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Analysis of Heavy Metals in Pylaisiella Moss (Pylaisia Polyantha) Growing in the City of ROSTOV-ON-DON

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Abstract: Contamination of environment by radionuclides in territories under urboecosystem conditions is actual problem. The search of new express methods for radioactivity determination of environment is important task of research. The results of present research showed mosses are bioindicators of radioactive contamination, because they accumulate radioactive substances in high concentrations. Using of bryoindication methods are promising techniques for the assessment of the contamination of ecosystems with radionuclides. The use of epiphytic mosses is the most efficient technique for assessing the contents of radionuclides in the surface air layer. The epiphytic moss (Pylaisia polyantha) growing in different zones of the city of Rostov-on-Don, was used for the radioactivity biomonitoring of urbosystems. The accumulation features of radionuclides in the epitaphic pylaisiella moss (Pylaisia polyantha) in the territory of the city of Rostov-on-Don have been considered. It was shown that Pylaisia polyantha is effective indicator of radioactivity for biomonitoring. The activity concentration of ^{137}Cs, ^{226}Ra, ^{40}K and ^{232}Th in the samples of moss, soils and aerosol air have been compared. The capacity of Pylaisia polyantha to accumulate radionuclides has been estimated for four radionuclides (^{137}Cs, ^{226}Ra, ^{232}Th and ^{40}K) with consideration for the background level. On the basis of radionuclide analysis, zones in the city of Rostov-on-Don with the highest accumulation coefficients of ^{137}Cs, ^{226}Ra, ^{40}K and ^{232}Th were revealed. These were primarily the zones with both industrial and traffic loads and the motor transport zones. The results of investigation showed that the epiphytic moss (Pylaisia polyantha) can be used as indicator of radioactivity pollution in different polluted zones.

Key words: Bioindication method · Pylaisiella moss · Heavy metals · Pollution · Bryophites

INTRODUCTION

Leafy mosses are known to be effectively used as objects of bioindication, because they are highly sensitive to any stress factor [1-6]. Many authors [7-11] showed the application perspectiveness of bryoindication methods or assessing the contamination of ecosystems with radionuclides and heavy metals (HMs). These methods consider the changes in the biochemical and physiological processes, the biodiversity and the presence or absence of species sensitive to the content of specific pollutants in the atmosphere. The capacity of bryophites for the primary interception and accumulation of various chemical elements in relation to the age, height and ecology of species and the features of propagation were relatively well studied [3, 4, 6, 12].

Of special interest is the bryloflora of urbanized areas; this is an important element of urban plants, which is frequently used for the indication of atmospheric pollution and the bioindicational mapping of urban areas [13, 14]. The suitability of mosses as objects of monitoring studies is due to the fact that they successfully grow under strong atmospheric pollution and that the accumulation of elements by the mosses is less dependent on climatic conditions compared to the lichens [3, 12].

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Some works [4, 6] deal with assessing the capacity of separate moss species to accumulate HMs and revealing differences in the sorption of separate metals by individual moss species. It is known that the content of HMs in mosses is determined by several factors: the natural background (plant homeostasis), transboundary transfer, precipitation and the effect of local pollution sources. In mosses of a forest landscape, the accumulation of HMs is related to both the features of anthropogenic impact and the natural factors (vegetation, soil type, climatic parameters) [3]. Some correlation models allow the calculation of the absolute contents of HMs in the air from their contents in two moss species (Hylocomium splendens and Pleurozium schreberi) [6].

The chemical composition of mosses is an informative parameter for assessing the contents of HMs and other chemical elements in the atmospheric air of the studied areas. The mosses accumulating toxicants in their aboveground organs are widely distributed and have a relatively long life cycle [1, 2, 3, 15, 16, 17]. They are frequently used for the bioindication of the chemical contamination of the atmosphere [3, 15, 18, 6].

The bioindication of atmospheric fallouts of HMs in the Kaliningrad oblast was performed with the use of forest mosses Pleurosium schrcberi, Hilocomium splendens, Scleropodium purum and Rhitidiadelphussp. il [3]. The best indicators of air pollution with HMs were revealed (Pleurosium schreberi and Hilocomium splendens); the seasonal and interannual variability of HM content was determined, as well as the biogeochemical features of the accumulation of atmospheric HM fallouts in the Kaliningrad oblast.

However, the bioindication using terrestrial forest mosses has some limitations: these bryoflora species cannot be used for the bioindication of urbanized areas; the source of pollution is difficult to identify; and the mosses have different accumulation capacities.

Most of the works on the revelation of the chemical pollution of the atmospheric air [18, 3] were performed with the use of epiphytic mosses, which inhabit not only natural, but also urbanized ecosystems and have high accumulation capacities. The mosses growing on the bark of perennial trees almost do not touch the soil; they uptake chemical substances and water from the atmospheric air alone and represent suitable test objects for bioindication and biomonitoring.

The study of the peculiar features of different moss species (forest, bog and epiphytic species) used in the monitoring of atmospheric pollution showed differences in their accumulative properties. The epiphytic mosses have a higher accumulation capacity than the terrestrial mosses and the species Pylaisia polyantha is the best test object for the bioindication of the atmospheric air [19,20]. Epiphytic mosses were used for assessing the state of the atmospheric air in the forest ecosystems on the areas of the chemical weapon storage and disposal facilities (with the Pochep district of the Bryansk oblast as an example [6]. The epiphytic moss P. polyantha growing on the bark of trees (most frequently, poplars) was successfully used as a bioindicator for assessing the pollution of the atmospheric air by neutron activation analysis [21]. The hydrophyte Fontinalis antipyretica and the epiphyte Pylaisia polyantha are used for the determination of the contents of Al, Ti, Fe, Cr, Cu, Zn, As, Se, Cd, Pb and rare-earth elements (REEs) by mass spectrometry. The assessment of the distribution of heavy metals in the basins of small and medium rivers (in the Vologda and Kostroma oblasts) showed that the aquatic mosses are good indicators for the presence of REEs and the terrestrial mosses are suitable for such pollutants as Cu, Zn, Se and Pb. In the study of the contents of macroelements (Al, Ti and Fe), no distinction was made between the epiphytic and hydrophytic mosses [22].

MATERIALS AND METHODS

In this work, the total contents of heavy metals were determined in samples of pylaisiella moss (P. polyantha) growing on poplar (Populus deltoides) plants on 10 plots located in the motor transport zone, the zone with both industrial and traffic loads and the park zone of the city of Rostov-on-Don (Fig. 1). The background plot was located in the relatively pure zone, in the Kamenskii district of the Rostov oblast, with the natural and climatic conditions similar to those of the areas under biomonitoring and remote to more than 100 km from industrial centers.

On each plot, moss samples were collected from 10 trees of P. deltoids located no more than 10 m from each other. Samples of pylaisiella moss (Pylaisia polyantha) (Hedw.) B.S.G., were collected at a height of 1.5–2.0 m on the studied plots in the city of Rostov-on-Don, which corresponds to the air layer breathed by adult humans. Pylaisiella moss is the dominant epiphytic moss species; it occurs on all the studied plots and has long life cycle and high accumulative capacity. The contents of HMs in the samples of pylaisiella moss were determined with a Spektroskan MAKC-GV spectrometer. The priority pollutants typical for the urban landscapes of the Lower Don region, such as Pb, Zn, Cr, Ni, Cu, As and Sr, were quantified.

Fig. 1: Schematic map of biomonitoring plots: transport emission zone (plot 9, Zmievskii St.; plot 10, Sholokhova Ave.); industrial emission zone (plot 2, thermal power plant; plot 3, thermal power plant 2; plot 10, bearing plant); industrial and transport emission zones (plot 4, Portnova St.; plot 5, Siversa St.; plot 6, Budenovskii Ave, Dolomanovskii St./Tekucheva St. and Mechnikova St.; plot 7, Vavilova St.; plot 8, Taganrogskoe sh.); recreation park zone (plot 1 (relative control), Botanic Garden).

Samples of pylaisiella moss were collected from April through October in 2010–2012. The total contents of HMs in the moss samples from the studied plots in Rostov-on-Don were compared to those in the background mosses.

The concentration indices of some elements (Kc) were calculated from the formula $Kc = Cs/Cb$, where Cs is the content of an element in the test sample and Cb is the content of this element in the background sample [23].

The total contamination index was calculated for the test plots in Rostov-on-Don from the equation [23]:

$$Zc = \sum Kc - (n - 1),$$

where Kc denotes the concentration indices of the heavy metals in the mosses for which $Kc > 1$ and n is the number of the considered heavy metals for which $Kc > 1$ [3, 14, 20, 24].

Results and discussion: The results of determining the contents of heavy metals in the samples of pylaisiella moss are given in Table 1.

The concentration indices Kc and total contamination indices Zc for the test plots in Rostov-on-Don are given in Table 2.

From the total contents of heavy metals in the samples of pylaisiella moss, the accumulation capacity of the moss under the natural conditions and the environmental state of the studied regions were assessed by spectrometric analysis. The maximum total contamination index was observed in the industrial zone (the regions of the thermal power plant, thermal power plant 2 and gas processing plant 10). The obtained results indicate that pylaisiella moss is a promising object for biomonitoring studies.

Excess over the background level was observed by 1.2–5.9 times for zinc, by 1.2–2.7 times for strontium and by 1.2–3.1 times for lead (Table 1). In the other cases, an insignificant excess was noted (V, Cr), or the determined values were below the background level (46.57 ppm for Cu, 58.67 ppm for Ni). Trace amounts of Co were found in the samples from all the regions studied,

Table 1: Total heavy metal contents in the samples of pylaisiella moss (P. polyantha) taken from the test plots in Rostov-on-Don, ppm

	Heavy metals, ppm								
Plot	V	Cr	Co	Ni	Cu	Zn	As	Sr	Pb
Back-ground	27.39±1.78	47.8±3.11	-	58.67±3.81	46.57±3.03	228.76±14.87	-	184.67±12	84.23±5.47
1	21.48±1.39	55.37±3.59 **,	-	63.27±4.11**,	36.61±2.36**,	640.24±41.62**,	43.47±2.83 **,	245.06±15.92**,	203.04±13.19**,
2	57.01±3.71**,++	125.39±8.15**,++	4.29±0.28**,++	30.81±2 **,++	36.11±2.34**,++	302.77±19.68**,++	32.053±2.08**,++	419.82±27.29**,++	139.60±9.07 **,++
3	43.03±2.79**,++	102.98±6.69**,++	-	57.90±3.76**,++	30.47±1.98**,++	705.38±45.85**,++	33.264±2.16**,++	179.45±11.66**,++	148.39±9.65 **,++
4	54.83±3.56**,++	76.49±4.97 **,++	-	39.35±2.56**,++	40.44±2.63**,++	340.7±22.15 **,++	22.74±1.48 **,++	495.4±32.2 **,++	88.95±5.78 **,++
5	42.67±2.77**,++	75.91±4.93 **,++	-	43.76±2.84**,++	22.29±1.44**,++	201.7±13.11 **,++	21.94±1.43 **,++	244.9±15.91 **,++	86.95±5.56 **,++
6	51.08±3.32**,++	76.62±4.98 **,++	-	56.01±3.64**,++	36.07±2.34**,++	444.8±28.91 **,++	24.58±1.59 **,++	223.5±14.53 **,++	101.6±6.6 **,++
7	32.85±2.14**,++	82.77±5.38 **,++	-	50.11±3.28**,++	47.30±3.07**,++	338.4±21.99 **,++	54.35±3.53 **,++	95.12±6.1 **,++	262.6±17.7 **,++
8	35.18±2.29**,++	59.86±3.89 **,++	-	53.08±3.45**,++	27.24±1.77**,++	808.3±52.54 **,++	25.96±1.68 **,++	281.8±18.31 **,++	108.3±7.04 **,++
9	34.37±2.23**,++	72.97±4.74 **,++	0.26±0.02**,+	37.28±2.42**,++	39.73±2.58**,++	281.7±18.31 **,++	34.14±2.21 **,++	165.9±10.78 **,++	153.5±9.98 **,++
10	52.0±3.38 **,++	63.13±4.1 **,++	-	46.90±3.05**,++	31.88±2.07**,++	1354±88.01 **,++	33.75±2.19 **,++	298.78±19.42**,++	149.61±9.72 **,++

(**) the significance level for the difference between the experimental sample and the background P<0.01;

(++) the significance level for the difference between the experimental sample and the relative control P<0.01;

Motor transport zone: plot 9, Zmievskii St.; plot 10, Sholokhova Ave.; industrial zone: plot 2, thermal power plant; plot 3, thermal power plant 2 and gas processing plant 10; zones with both industrial and traffic loads: plot 4, Portnova St.; plot 5, Siversa St.; plot 6, Budenovskii Ave., Dolomanovskii St./Tekucheva St. and Mechnikova St.; plot 7, Vavilova St.; plot 8, Taganrogskoe sh.; recreation park zone: plot 1, Botanic Garden.

Table 2: oncentration indices (Kc) and total contamination indices (Zc) for the test plots in Rostov-on-Don

	Kc									
Plot	V	Cr	Co	Ni	Cu	Zn	As	Sr	Pb	Zc.	Contamination category
1	0.8	1.2	-	1.1	0.8	2.8	-	1.3	2.4	4.8	permissible
2	2.1	2.6	4.3	0.5	0.8	1.3	-	2.3	1.6	9.2	permissible
3	1.6	2.2	-	0.98	0.7	3.7	--	0.97	1.8	6.3	permissible
4	2.0	1.6	-	0.7	0.9	1.5	-	2.7	1.0	4.8	permissible
5	1.6	1.6	-	0.8	0.5	0.9	-	1.3	1.0	2.5	permissible
6	1.9	1.6	-	0.9	0.8	1.9	-	1.2	1.2	3.8	permissible
7	1.2	1.7	-	0.9	1.0	1.5	-	0.5	3.1	4.5	permissible
8	1.3	1.3	-	0.9	0.6	3.5	-	1.5	1.3	4.9	permissible
9	1.2	1.5	0.3	0.6	0.9	1.2	-	0.9	1.8	2.7	permissible
10	1.9	1.3	-	0.8	0.7	5.9	-	1.6	1.8	8.5	permissible

except the Sovetskii (plot 2) and Oktyabr'skii (plot 8) districts. The series of Kc values for the HMs whose concentrations reliably exceed the background level are as follows: Leninskii district, V > Ñr > Sr > Zn > Pb; Sovetskii district, Co > Zn > Sr > Pb > Cr > V; Zheleznodorozhnyi district, Sr (2.7) > Cr (2.2) > V (2.0) > Zn (1.5); Oktyabr'skii district, Zn > Pb > Cr> V> Co; Pervomaiskii district, Zn > V > Pb > V > Sr > Cr (Table 2).

Pylaisiella moss (P. polyantha) accumulates the largest amounts of the following heavy metals: Zn (Kc 1.2–5.9), Cr (Kc 1.2–2.6), Pb (Kc to 3.1), Sr (Kc to 2.7), Ni (Kc to 1.07) and Cu (Kc to 1.0). According to the Kc values, all the studied elements accumulated by pylaisiella moss form the following series of biological uptake: Zn > Pb > Sr > Cr > V > Ni > Cu > Cî.

CONCLUSION

Thus, the assessment of the accumulation capacity of pylaisiella moss for heavy metals in an urbanized ecosystem showed that, in accordance with their concentration indices (Kc), all the studied heavy metals form the series: Zn > Pb > Sr > Cr > V > Ni > Cu > Cî. The maximum Kc values were found for Zn (5.9), Pb (3.1) and Sr (2.7).

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