitat for soil invertebrates. Especially in Unirea Park, the higher values of humidity (12.36%) are reflected in a higher abundance of mites. Soil acidity influenced mite abundance in all three parks investigated.

In terms of mite abundance from individual investigated transects, the highest numbers of Gamasina species were recorded in T1, T2 of Izvor on; T1 of Cişmigiu and T3 in Unirea, despite the concentrations of Pb exceeding the legally admissible limit. Explanations of this phenomenon might be: a) adaptation of some cosmopolitan Gamasina mites to severe environmental conditions (*Hypoaspis aculeifer*); b) able to migrate within the soil, due to their small dimensions (*Rhodacarellus silesiacus, Rhodacarellus perspicuus*); or b) resistant to dry habitats such as agro-ecosystems, dunes or inland meadows (*Veigaia exigua, Hypoaspis praesternalis* and *Amblyseius meridionalis*). *Rhodacarellus silesiacus*, a slender species of the deeper soil, is considered a pioneer species in the natural regeneration process of soils (Bedano and Ruf, 2007; Koehler, 1999; Salmane, 2001). The presence of a thin layers of litter-fermentation and humus in Cişmigiu (about 75% from all described trees, shrubs and herbaceous plants species were identified from this park), could create a favorable habitat for gamasids.

The correlation between pH and abundance indicated that increased acidity leads to an abundant fauna of mites, as in Izvor and Cişmigiu parks. In these areas, the abundant vegetation (high coverage and dense and/or large canopy) developed thin litter-fermentation and humus soil layers, which together are a very suitable habitat for soil mite fauna. Low soil pH is considered to be favorable both for fungi and for other soil invertebrates that constitute the food for predatory mites (Bååth and Anderson, 2003; Klironomos and Kendrick, 1995). These results also confirm the research of Bryant et al. (2005), which demonstrated that total soil organic matter was significantly greater (35%) in older urban soils (as those from Cişmigiu Park) compared with soils from the youngest sites (as Unirea Park).

In Unirea Park, although the soil had the highest pH value (7.45), nonetheless the soil mite communities had the highest abundance. This phenomenon could be explained both by the presence of some characteristic species for this area (e.g. *Alliphis siculus, Ameroseius fimentorum, Crassicheles concentricus*), and by the dominance of other species (e.g. *Asca bicornis, Hypoaspis praesternalis* and *Ameroseius fimentorum*). These species can tolerate dry habitats such as agro-ecosystems, dunes or inland meadows. In addition, due to the soil bulk densities (which are significantly greater in newer compared to older urban soils), these species can migrate as far as 20 cm depth (Bedano and Ruf, 2007; Bryant et al., 2005; Koehler, 1999; Salmane, 2001).

In each investigated park, the relatively similar environmental conditions (vegetation, soil type, small differences in recorded soil moisture values, heavy metal concentrations, which not exceed the limits of interventions-see table 4) for each transect and the small distances between the three transects (50 - 225 metres) resulted in no significant difference in mite species abundance being demonstrated by GLM analysis.

Among the species identified in the present study, some were also found in Romania, within the Zlatna industrially polluted deciduous forests (e.g. *Ameroseius fimentorum*; *Asca bicornis*; *Pachylaelaps furcifer*; *Rhodacarellus perspicuus*; *Veigaia nemorensis*) (Georgescu, 1984). Other species were identified in the Cu polluted pine forest at Glogow, Poland (e.g. *Alliphis siculus*; *Asca bicornis*; *Hypoaspis aculeifer*; *Hypoaspis praesternalis*; *Pachylaelaps furcifer*; *Rhodacarellus silesiacus*; *Veigaia exigua*) (Seniczak et al., 1995).

Some similarities were found within the structure of soil mite communities observed in this study and those recorded from urban parks in Warsaw, where 16-26 species of gamasids were found, with numerical densities between 2462 ind./sq.m. in urban green habitats and 922 ind./sq.m. in parks. From the species identified in the Polish city, the following were also found in Bucharest: *Alliphis siculus, Asca bicornis, Hypoaspis aculeifer, Hypoaspis praesternalis, Veigaia exigua, Veigaia nemorensis* (Niedbała et al. 1982, 1990). These represent 42.65% of all identified gamasids in the Romanian city centre parks. The similarities in the environmental conditions of European urban parks (i.e. allochthonous soils brought with plants or trees from different areas from world, dryness, low quantity of organic matter) could be factors that lead to the development of similar habitats for these cosmopolitan gamasid species.

The number of gamasid species and their abundance are much lower in urban parks compared to natural areas. Worldwide, ruderal sites support about 25 species of Gamasina, shrub ecosystems have 15-40 species, dune habitats 100 species, open grassland sites 20-140 and forest ecosystems as many as 90-150 species, with densities between 4.000 and 10.000 individuals/sq.m. (Bedano and Ruf, 2007; Gulvik, 2007; Gwiazdowicz et al., 2011; Koehler, 1999; Ruf and Beck, 2005; Salmane, 2001, 2003).

In polluted ecosystems with heavy metals, the number of Gamasina species can vary from 54 species in deciduous forest to 30 species in pine forest, with a density between 0.30 and 0.64 individuals per 100 cm^2 (Georgescu, 1984; Seniczak et al., 1995). This feature of urban soil invertebrates (decreased species diversity) is due to specific environmental conditions (soil moisture, pH, dryness, lack of organic matter) or due to the air and soil pollution.

Another factor which influences the species diversity and abundance is the presence of heavy metal pollutants, especially Cd and Cu. The generalised linear model showed that even where the concentrations of Cu and Cd did not exceed the references values and the legal limits requiring notification, they still influence the abundances of mites in Unirea and Izvor parks, as follows: the number of species increases with higher concentration of Cu and with lower concentration of Cd. It is possible that, in the soil of urban parks, the mites migrate and remain within "islands" (where the content of organic matter is richer) or move into deep soil layers (Gulvik, 2007; Koehler, 1999). In Cişmigiu Park, due to the denser vegetation (with the highest measured percentage of cover and canopy: 91% and 39.4% respectively), the heavy metals did not appear to influence the mite population. In this urban area the bioaccumulation level recorded for plants was higher (Onete and Paucă Comănescu, 2008), and this phenomenon could constitute a way that both soil and mites are protected from heavy metal pollution.

In 2002, Polish acarologists demonstrated that the sensitivity of soil mites to Cd is connected with their ability to accumulate Cd from food and eliminate it from their bodies. In laboratory conditions, a low concentration of Cd does not affects the mites, but a higher concentration (251 μg^{-1}) is harmful to them (Seniczak and Seniczak, 2002).

Other researchers have observed that a high concentration of heavy metals reduces the species number of Gamasina, while small concentrations were associated with an increased number of species. The following categories of mites have been distinguished: a) sensitive to heavy metals (some species from genera *Pergamasus* and *Zercon*), b) sensitive to a high concentration, but tolerant of small concentrations (*Asca aphidioides* and *Zercon triangularis*) and c) tolerant of these metals (*Pergamasus crassipes* and *Rhodacarus coronatus*). An altered vertical distribution of mites has been observed in the most polluted soil, due to accumulation of heavy metals in the first 10 cm of soil (Georgescu, 1984; Seniczak, 1995).

Abundance of mite species was significantly related with the parks from Bucharest, transects, soil moisture content, pH, Cd and Cu concentration. Soil moisture content and pH were significantly correlated with mite species abundance, the correlation being positive for soil moisture content and negative for pH. This analysis indicated a significant negative effect of Cd concentration and a significant positive effect of Cu concentration on mite species abundance. Species influenced by the heavy metals concentrations were: *Veigaia nemorensis*, *Rhodacarellus perspicuus* by Cd and *Pachylaelaps furcifer* by Cu.

The multivariate analysis allowed us to give a positive answer to our proposed hypothesis (does the heavy metal pollutant from different transects influence the mite community structure?). The abundances in the soil mite communities were indeed influenced by the recorded Cd and Cu concentrations, taking account of the habitats (urban parks) and transects, especially in transect T3 from Unirea and in transect T2 from Cişmigiu.

Soil Gamasina could be used as a precious management tool for urban areas, due to their response (modification of the population structure) on soil pollution on or other environmental factors (soil acidity and water content, vegetation). These invertebrates represent an important biological component of the edaphically environment and every management plants for existing or future urban green areas must to take into consideration this group.

4. Conclusions

This study revealed that even though concentrations of heavy metals in Bucharest do not exceed the admissible limits of intervention, according to national and European legislation, the recorded values of pollutants (especially the concentrations of Cd and Cu) influenced the structure of the mite communities in urban parks.

This differential response of soil mites to heavy metal pollution demonstrate that they could be used as bio-indicators for cities and for other ecosystems affected by industrial pollution.

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