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DETERMINATION OF HEAVY METAL DEPOSITION IN THE COUNTY OF OBRENOVAC (SERBIA) USING MOSSES AS BIOINDICATORS. III. COPPER (Cu), IRON (Fe) AND MERCURY (Hg)

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Abstract — In this study, the deposition of three heavy metals (Cu, Fe and Hg) in four moss taxa (*Bryum argenteum*, *Bryum capillare*, *Brachythecium* sp. and *Hypnum cupressiforme*) in the county of Obrenovac (Serbia) is presented. The distribution of average heavy metal content in all mosses in the county of Obrenovac is presented on maps, while long-term atmospheric deposition (in the mosses *Bryum argenteum* and *B. capillare*) and short-term atmospheric deposition (in the mosses *Brachythecium* sp. and *Hypnum cupressiforme*) are discussed and given in a table. Areas of the highest contaminations are highlighted.

Key words: Heavy metal deposition, mosses, bioindicators, Serbia

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INTRODUCTION

Surveillance of heavy metals in mosses was originally established in the Scandinavian countries in the 1980's. However, the idea of using mosses to measure atmospheric heavy metal deposition was developed already in the late 1960's (Rühling and Tyler, 1968; Tyler, 1970). It is based on the fact that mosses, especially the carpet-forming species, obtain most of their nutrients directly from precipitation and dry deposition. Nowadays, this method is widely used in many countries (Schaug et al., 1990; Sérgio et al., 1993; Kuik and Wolterbeek, 1995; Berg and Steinnes, 1997a; Pott and Turpin, 1998; Sucharova and Suchara, 1998; Grodzinska, et al. 1999; Tsakovski et al., 1999; Fernández et al., 2000, 2002; Gerdol et al., 2000; Loppi and Bonini, 2000; Figueira, et al., 2002; Schilling and Lehman, 2002; Salemaa et al., 2004; Peñuelas and Filella, 2002; Cucu–Man et al., 2002). Mosses have also been used to analyze contaminants spreading around thermal power plants (Tonguç, 1998; Carballeira and Fernández, 2002) or oil-fired power plants (Genoni et al., 2000).

Moreover, some bryophytes are known to be heavy metal bioindicators in their environments (Samecka–Cymerman et al., 1997; Onianwa, 2001; Nimis et al., 2002; Cuoto et al., 2004; Schröder and Pesch, 2004) and are often used in environmental monitoring (Rasmussen and Andersen, 1999; Giordano et al., 2004; Cuny et al., 2004; Gstoettner and Fisher, 1997; Zechmeister et al., 2005).

In the present investigations, we decided to use two acrocarpous moss species (*Bryum argenteum* Hedw. and *Bryum capillare* Hedw.) that can give us an idea of long-term atmospheric deposition, inasmuch as they are attached to the substrate and also accumulate metals deposed during the last few decades in the surface layers of substrate. In addition, some other *Bryum* species are considered from the standpoint of trace metal deposition (Schintu et al., 2005).

Two pleurocarpous taxa (*Brachythecium* sp. and

Hypnum cupressiforme Hedw.) were used to scan short-term atmospheric deposition of heavy metals, considering that these taxa are not strongly attached to the substrate and accumulate mostly from precipitation (T h ö n i et al., 1996; F a u s – K e s s l e r et al., 2001; F e r n á n d e z and C a r b a l l e i r a 2001; C u o t o et al., 2004).

Mosses are better than other higher plants in scanning heavy metal deposition because:

-they are perennial without deciduous periods;

-they have a high cation exchange capacity that allows them to accumulate great amounts of heavy metals between apoplast and symplast compartments without damaging vital functions of the cells (V á s q u e z et al., 1999); one of the main factors influencing cation exchange capacity is the presence of polygalacturonic acids on the external part of cell wall and proteins in the plasma membrane (A c e t o et al., 2003).

-mosses do not posses thick and strong protective layers like cuticles.

More about hyperaccumulation of metals in plants and mosses can be found in P r a s a d and F r e i t a s (2003). *Bryum argenteum* has already been shown to have special metal accumulation peculiarities (A c e t o et al., 2003; V u k o j e v i ć et al., 2005).

It should also be noted that this time-integrated way of measuring patterns of heavy metal deposition from the atmosphere in terrestrial ecosystems, besides being spatially oriented, is easier and cheaper than conventional precipitation analyses, as it avoids the need for deploying large numbers of precipitation collectors. The higher trace element concentration in mosses compared to rain water makes analysis more straightforward and less prone to contamination (B e r g and S t e i n n e s, 1997b).

Use of mosses to investigate heavy metal deposition shows transboundary heavy metal pollution and can indicate the paths by which atmospheric pollutants enter from other territories or reveal their sources within the investigated area.

Although, 15 heavy metals have been analyzed in all, only deposition and distribution of Copper (Cu), Iron (Fe) and Mercury (Hg) are treated in the present study, due to limitation of space. The presence and distribution of aluminium, arsenic, boron, cadmium, cobalt and chromium in the county of Obrenovac as screened by mosses were considered in two already published papers (S a b o v l j e v i ć et al., 2005 and V u k o j e v i ć et al., 2006).

The mean value of the copper concentration in the Earth's crust is 47 g/t. The sources of copper are its ores: chalcopyrite, cuprite and malachite (T h ö n i and S e i t l e r, 2004). Yearly, 11 million tons are produced worldwide, some 20% are coming from recycling (Metalgesellschaft, 1993). Copper is widely used as an electricity conductor, in architecture, for coins, in the paint industry, and in production of algaecides and fungicides (G r e e n w o o d and E a r n s h a w, 1988). The yearly emission of copper into the atmosphere from anthropogenic sources is ca. 26000 t (P a c y n a and P a c y n a, 2001) and from natural sources ca. 20000 t (L a n t z y and M a c k e n z i e, 1979). In deposition dust in some regions, copper is 1.3-2.8 times more concentrated than in the Earth's crust (T h ö n i et al., 1999).

Copper serves as building matter in many enzymes of extreme importance for plant development, but its use by plants is minimal. A deficiency of copper causes chloroses and changes in the root system of plants. The lives of humans and animals are dependent on copper. However, in higher concentrations it causes hepatitis and hemolytic anemia (T h ö n i and S e i t l e r, 2004). In still higher concentrations it can cause coma and death in humans. Legal limits in developed countries are: emission – 5 mg/m^3; in soil – 40 mg/kg; and in drinking water – 1.5 mg/l (T h ö n i and S e i t l e r, 2004).

Iron is very common in the Earth's crust (46.5 kg/t or 4.65%) (S c h e f f e r and S c h a c h s c h a b e l, 1984). It is produced from ores that contain 20-70% of it. Yearly production is ca. 973 million tons (M e t a l g e s e l l s c h a f t, 1993). It is often used in the production of construction material, glass,

ceramics, plastics, paper, electronic devices, magnets, machines, gears, etc. Anthropogenic emission is ca. 10.7 million tones vs. ca. 27.8 million tons naturally emitted into the atmosphere (Lantzy and Mackenzie, 1979). The biggest emmission sources are industrial accidents and waste (Merian, 1984). Iron is for plants an essential element, vital for chlorophyll synthesis. It is usually insufficiently present in plant substrata, but high concentrations are known to be toxic and induce root illness. In humans and animals, it is essential due to its role in hemoglobin and myoglobin structuring. Acute intoxications with high concentrations of iron are rare, and many humans suffer from iron deficiency of iron especially females (Merian, 1984). In developed countries, its maximum permissible concentration in drinking water is 0.3 mg/l (Thöni and Seitler, 2004).

Mercury is quite rare in the Earth's crust (0.08 g/t), but it is very much present in geo-chemical cycles. In nature, it is mostly present in red sulfides or cinnabar, and from this ore it is industrially produced in amounts of ca. 7000 tons yearly (Trueb, 1996). Because of its mobility, it is widespread in the environment. Some 150000 tons enter the atmosphere from volcanoes every year (Treub, 1996). In 2000, its emission was ca. 200 tons in Europe (Pacyna et al., 2002). The deposition of mercury is 8-13 time highers than its value in the Earth's crust (Thöni et al., 1999). Mercury is essential for living organisms, but higher concentrations are toxic and in plants cause developmental problems, chloroses, and necroses (Bergmann, 1988). In animals and humans, it is very toxic in small concentrations, especially its methylated forms, which cause much damage to SH groups of proteins and DNAs. Many nerve diseases are known to be induced by mercury toxicity. In developed countries, its emission limit is 0.2 mg/m^3, while in soil its content is limited to 0.5 mg/kg and in drinking water to 0.001 mg/l (Thöni and Seitler, 2004).

MATERIAL AND METHODS

The acrocarpous mosses *Bryum argenteum* and *Bryum capillare* were used to research long-term atmospheric deposition, while the pleurocarpous *Brachythecium* sp. and *Hypnum cupressiforme* were used to scan short term atmospheric deposition in the county of Obrenovac (Serbia). *Hypnum cupressiforme* is one of the standard species used in Europe for heavy metal deposition surveys (Buse et al., 2003), whereas the other three standard species used for this purpose in Europe do not grow in the Obrenovac region. In judging which other species are eligible for heavy metal deposition monitoring, the experience of Thöni (1996), Herpin et al. (1994), Siewers and Hairpin (1998) Zechmeister (1994), and Ross (1990) was consulted.

As far as possible, moss sampling followed the guidelines set out in the experimental protocol for the 2000/2001 survey (UNECE, 2001). The procedure is given in detail in **Rühling (1998).**

Each sampling site was located at least 300 m from main roads and populated areas and at least 100 m from any other road or single house. In forests or plantations, samples were collected in small open spaces to preclude any effect of canopy drip. Sampling and sample handling were carried out using plastic gloves and bags. About three repeat moss samples were collected from each site. Dead material and litter were removed from the samples. Green parts of the mosses were used for analyses.

The county of Obrenovac was chosen for this investigation because of its industry and location.

Each sampling site was GPS-located with a precision of ±10 m, and GPS data (Garmin) were digitalized on maps with the OziExplorer 3.95.3b (© D&L Software), and WinDig 2.5 Shareware (© D.Lovy) softwares.

All material was collected during November of 2002.

Not more than one site was chosen per square measuring 50 x 50 m. Seventy-five out of 129 localities were chosen for comparison and further analyses based on all investigated species present and yearly biomass.

More than 500 samples were analyzed. After

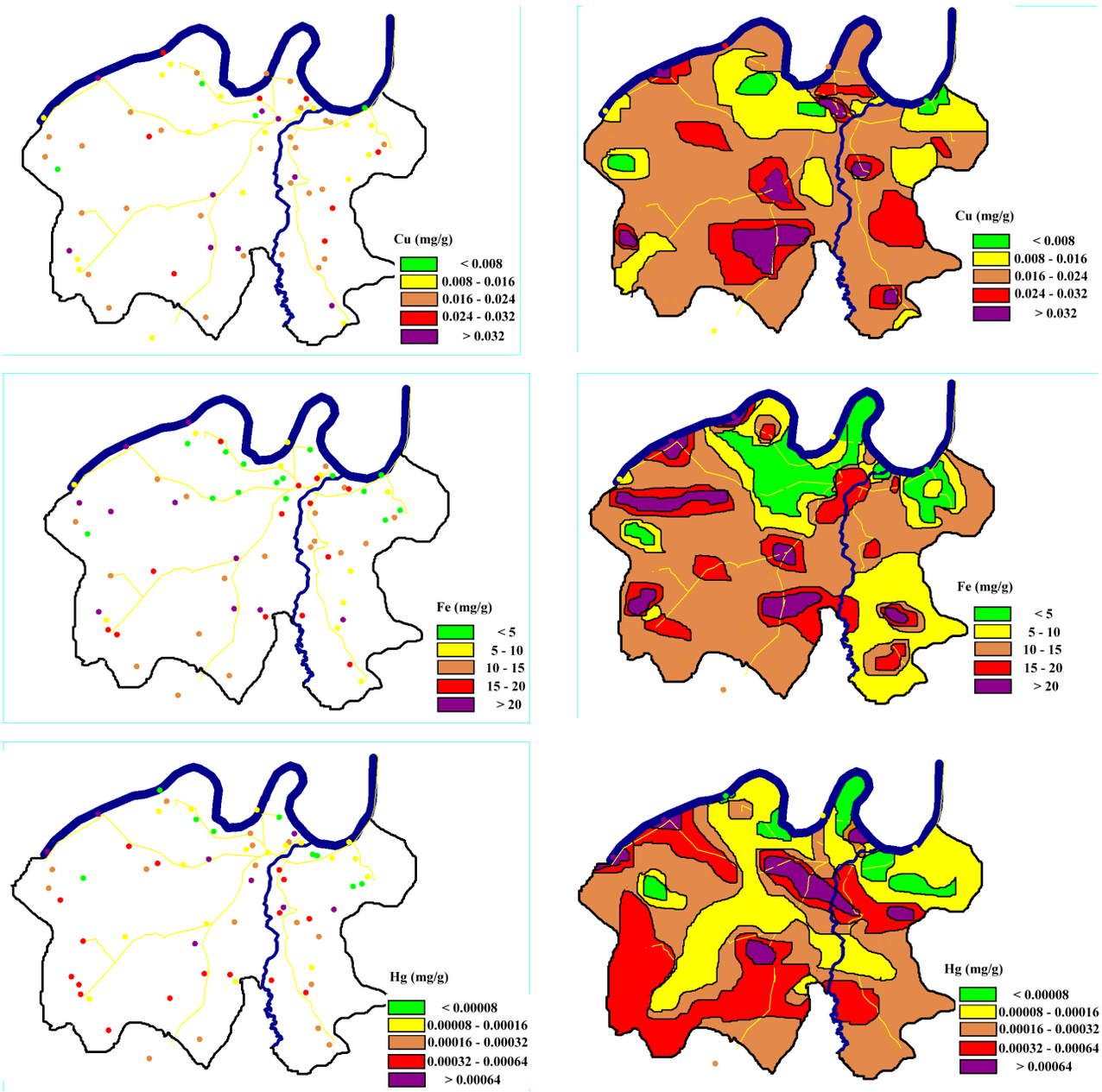

Fig. 1. Maps of the county of Obrenovac showing sampling sites (left) and extrapolated maps of average deposition of selected elements in mosses (right). 1. Copper (Cu), 2. Iron (Fe) and 3. Mercury (Hg) deposition.

collecting, samples were dried as soon as possible in a drying oven to a constant dry weight (dw) at a constant temperature of 35°C, then stored at -20°C.

Following homogenization in a porcelain mortar, the samples were treated with 5+1 parts of nitric acid and perchloric acid (HNO_3:$HClO_4$ = 5:1) and left for 24 hours.

After that, a Kjeldatherm digesting unit was used for digestion at 150-200°C for about one hour. Digested samples were filtered on qualitative filter

Table 1. Deposition of Cu, Fe and Hg in the county of Obrenovac as screened by mosses. Abbreviations: H.c. – *Hypnum cupressiforme*, Bra. – *Brachythecium* sp., B.c. – *Bryum capillare*, B.a. – *Bryum argenteum*

Sample No.	Locality	Longitude	Latitude	Cu	Fe	Hg
				mg/g	mg/g	mg/g
1	Vinogradi H.c.	20.163702	44.391758	0.0088	0.0203	0.0002
2	Moštanica 1 H.c.	20.183672	44.384249	0.0087	6.6973	0.0003
3	Iskra 1 B.c.	20.155235	44.392722	0.0158	15.4326	0.0001
4	Iskra 2 B.a.	20.152826	44.393284	0.0291	20.1688	0.0001
5	Iskra 1 H.c.	20.155235	44.392722	0.0161	5.5460	0.0002
6	Iskra 2 B.c.	20.152826	44.393284	0.0165	12.4181	0.0000
7	Rvati 1 B.c.	20.118796	44.396930	0.0439	34.3733	0.0001
9	Deponija B ulaz 1 B.c.	20.023331	44.383735	0.0172	37.6101	0.0000
10	Zabrežje 1 B.c.	20.121273	44.411245	0.0195	14.0538	0.0001
11	Ušće 2 B.c.	20.066441	44.419235	0.0216	17.3381	0.0002
12	Vinogradi B.c.	20.163702	44.391758	0.0103	5.2383	0.0001
13	Iskra 1 B.a.	20.155235	44.392722	0.0182	16.9542	0.0000
14	Ušće 2 H.c.	20.066441	44.419235	0.0262	22.5906	0.0000
15	Ušće 1 B.c.	20.070343	44.414738	0.0158	9.5019	0.0002
16	Urozv Bra.	20.079770	44.389043	0.0261	15.7787	0.0001
17	Zabrežje 2 H.c.	20.133796	44.408293	0.0188	9.6913	0.0001
18	Orašac 1 H.c.	20.021819	44.336717	0.0233	9.3700	0.0001
19	Hotel B.a.	20.127451	44.394049	0.0396	19.6209	0.0001
20	Moštanica 1 H.c.	20.183672	44.384249	0.0091	3.7267	0.0001
21	Grabovac 1 H.c,	20.046934	44.359997	0.0182	4.5629	0.0001
22	Šab.put nadv. B.c.	20.094085	44.391367	0.1232	33.7743	0.0001
23	Vranić H.c,	20.152122	44.347529	0.0245	9.9011	0.0001
24	Jasenak 2 Bra.	20.156246	44.360071	0.0227	27.0918	0.0001
25	Dren 1 Bra.	20.023224	44.358238	0.0170	14.9868	0.0001
26	Veliko Polje 1 H.c.	20.108648	44.365954	0.0153	10.0309	0.0002
27	Grabovac 1 B.c.	20.046934	44.359997	0.0187	6.4568	0.0001
28	Belo Polje 1 B.c.	20.118064	44.382783	0.0118	15.0132	0.0001
29	Brović 1 B.c.	20.072201	44.335108	0.0204	13.2237	0.0001
30	Ljubinić 2 Bra.	20.026762	44.334832	0.5663	6.5085	0.0001
31	Hotel H.c.	20.127451	44.394049	0.0425	18.4519	0.0001
32	Grabovac 1 Bra	20.046934	44.359997	0.0232	18.1900	0.0001
33	Ljubinić 2 B.c.	20.026762	44.334832	0.0161	16.6093	0.0001
34	Veliko Polje 4 H.c.	20.109057	44.341908	0.0155	13.3856	0.0000
35	Zabran 3 H.c.	20.137615	44.396905	0.0196	4.5594	0.0001
36	Zabran 1 H.c.	20.139396	44.398268	0.0403	12.2592	0.0001
37	Orašac 3 H.c.	20.016612	44.343855	0.1554	278.7770	0.0005
38	Orašac 2 H.c.	20.020860	44.340639	0.0176	11.0736	0.0000
39	Zabran 2 B.a.	20.142377	44.401672	0.0310	4.9981	0.0001
40	Belo Polje 1 B.a.	20.118064	44.382783	0.0183	16.3593	0.0009
41	Orašac 2 Bra.	20.020860	44.340639	0.0129	7.5808	0.0004
42	Ljubinić 1 Bra.	20.037630	44.322132	0.0174	10.9400	0.0004
43	Grabovac nad. B.a.	20.092788	44.365167	0.0192	13.1077	0.0003

Table 1. Ctd.

44	Joševa H.c.	20.060545	44.310742	0.0341	27.6251	0.0003
45	Brović 2 Bra.	20.088929	44.318537	0.0196	11.2681	0.0002
46	Jasenak 2 B.a.	20.156246	44.360071	0.0189	10.5078	0.0002
47	Garbovac nadv. Bra.	20.092788	44.365167	0.3163	25.1420	0.0001
48	Baljevac 1 B.c.	20.152044	44.340743	0.0205	25.6260	0.0002
49	Joševa B.c.	20.060545	44.310742	0.0193	15.4758	0.0004
50	Joševa Bra.	20.060545	44.310742	0.0131	14.1233	0.0003
51	EPS B.c..	20.120401	44.388845	0.0095	4.4895	0.0002
52	Konatice II Bra.	20.148928	44.337410	0.1419	15.4913	0.0002
53	Zabran 1 B.a..	20.139396	44.398268	0.0185	4.8773	0.0003
54	Mislođinl 1 Bra.	20.136579	44.383096	0.0160	12.4831	0.0004
55	Brović 1 H.c.	20.072201	44.335108	0.0295	10.0100	0.0004
56	Mislođin 4 H.c.	20.134067	44.369616	0.0225	10.2435	0.0003
57	Stubline 2 H.c.	20.091649	44.345095	0.0356	40.1699	0.0006
58	Konatice 1 B.c.	20.162150	44.316265	0.0116	6.2199	0.0008
59	Zabran 3 B.a.	20.137615	44.396905	0.0194	4.7602	0.0002
60	Jasenak H.c.	20.143804	44.365736	0.0202	17.0233	0.0002
61	Konatice 2 B.a.	20.155831	44.322960	0.1389	19.9435	0.0002
62	Veliko Polje 4 B.c.	20.109057	44.341908	0.0183	18.2987	0.0001
63	Mislođin 1 Bra.	20.133857	44.387041	0.0165	15.9461	0.0005
64	Veliko Polje 3 B.c.	20.106117	44.344670	0.1910	36.0164	0.0005
65	Konatice II B.c.	20.148928	44.337410	0.0181	25.6692	0.0002
66	Mislođin 6 B.a.	20.164676	44.371027	0.0005	12.5006	0.0006
67	Stubline 1 H.c.	20.086353	44.357185	0.0233	12.3569	0.0008
68	Šab.put nadv. B.a.	20.094085	44.391367	0.0876	28.6316	0.0009
69	Dren 1 H.c.	20.023224	44.358238	0.0193	12.3381	0.0004
70	Zabran 2 B.c.	20.142377	44.401672	0.0277	11.8605	0.0007
71	Baljevac 2 H.c.	20.129432	44.342383	0.0210	16.3861	0.0006
72	Mislođin 5 B.a.	20.150813	44.367274	0.0166	11.9065	0.0004
73	Orašac 1 Bra.	20.021819	44.336717	0.0177	14.5195	0.0006
74	Konatice II H.a.	20.148928	44.337410	0.0175	5.1718	0.0004
75	Šab.put 1 Bra.	20.049094	44.396566	0.0233	12.7999	0.0006
76	TENT<B 3 B.c.	20.003761	44.379624	0.0257	15.7750	0.0010
77	Šab.put 1 H.c.	20.094085	44.391367	0.0127	0.0285	0.0038
78	Ratari 2 Bra.	20.058939	44.387315	0.0193	17.2217	0.0002
79	TENT<B 1 H.c.	19.593841	44.380930	0.0108	0.0203	0.0009
80	TENT<B 2 H.c.	20.010398	44.374841	0.0128	3.3247	0.0006
81	Ratari 1 H.c.	20.065292	44.389672	0.0168	14.1877	0.0005
82	Ušće<Skela B.c.	20.031781	44.409564	0.1197	18.3721	0.0007
83	Ratari 2 B.a.	20.058939	44.387315	0.0272	21.5550	0.0003
84	TENT<B 4 B.a..	20.005827	44.387162	0.0173	17.4633	0.0001
85	TENT<B 2 Bra.	20.010398	44.374841	0.0113	6.7149	0.0004
86	TENT<B 1 Bra.	19.593841	44.380930	0.0045	0.0242	0.0005
87	TENT<B 4 B.c.	20.005827	44.387162	0.0181	145.0100	0.0003

Table 1. Ctd.

88	TENT<B 3 B.c.	20.003761	44.379624	0.0169	10.2300	0.0002
89	Orašac 1 Bra.	20.021819	44.336717	0.0080	18.9934	0.0005
90	Ušće<Skela Bra.	20.031781	44.409564	0.0537	29.5157	0.0009
91	Šab.put 1 B.c.	20.049094	44.396566	0.0173	10.0390	0.0005
92	TENT<B entr. Bra.	20.002958	44.394451	0.0132	7.2032	0.0010
93	Depoija 1 Bra.	20.087035	44.407417	0.0205	9.5989	0.0004
94	TENT<B 2 B.c.	20.010398	44.374841	0.0039	0.0140	0.0004
95	Konatice 1 H.c.	20.162150	44.316265	0.0128	6.9658	0.0003
96	Mislođin 6 Bra.	20.164676	44.371027	0.0206	7.7294	0.0003
97	Mislođin 3 Bra.	20.136294	44.371922	0.0322	10.1257	0.0007
98	Mislođin 6 B.c.	20.164676	44.371027	0.0153	10.0836	0.0008
99	Jasenak 2 B.a.	20.156246	44.360071	0.0295	7.8571	0.0002
100	Mislođin 4 B.c.	20.134067	44.369616	0.0206	13.9220	0.0006
101	Zabran 1 Bra.	20.139396	44.398268	0.0224	5.9802	0.0003
102	Rojkovac 1 B.c.	20.117592	44.401807	0.0181	8.8105	0.0002
103	Rojkovac 1 Bra.	20.117592	44.401807	0.0760	9.8646	0.0007
104	Rvati 1 Bra.	20.118796	44.396930	0.0328	0.0348	0.0002
105	Rojkovac 1 B.a.	20.117592	44.401807	0.0273	7.2717	0.0002
106	Moštanica 3 Bra.	20.175487	44.380355	0.0173	22.1358	0.0001
107	Razu Bra.	20.065879	44.410726	0.0058	4.9027	0.0002
108	Ušće 3 Bra.	20.084220	44.411524	0.0171	15.4046	0.0001
109	Duboko 3 H.c.	20.176888	44.391497	0.0107	5.1366	0.0001
110	Zabrežje 1 Bra.	20.121273	44.411245	0.0203	7.9414	0.0001
111	Zabran 3 Bra.	20.137615	44.396905	0.0129	19.4339	0.0001
112	Moštanica 2 B.c..	20.180515	44.381400	0.0302	13.2512	0.0000
113	Razu B.a..	20.065879	44.410726	0.0222	6.9205	0.0001
114	Rvati 3 Bra.	20.115276	44.395254	0.0074	4.9494	0.0001
115	TENT<A 1 Bra.	20.096950	44.402553	0.0199	0.0249	0.0001
116	Moštanica 3 B.c.	20.175487	44.380355	0.0081	0.0129	<0.0002
117	Zabrežje 2 Bra.	20.133796	44.408293	0.0126	0.0225	0.0001
118	Urozv B.c..	20.079770	44.389043	0.0191	0.0155	0.0001
119	Depoija 1 H.c..	20.087035	44.407417	0.0032	0.0085	<0.0002
120	Zabrežje 2 B.a.	20.133796	44.408293	0.0154	2.5422	0.0001
121	Moštanica 1 B.c.	20.183672	44.384249	0.0162	2.4874	0.0001
122	Vinogradi B.a.	20.163702	44.391758	0.0231	0.0166	0.0001
123	Urozv H.c.	20.079770	44.389043	0.0125	0.0118	0.0001
124	Razu H.c.	20.065879	44.410726	0.0126	0.0127	0.0001
125	Duboko 1 B.a.	20.173260	44.398253	0.0028	0.0102	0.0001
126	Vinogradi Bra.	20.163702	44.391758	0.0156	0.0041	0.0001
127	Duboko Bra.	20.146281	44.397974	0.0122	0.0094	0.0001
128	TENT<A 1 B.c.	20.096950	44.402553	0.0080	0.0092	0.0000
129	Zabrežje 2 B.c.	20.133796	44.408293	0.0185	3.6458	0.0000
Median				0.0323	14.8180	0.0003

paper to dispose of silicate remains, and the volume of samples was then normated to 50 ml.

Copper (Cu), Iron (Fe) and Mercury (Hg) were detected by AAS Philips Pye Unicam SP9 instrument. The content of copper and that of iron were determined with a flame of acetylene/nitrogen-suboxide, while mercury was detected using hydride techniques.

For the explanation of the results and their map presentation, the following statistical parameters were used: average values, standard deviation, minimum and maximum values, and percent deviation. Map making and interpolation of precise data were made with Agis v1.71 32bit (© Agis Software, 2001) software.

RESULTS AND DISCUSSION

Since it was impossible to find all the sampled species at any precise locality, the average of all specimens is given on extrapolated map to get an idea of heavy metal deposition in the county of Obrenovac (Fig. 1). However, if we separate the values of deposition obtained from pleurocarpous (*Brachythecium* sp. and *Hypnum cupressiforme*) and acrocarpous (*Bryum argenteum* and *Bryum capillare*) mosses, it can be clearly seen that the first two give us an idea of short-term deposition and the last two of long-term deposition (Table 1). This can be easily explained in terms of the life forms of these mosses and thair uptake of heavy metals. Pleurocarps are not closely attached to the substrate and thus receive the bulk of deposited heavy metals directly from the atmosphere (during their pauciennial life period), while acrocarps are strictly attached to substrata and get most of deposited heavy metals with the substrate solution (metals are deposited over a period of time that is longer than their pauciennial life span).

Scanning of trace metal (Cu, Fe, Hg) content in the county of Obrenovac (W. Serbia) clearly shows that the entire area of the county is loaded with these three metals as a result of heavy industry and intense traffic (Fig. 1). The north-central region of the county is less loaded. Copper is spread over the county from a few points in the central and SW and SE regions. The pattern of iron spreading is simmilar, while mercury spreads from the central, northwestern, and southwestern parts of the county.

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ДЕТЕРМИНАЦИЈА ДЕПОЗИЦИЈЕ ТЕШКИХ МЕТАЛА У ОПШТИНИ ОБРЕНОВАЦ (СРБИЈА) АНАЛИЗОМ МАХОВИНА КАО БИОИНДИКАТОРА. III. БАКАР (Cu), ГВОЖЂЕ (Fe) И ЖИВА (Hg)

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У овој студији дефинисана је депозиција три тешка метала (Cu, Fe и Hg) на подручју општине Обреновац (Србија) на бази анализе четири таксона маховина (*Bryum argenteum, Bryum capillare, Brachythecium* sp. и *Hypnum cupressiforme*) као биоиндикатора. Утврђене су области са највишим степеном контаминације, и истовремено презентоване на илустрацијама у овом раду.