MOSSES AND LICHENS – BIOINDICATORS OF HEAVY METALS POLLUTION OF FOREST ECOSYSTEMS

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ABSTRACT. Mosses and lichens – bioindicators of heavy metals pollution of forest ecosystems. This study is a comparative investigation of the content of heavy metals (Pb, Cu, Ni, Zn and Cr) in mosses and lichens recorded in ten deciduous forests in the Republic of Moldova included in a transnational grid (16x16 km) of forest monitoring throughout Europe. The content of heavy metals doesn't differ significant by depending on the location of studied forest ecosystems. The trends of larger accumulation are observed near the local stationary and mobile sources of pollution. Mosses were confirmed as good indicators of air pollution with heavy metals to forest ecosystems located near sources of pollution and lichens show good bio-indicators particularities for background pollution. The good correlation between the concentrations of moss and lichen were Cr, Cu and Ni, and the low correlation between Pb and Zn, which are considered to be metals which are amenable to long-distance dispersal.

Keywords: heavy metals, air pollution, bio-indicators, forest ecosystems.

1. INTRODUCTION

The environmental quality can be monitored by measuring pollutants, including heavy metals, directly to environmental compartments (air, water, soil and biota) by constructing models that describe the distribution of pollutants, or by using bio-indicators. The main advantage of bio-indicators is the possibility to detect early change of environmental and pollution, for a wide range of pollutants, before affected the other ecosystems components. The biological monitoring methods are fast and cheap (Markert et al. 2003); (Begu, 2011). According to the literature (Puckett, 1988), mosses and lichens are considered to be the best body to be used as bio-indicators of air pollutants. Mosses and lichens do not have a well-developed cuticle and roots, they rely largely on atmospheric deposition for nourishment. They don't shed plant parts as readily as higher plants and accumulate persistent atmospheric pollutants to concentrations far greater than those in air (Begu, 2011).

Bio-monitoring of spatial and temporal deposition patterns of heavy metal deposition could be useful for environmental management, but its acceptance and applications are long overdue. Indeed, most lichen and moss surveys are based solely on data collection, representing metal concentrations in a study area without distinguishing natural and anthropogenic sources and biological variability. Bio-

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monitor species collected in the field are subject to uncontrollable variations depending on environmental conditions, which may modify growth rate, form, accumulation and/or remobilization of metals, and entrapment of airborne soil and rock particles (Bargagli et al.,1995); (Begu, 2011).

2. AREA AND RESEARCH METHODS

The passive biological monitoring of heavy metals was performed in 10 experimental surfaces (SE) of the European systematic (16x16 km) network of forest monitoring, located in forest ecosystems of Republic of Moldova (Fig. 1). The particularities of accumulation metals in studied forest ecosystems were evaluated of bio-indicator plant species (lichens and mosses) present in those ecosystems. As bio-indicators have been studied species of lichens *Parmelia sulcata* and *Evernia prunastri* species used in biological monitoring of several countries in Europe and the first being recommended for Republic of Moldova by Begu and Brega (2009). In the case of mosses, it has been impossible sampling the same species, why were sampled species of representative mosses for those ecosystems. As in the case of mosses, and in the case of lichens, the sample medium was composed of at least three subsamples.

In laboratory the lichen and moss samples were subjected to the thermal calcinations (400-450 °C) and in the obtained mass were analyzed heavy metals by the spectrometry Roethgen – fluorescent method to device Spectroscan MAX-G. The results of on the accumulation of heavy metals in mosses were analyzed and compared with results obtained in EMEP network (50x50 km) (Harmens, 2013).

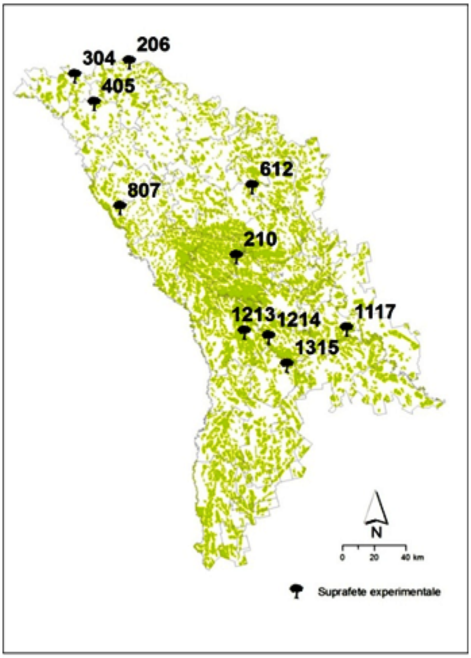

Fig. 1. Location of experimental surfaces from the Republic of Moldova

3. RESULTS AND DISCUSSIONS

The study conducted in 10 forest ecosystems in the experimental areas are located in the European forest monitoring network, shows some regularities differential accumulation of heavy metals by bio-indicators – mosses and lichens and the particular sources of pollution.

Heavy metals concentrations in mosses. Both mosses and lichens showed increased capacity for accumulation of Cu and Zn (Fig. 2 and Fig. 3). The increased concentrations of Cu and Zn are characteristic for biota for Republic of Moldova, especially for Cu, as a result of intensive processing of agricultural land and forests with chemicals containing Cu, as well from combustion the vegetal remnants.

Concentrations of metals Pb, Cr and Ni in mosses did not vary significantly depending on the area of study, registering only a slight decrease in Ni content from north to central and south-east (Fig. 2). Pb contents has registered maximum values significantly higher than the rest of the study, the SE 1214 (13,3 mg/kg), the SE 1117 (11,8 mg/kg) and SE 405 (13,3 mg/kg) placed near auto routes, the main local source of Pb pollution. Thus, in SE 1214 and SE 1117 are influenced by emissions from road transport, rout Chisinau - Tighina - Tiraspol (SE 1117) and the route Chisinau – Cahul (SE 1214) and urban emissions from Chisinau and respectively Tiraspol and Tighina. SE 405 is negatively influenced by emissions from auto traffic on the route Edineţ - Briceni.

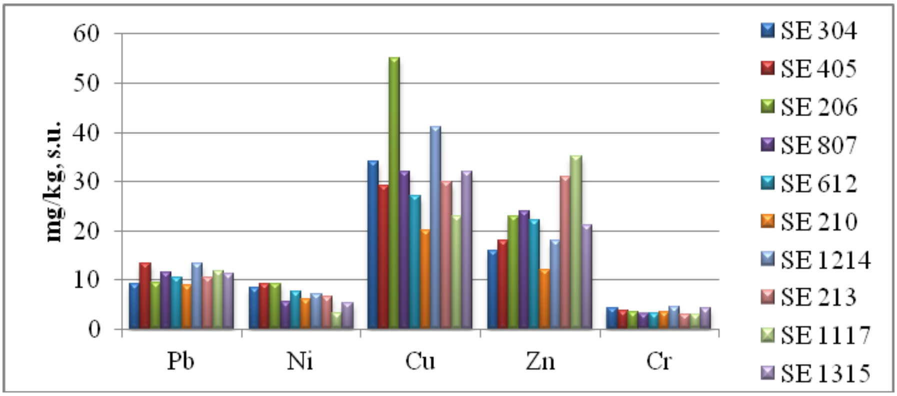

Fig. 2. The concentration of heavy metals in mosses, mg/kg, d.w.

The content of heavy metals in mosses to forest ecosystems studied, was compared with values recorded in EMEP grid (50x50 km) to monitor atmospheric deposition of heavy metals in mosses (Table 1) in 2010/2011 after the ICP Vegetation (Harmens, 2013). Thus, according to this scale, Zn was within the lower concentrations classes – *very low – moderate,* followed by metals Pb, Ni and Cr *optimal – high* concentrations. These values are virtually identical to the concentrations recorded in Romania, EMEP cells located at the border of our country and specific regions of south-eastern Europe.

The high pollution level in moss samples analyzed, which is different from the area of Europe, was recorded for Cu, being in the *high* and *very high* levels. This confirms the persistence of risk of pollution with environmental components in Moldova, as a result of use with very large-scale processing chemicals against diseases and pests of crops and forests.

Table 1. The content of heavy metals in mosses from studied ecosistems mg/kg, d.w.

Experimental Surface	Geographic coordinates		Pb	Ni	Cu	Zn	Cr
	Latitude	Longitude					
SE 304	48°22′36″	27°08′36″	**9,1**	**8,3**	**34,4**	**16,4**	**4,3**
SE 405	48°12′57″	27°18′06″	**12,6**	**5,8**	**27,3**	**19,1**	**3,3**
SE 206	48°27′05″	27°36′05″	**9,6**	**9,1**	**54,9**	**22,6**	**3,4**
SE 807	47°35′56″	27°31′16″	**11,6**	**5,5**	**31,8**	**24,3**	**3,1**
SE 612	47°42′39″	28°37′40″	**10,4**	**7,6**	**26,8**	**21,6**	**3,3**
SE 210	47°18′06″	28°28′46″	**8,8**	**6,1**	**20,3**	**11,4**	**3,4**
SE 1214	46°49′33″	28°43′51″	**13,3**	**7,0**	**40,7**	**17,9**	**4,6**
SE 1213	46°51′33″	28°31′57″	**10,5**	**6,5**	**30,1**	**31,0**	**3,0**
SE 1117	46°51′37″	29°22′33″	**11,8**	**3,2**	**22,9**	**34,6**	**2,8**
SE 1315	46°39′22″	28°52′47″	**11,2**	**5,3**	**32,2**	**21,2**	**4,2**
European scale for evolution of the heavy metals concentrations in mosses (Harmens, 2013)							
Level of contents			**Pb**	**Ni**	**Cu**	**Zn**	**Cr**
Very low concentrations			**< 2**	**< 1**	**< 4**	**< 20**	**< 1**
Low concentrations			**2-4**	**1-2**	**4-6**	**20-30**	**1-2**
Moderate concentrations			**4-8**	**2-3**	**6-8**	**30-40**	**2-3**
Optimal concentrations			**8-12**	**3-6**	**8-12**	**40-60**	**3-4**
Increased concentrations			**12-16**	**6-9**	**12-16**	**60-80**	**4-6**
Enhanced concentrations			**16-20**	**9-12**	**16-20**	**80-100**	**6-10**
High concentrations			**20-30**	**12-15**	**20-24**	**100-120**	**10-15**
Very high concentrations			**> 30**	**> 15**	**> 24**	**> 120**	**> 15**

Heavy metals concentrations in lichens. A very obvious regularity is observed in the case of lichens, as in the mosses for the metals Pb, Cr and Ni, which were recorded for the whole country the same levels of pollution (Fig. 3), thus emphasizing the impact of cross-dominant, for Republic of Moldova. There is a greater tendency for cumulating in lichens of Pb, Ni and, to a lower ratio, Cr in SE 612, indicating a common source of air pollution to the forest ecosystem - the emissions from the industrial area Râbniţa-Rezina (cement and metallurgy industry).

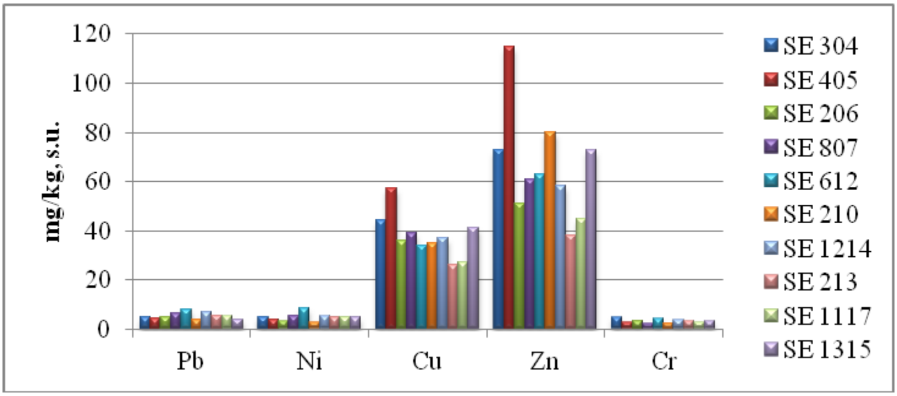

Fig. 3. The concentration of heavy metals in lichens, mg/kg, d.w.

Lichens are remark as good accumulators by Cu with assuming penetration with Cu in forest ecosystems by air. Maximum values were recorded in SE 405 (57 mg/kg), significantly higher than in other studied experimental areas (Fig. 3) as a result of the location closest to agricultural land. Similarly, lichens were found to be better accumulation of Zn values which significantly exceed the average 3 times, the Zn levels in the mosses (Fig. 2). Zn content in lichens is between 45 and 115 mg/kg, with values significantly increased, as in the case with the SE 405 (115 mg/kg), thus indicating good synergy between the metal and the source of air pollution common to them.

Comparison of lichen and moss data. The estimated concentrations of heavy metals by accumulation in lichens and mosses showed a highly variable correlation between them. The good correlation between the concentrations of moss and lichen were Cr, Cu and Ni, and the low correlation between Pb and Zn, which are considered to be metals which are amenable to long-distance dispersal. Higher Pb content in moss samples compared with lichen samples (Table 3) is explained by the greater influence of the trunk leaks "stemflow" on the mosses, which were collected from the base of the tree trunk. Mosses occupies a larger area of the substrate, compared with lichen cumulates larger amounts of Pb. Another factor that may explain the lower concentrations of Pb cumulated in lichens, as mentioned Evans and Hutchinson (1996), particularly heavy metals (Pb and Hg) are volatile, are continuously recycled back into the atmosphere more easily than mosses. Variations in concentrations of Cu and Zn in mosses and lichens can be determined and uniform distribution of rainfall within the country, with increased rainfall in winter. Thus Cu and Zn concentrations in lichens are higher than moss, caused by the fact that lichens are exposed to air pollutants throughout the year, while the mosses (collected at the base of trees or of the soil) are protected by snow layer in winter.

Studies effectuated by Reimann et al. (1999) showed that mosses accumulate noxious form of dust easier than lichens near emission sources. Higher concentrations of Pb in mosses to lichens are explained by SE location close to local fixed and mobile sources of emissions (city, auto routes) report this difference decreases with increasing distance from any source of emissions in the areas of fund (SE 210, 612, 807). For metals Ni and Cr in background areas (SE 612, 1117, 1315 and 1213), these concentrations in lichens were higher than those in mosses.

Ni values recorded in SE 807, 612, 1117 and 1315, statistically insignificant between moss and lichen samples (Table 3) clearly shows the persistence of atmospheric inputs of Ni transboundary in the Republic of Moldova. The location of forest ecosystems in different parts of the country, which may be influenced by local biotic and abiotic factors, but basically the same amount of Ni cumulating in mosses and lichens, indicates dominance transboundary pollution.

Record the highest values of heavy metals in mosses and lichens analyzed for forest ecosystems (SE 612, 1214, 405) arranged around the obvious sources of pollution (metallurgy and cement industry of and Rezina and Râbniţa, fixed and mobile sources of Chisinau and some auto trails national/international conglomerates), confirming by air pollution. Also, it is assumed that ecosystems and the increased risk of heavy metal pollution, as confirmed in other studies for data areas (Begu, 2011; Begu and Braşoveanu, 2011).

4. CONCLUSIONS

Bio-indicators of heavy metal pollution of forest ecosystems studied, demonstrates for the whole country increased accumulation of Cu and Zn, thus, *high* and *very high* levels of Cu content in the moss, which differs to the area of Europe, confirms the persistence of risk of pollution of forest ecosystems with Republic of Moldova.

Mosses were confirmed as good indicators of air pollution with heavy metals to forest ecosystems located near sources of pollution and lichens manifests good peculiarities of indicators for fund pollution.

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