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ФИЗИКО-ХИМИЧЕСКИЙ И БИОЛОГИЧЕСКИЙ МОНИТОРИНГ В ЦЕНТРАЛЬНОЙ РОССИИ: ИССЛЕДОВАНИЕ КАЧЕСТВА АТМОСФЕРНОГО ВОЗДУХА И ПОЧВЫ НА ТЕРРИТОРИИ г. РОДНИКИ

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В г. Родники Ивановской области с использованием методов физико-химического анализа и биомониторинга была выполнена оценка качества атмосферного воздуха и почвенного покрова: проведен анализ образцов почвы и снега, биомониторинг образцов мха, определен показатель флуктуирующей асимметрии (ИФА) для листьев Березы повислой (Betula pendula Roth.). Содержание элементов в образцах мха, почвы и снега установлено при помощи нейтронно-активационного анализа (НАА) и атомно-абсорбционной спектрометрии (ААС). В общей сложности методом НАА было обнаружено 40 элементов (Na, Mg, Al, Cl, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Zn, As, Se, Br, Rb, Sr, Zr, Mo, Ag, In, Sb, I, Cs, Ba, La, Ce, Nd, Sm, Eu, Gd, Tb, Tm, Yb, Lu, Hf, Ta, W). Pb, Cd и Cu определялись с использованием техники ААС. Для идентификации потенциальных источников загрязнения применялись описательная статистика и факторный анализ, реализованные в программных пакетах OriginPro 8 и SPSS 17.0. Чтобы оценить вклад поступления металлов в образцы мха от антропогенных источников, были рассчитаны коэффициенты обогащения (EF). Для того, чтобы выявить наиболее загрязненные участки и охарактеризовать основные источники эмиссии полютантов, были построены карты пространственного распределения изучаемых элементов. При создании ГИС-карт использовалось программное обеспечение QGIS. Комплексная оценка качества воздуха и почвы в г. Родники и его окрестностях показала приемлемый уровень загрязнения. Установлено, что основным источником загрязнения является машиностроительный завод, расположенный в северной части населенного пункта. Именно этот завод является источником загрязнения почвы Zn, As, Fe и Co. Значения ИФА успешно подтверждают полученные данные. Выявлено, что загрязнение почвы оказывает большее влияние на ИФА, чем загрязнение атмосферы. Предложены меры по охране природы.

Ключевые слова: качество воздуха и почвы, атмосферные выпадения, нейтронный активационный анализ, атомная абсорбционная спектроскопия, биомониторинг при помощи мхов, флуктуирующая асимметрия, факторный анализ

PHYSICAL AND CHEMICAL AND BIOLOGICAL MONITORING IN CENTRAL RUSSIA: INVESTIGATION OF QUALITY OF ATMOSPHERIC AIR AND SOIL IN TERRITORY OF RODNIKI TOWN

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Air and soil quality assessment at the Rodniki town, Ivanovo Region, was performed using physical chemical analysis and biomonitoring techniques: soil and snow analysis, moss biomonitoring, fluctuating asymmetry (IFA) for the silver birch (Betula pendula Roth.). Elemental content in moss, soil and snow samples was determined by neutron activation analysis (NAA) and atomic absorption spectrometry (AAS). A total of 40 elements (Na, Mg, Al, Cl, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Zn, As, Se, Br, Rb, Sr, Zr, Mo, Ag, In, Sb, I, Cs, Ba, La, Ce, Nd, Sm, Eu, Gd, Tb, Tm, Yb, Lu, Hf, Ta, W) was determined by NAA. To determine concentrations of Pb, Cd, and Cu AAS technique was used. To reveal potential sources of element-pollutants the descriptive statistics and factor analysis were applied in OriginPro 8 and SPSS 17.0 software packages for Windows. To evaluate the contribution to the metal content in moss from anthropogenic sources, enrichment factors (EF) were calculated. Distribution maps were prepared to point out areas most affected by pollution and to characterize the main deposition patterns of pollutants. To create GIS maps QGIS software was used. The complex assessment of the air and soil quality of the Rodniki town and its vicinity showed an acceptable level of the contamination. It was established that the main source of pollution is the machine-building plant situated in the north of the town. This plant causes soil contamination by Zn, As, Fe, and Co. The IFA values successfully confirm the obtained concentration data. Besides, it was established that the soil contamination has a bigger influence on IFA than atmospheric pollution. Measures for nature conservation are suggested.

Keywords: air and soil quality, atmospheric deposition, neutron activation analysis, atomic absorption spectrometry, moss biomonitoring, fluctuating asymmetry, factor analysis

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INTRODUCTION

Environmental quality is one of the main factors determining the living standard of population. Nowadays along with the traditional physical chemical methods, the biomonitoring techniques have become more attractive owing to the high-speed of the response, simplicity, and cheapness.

Mosses showed themselves the most appropriate organisms among different species used for the atmospheric deposition of air pollutants such as heavy metals, nitrogen, POPs (persistent organic pollutants) and radionuclides due to the lack of cuticle, roots, and conducting tissues [1, 2].

Monitoring of atmospheric air pollution using moss and lichens are successfully carried out around the world since 1980 [3-9]. The background monitoring of the ambient air quality in Ivanovo region was performed in preparation to the moss survey 2010 in the framework of the UNECE ICP Vegetation [10]. The increased concentrations of heavy metals (V, Fe, Co, Zn) and arsenic were observed in the vicinity of the town of Rodniki (Fig. 1).

To investigate this phenomenon in details, the additional monitoring studies were performed: (I) moss biomonitoring; (II); soil analysis; (III) snow investigation; (IV) fluctuating asymmetry.

The developmental instability is one of the major properties of higher plants used recently to access an effect of environmental degradation. Quantitatively the developmental instability can be found as an index of fluctuating asymmetry (IFA) [11].

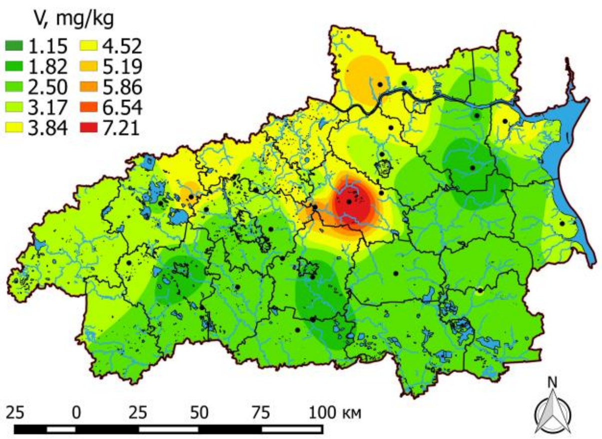

Fig. 1. Spatial distribution of vanadium in mosses of Ivanovo region

Рис. 1. Пространственное распределение ванадия во мхах Ивановской области

METODOLOGICAL ASPECTS

Sampling of moss and soil was carried out in the summer of 2012 and 2013 according to the following scheme: 5 samples of moss and soil were collected at the same sampling sites within the area of the town and 20 samples were collected along the cardinal directions (the North, South, East and West) at 0, 0.5, 1, 5, and 10 km distance.

Moss samples were collected and prepared according ICP Vegetation moss manual [12]. Samples of soil were collected from the topsoil at the depth of 10-20 cm, dried at room temperature for the constant weight, sieved through 1×1 mm grid, and cleaned from extraneous materials. The 10 samples of snow collected in February of 2014 were melted, and filtered. Two complementary analytical techniques were used: neutron activation analysis (NAA) at the reactor IBR-2 of FLNP JINR for determination of elemental content of moss and soil samples and atomic absorption spectrometry (AAS) at the ISUCT for those in snow. A total of 40 elements (Na, Mg, Al, Cl, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Zn, As, Se, Br, Rb, Sr, Zr, Mo, Ag, In, Sb, I, Cs, Ba, La, Ce, Nd, Sm, Eu, Gd, Tb, Tm, Yb, Lu, Hf, Ta, W) was determined by NAA. To determine concentrations of Pb, Cd, and Cu AAS was used. (Pb is not determined by NAA, and Cd and Cu are better determined by AAS at low concentrations).

According to the theory of the developmental stability of the environment, the deviation from the homeostasis conditions is expressed in increased IFA: small random deviations between left and right parts of the different morphological structures which normally possess bilateral symmetry [13].

Among the recommended species of higher plants [13], the silver birch (Betula pendula Roth.) was chosen. Leaves sampling was carried out according [14] in July of 2012-2013 at 26 sampling sites in the town of Rodniki and its vicinity. Leaves were collected from the trees having similar age, location, and duration of illumination. 5200 samples of the leaves (left and right side of 10 leaves from 10 trees from each sampling site) were analyzed by the five morphological characteristics measured by the divider and protractor. Classification of IFA was made in accordance with [15].

Software package SPSS 17.0 for Windows was used for multivariate statistical analysis, for descriptive and correlation analyses of the results obtained. Skewness and kurtosis coefficients were used to assess the frequency distributions of heavy metal concentrations. OriginPro 8 package was used to plot of the results of descriptive analysis (mean, standard deviation (SD), minimum, maximum). The data set of the concentrations obtained was subjected to the principal component factor analysis (PCA) with the Varimax rotation in order to highlight the relations between the elements and to reveal potential sources of the element-pollutants.

To evaluate the contribution to the metal content in moss from anthropogenic sources, enrichment factors (EF) were calculated. Applied to mosses, EF compare the concentration of elements of interest (*Ci*) with the concentration of a conservative soil element (scandium in our case) in moss versus local parent material according to the following equation [16]:

$$EF = \frac{C_i^{moss}/C_{Sc}^{moss}}{C_i^{soil}/C_{Sc}^{soil}}$$

Ratio values above 10.0 are generally considered to reflect enrichment of the element in moss [17, 18].

To create GIS maps QGIS software was used. The Pulkovo 1995 / Gauss-Kruger zone 7 (EPSG 20007) coordinate reference system was used. Spatial distribution maps were constructed using Inverse Distance Weighting (IDW) interpolation with the power value 2.

RESULTS AND DISCUSSION

The obtained data are given in the Tables 1-2. Element content in soil was compared between the territory of the town and its vicinity. Temporal trends of the concentrations were also established. Local background concentrations (lbg) were evaluated as an average value among ten lowest concentrations. The comparison with literature background concentrations [19] and maximum permissible concentration [20, 21] was also performed.

Table 1

Average element concentrations (mg/kg) in soil and in moss samples for the Rodniki town
***Таблица 1.* Средние концентрации элементов (мг/кг) в образцах почвы и мха в г. Родники**

	Rodniki town			Region	
	Town	Vicinity		Ivanovo	lbg
	2013	2013	2010	2010	
Na	7010[1)]/471[2)]	7850/566	5700/496	5000 /240	2856/138
Mg	1930/355	1640/474	1500/3580	1299/2650	769/1870
Al	40200/3800	40200/3780	28800/2370	26698/1100	16803/615
K	12900/10200	14700/9850	13500/13900	12069/10700	5959/7570
Ca	10100/7190	5840/6150	4000/6370	3726/4000	2105/2600
Sc	7.00/0.67	7.25/0.76	6.10/0.90	5.37/0.36	2.86/0.19
Ti	3160/296	4120/384	6.10/-	5.37/-	2.86/-
V	55.3/6.62	50.9/6.54	38.2/5.14	34.1/2.69	19.5/1.57
Cr	315/8.53	374/8.18	64.4/5.92	56.8/2.74	38.7/1.60
Mn	481/164	720/412	850/777	746/682	343/395
Fe	18000/2650	16400/2540	13200/1420	12196/752	8303/422
Co	7.5/1.12	10.1/1.59	7.9/0.87	7.21/0.49	4.48/0.32
Ni	48.6/4.83	33.9/6.36	15.8/6.05	15.3/4.33	6.8/2.62
Cu	-/-	-/-	6.64/18.4	6.43/8.6	1.59/2.0
Zn	115/228	77/132	45/68.5	39.9/51.5	23.0/34.1
As	3.74/0.72	3.94/0.72	3.1/0.98	2.94/0.60	1.81/0.43
Br	2.41/3.44	3.32/3.87	2.0/4.45	1.92/4.49	1.03/3.05
Rb	55.5/17.5	67.9/17.4	58/14.8	52.3/17.2	29.6/9.70
Sr	98.9/21.1	114/25.3	78/37.0	73.2/26.7	35.3/16.0
Cd	-/1.32	-/0.72	0.05/0.58	0.03/0.14	<0.002
Sb	0.51/0.30	1.80/0.25	0.42/0.24	0.38/0.19	0.24/0.11
Cs	1.83/0.26	1.88/0.28	1.6/0.19	1.43/0.16	0.82/0.10
Ba	350/70.3	449/96.0	410/135	371/95	247/45.9
La	20.7/2.20	24.8/2.54	21/1.58	19.2/0.81	10.9/0.44
Ce	40.3/3.96	50.4/4.21	32/2.82	28.4/1.44	16.2/0.75
Sm	2.37/0.40	2.36/0.41	9.5/0.42	11.0/0.18	3.8/0.10
Hf	-/0.53	-/0.68	-/0.47	-/0.19	-/0.07
Ta	-/0.05	-/0.07	-/0.09	-/0.04	-/0.02
Tb	0.43/-	0.51/-	0.47/-	0.42/-	0.21/-
Dy	3.90/-	4.33/-	-/-	4.75/-	<0.002
W	-/0.42	-/0.46	-/0.59	-/0.24	5.38/0.13
Hf	7.13/-	10.8/-	10.1/-	9.05/-	5.38/-
Pb	-/-	-/-	0.46/13.9	0.22/3.5	0.41/<0.002
Th	5.54/0.54	6.75/0.66	3.1/0.48	4.95/0.22	2.58/0.11
U	1.67/0.19	2.20/0.20	1.7/0.22	1.44/0.09	0.65/0.05

Note: [1)] - Element concentration in soil sample; [2)] - in moss sample
Примечание: [1)] - Концентрация элемента в образце почвы; [2)] - в образце мха

Table 2

Element concentrations (mg/l) in snow samples

***Таблица 2.* Концентрации элементов (мг/л) в образцах снега**

	Rodniki town 2013	
Metal	Town	Vicinity
Cr	0.011 (0.005 - 0.018)	0.016 (0.005 - 0.044)
Mn	0.053 (0.020 - 0.087)	0.068 (0.000 - 0.247)
Co	0.014 (0.014 - 0.015)	0.006 (0.003 - 0.013)
Ni	0.059 (0.057 - 0.060)	0.028 (0.006 - 0.096)
Zn	13.5 (1.0 - 25.9)	3.34 (1.46 - 8.70)
Pb	0.018 (0.005 - 0.030)	0.024 (0.010 - 0.065)

Box plots of the selected elements content in Ivanovo region soil presented in Fig. 2, together with the Mn concentration (chosen for the comparison as belonging to natural sources). One can see that the content of the majority of the elements under study in soil of the town of Rodniki and its vicinity is higher than the average regional concentration and local background. Otherwise, the concentration of Mn near the town of Rodniki does not differ from those for Ivanovo region.

Data obtained for the town of Rodniki and its vicinity were undergone frequency analysis (Table 2). Skewness coefficients indicated asymmetrical distribution for the majority of the elements of the territory of the town of Rodniki (only V and Mn approached normal distribution). Opposite situation was observed for the town vicinity.

Coefficients for cobalt and zinc strongly deviate from the normal distribution only. Positive values of the skewness and kurtosis coefficients pointed out the presence of the several points with heightened concentrations.

The ratio of the element content in the vicinity of the Rodniki town to the average regional concentration was found to compare 2010 and 2013 data. The averaged concentrations for the Rodniki district obtained in 2010 during background monitoring studies were used.

The comparison (Fig. 3) show strong increase of Zn content in soil (more than 2 times from 2010 till 2013). The concentrations of other elements have similar 30-40% growth. However, the concentration of primarily natural Mn, even slightly decreased. The obtained data point out the town of Rodniki as a source of the heavy metals.

To assess the soil quality the sum index of chemical pollution (Z_c) was used:

$$Z_c = \sum(C_i/C_{bg}) - (n-1),$$

where C_i is elemental concentration in the investigated soil; C_{bg} is background concentration of the element; n is number of elements included in calculation.

The local background concentrations obtained in 2010 were used for C_{bg}; n = 6 (V, Fe, Co, Zn, Mn, and As). Average value of the Z_c for the territory of the town of Rodniki was found to be 10, while for the vicinity it was 9. In accordance with the classification [22] obtained Z_c indicates the acceptable level of soil contamination.

The analysis of moss and snow successfully confirmed the conclusion made for soil. None selected element reached the normal distribution (Table 3). The narrowest distribution was obtained for Co, As, and Fe. It evidences for the existence of the point emission sources of these elements. Zn content in moss is two times higher than the background value, and Fe one is three times higher (Table 4). This fact justified an assumption that the origin of Zn in soil is not solid or liquid wastes, but the atmospheric depositions.

Table 3

Skewness and kurtosis coefficients of the moss and soil data for the Rodniki town and its vicinity (2013)

***Таблица 3.* Коэффициенты асимметрии и куртозиса для результатов анализа образцов почвы и мха в г. Родники и его окрестностях (2013)**

	V	Mn	Fe	Co	Zn	As
Soil						
Skewness	-0.09[1)] 0.07[2)]	-0.09 0.07	0.43 0.14	-0.67 1.22	1.78 1.92	0.74 0.003
Kurtosis	-3.00 -0.23	-2.08 -0.96	-1.12 -1.10	0.55 2.45	3.41 4.11	0.73 -0.97
Moss						
Skewness	-0.13 0.70	1.64 1.16	-1.57 1.74	1.19 3.54	1.56 1.68	-1.73 1.67
Kurtosis	-1.66	-0.43	-4.23	-13.88	-2.92	-4.81

Note: [1)] - Concentrations for the urban area; [2)] – for the vicinity
Примечание: [1)] – Концентрация в жилой зоне; [2)] – в окрестностях

Table 4

Concentration of selected elements in moss, soil and snow samples collected in the Rodniki town and its vicinity

***Таблица 4.* Концентрации некоторых элементов в образцах мха, почвы и снега, собранных в г. Родники и его окрестностях**

	Unit	V	Mn	Fe	Co	Zn	As
Soil 2013	mg/kg	54.9[2)] 50.0[3)]	566 727	18000 16400	8.60 10.08	96.5 79.6	3.85 3.92
Soil 2011	mg/kg	- 43.8	- 579	- 15600	- 7.6	- 52.2	- 3.49
Soil 2010*	mg/kg	38.0	850	12100	7.9	45.0	3.1
Moss 2013	mg/kg	7.24 6.28	254 425	3000 2510	1.21 1.65	179 132	0.74 0.71
Moss 2010[1)]	mg/kg	5.14	777	752	0.87	68.5	0.98
Snow 2014	ug/l	-	0.10 0.05	-	0.007 0.006	3.34 3.34	-

Note: [1)] - Results of the background monitoring.
[2)] - concentrations for the urban area; [3)] – for the vicinity
Примечание: [1)] – Результаты мониторинга фона; [2)] – концентрации для жилой зоны; [3)] – для окрестности

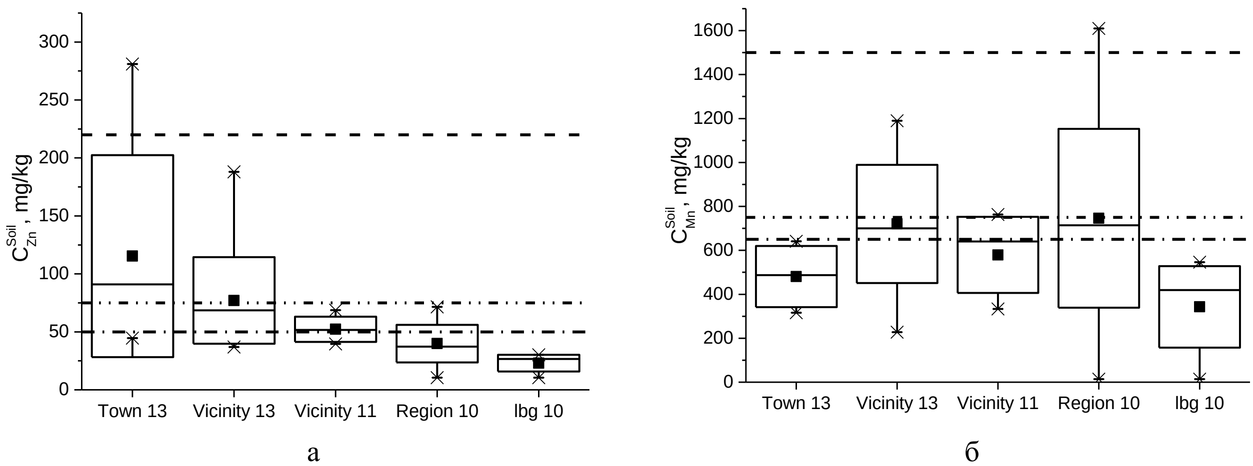

Fig. 2. Zinc (a) and manganese (б) concentration (mg/kg) in soil of the Ivanovo region and the Rodniki. (Town 13 – data of the Rodniki town of 2013; Vicinity 13 – data of vicinity of the Rodniki town of 2013; Vicinity 11 – data of vicinity of the Rodniki town of 2011; Region 10 – data of Ivanovo region of 2010; lbg 10 – data of local background of Ivanovo region of 2010; dashed line – maximum permissible concentration [13, 14]; dash-dot line – background level from [11]; dash-double-dot line – background level from [12])

Рис. 2. Содержание цинка (а) и марганца (б) в почве Ивановской области и г. Родники. (Town 13 – данные для г. Родники в 2013 г.; Vicinity 13 – данные для окрестностей г. Родники в 2013 г.; Vicinity 11 – данные для окрестностей г. Родники 2011 в г.; Region 10 – данные для Ивановской области в 2010 г.; lbg 10 – данные регионального фона Ивановской области в 2010 г.; пунктирная линия –предельно допустимая концентрация [13, 14]; штрихпунктирная линия – фон [11]; двойная штрихпунктирная линия – фон [12])

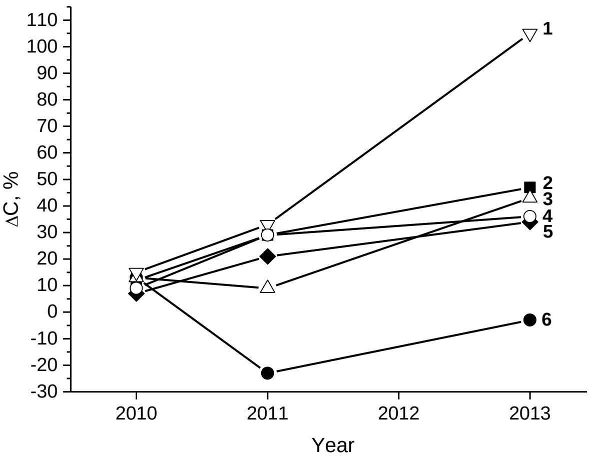

Fig. 3. Change in Zn (1), V (2), Co (3), Fe (4), As (5), Mn (6) concentration (%) in soil in 2010-2013

Рис. 3. Изменение содержания Zn (1), V (2), Co (3), Fe (4), As (5), Mn (6) в почве в 2010-2013 гг

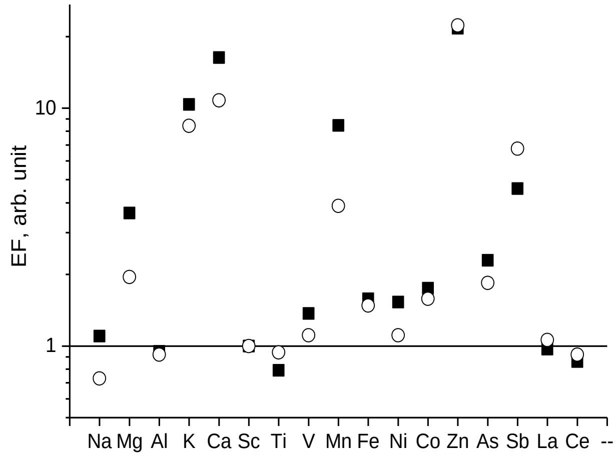

Fig. 4. Enrichment factors (EF) for the Rodniki town (open circles) and its vicinity (filled squares)

Рис. 4. Факторы обогащения (EF), рассчитанные для г. Родники (открытые круги) и его окрестностей (закрашенные квадраты)

Also for the territory of town of Rodniki the maximal concentrations of lead and cadmium in moss samples and snow were detected. The main source of these elements is traffic.

In 2013, the average IFA value for the territory of the town of Rodniki and its vicinity were 0.070 and 0.063 respectively. It is pointed out the significant level of the anthropogenic impact on the town ecosystems. The skewness (1.87 (town), 1.52 (vicinity)) and kurtosis (3.65 (town), 1.83 (vicinity)) coefficients calculated for the 2013 data also confirmed this conclusion. The average IFA value for the town of Rodniki was increased from 0.067 in 2012 to 0.070 in 2013.

To clarify the possible sources of the xenobiotic intake the enrichment factors were calculated (Fig. 4). Typical elements belonging to the earth crust (Al, Ti, and rare earths) have EF usually closed to 1. The biophilic elements (K, Ca, Mg, Mn) accumulate in moss owing to the active biological processes and uptake from atmospheric depositions. Among elements of interest, the EF only for Zn was more than 10. Vanadium, nickel, cobalt, iron, and arsenic have $1 < EF < 3$. It is pointed out different type of sources of Zn and other elements under study. Zn is highly enriched in moss and has the atmospheric deposition as a dominant way of the uptake. Otherwise content of Ni, Co, V, Fe, and As is very close to soil one, and soil probably was the origin of their arrival. Hence, the weathering of the soil at the territory of the town of Rodniki caused the increased levels of the above-mentioned elements. The EF of the majority observed elements for the territory of the town of Rodniki were less than those ones for the vicinity. It may be explained by the following manner. The higher level of element content of observed element in town soil led to smaller values of EF for this territory.

The distribution of the element concentration in moss and soil from the town boundary to 10 km distance was also investigated. To compare element content on the four main azimuths and between moss and soil all concentrations were recalculated to the relative ones: $\Delta C = C_i / \max(C_i)$.

To reveal location of the sources of elements under study the maps of spatial distribution were created. The arsenic and iron in soil are allocated almost identically. The Fe and As content in moss also have maximum at similar location but different from the soil one. The distributions of Zn in soil, moss, and snow coincide well justifying conclusion on the atmospheric origin of Zn. The most possible source of this element emission is the machine-building plant situated at the North of the town.

It should be noted that distribution of Zn coincides well with the IFA one, justifying correlation of the development instability of the higher plants and increased concentrations of heavy metals. The Pearson coefficient of the pair correlation, R, was calculated to reveal the most significant cause of IFA increasing (Fig. 5).

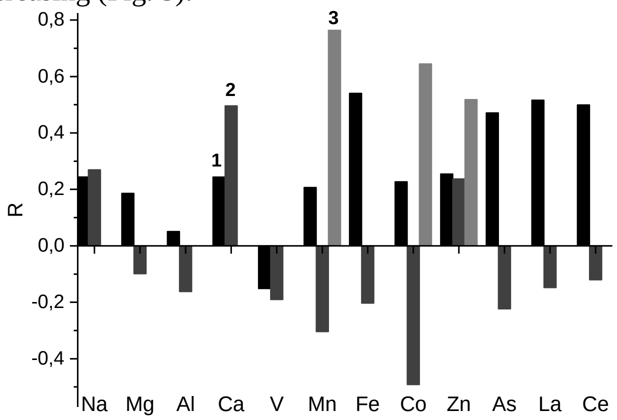

Fig. 5. Pearson coefficient (R) of the correlation between FA and soil (1), moss (2), and snow (3) data

Рис. 5. Коэффициент корреляции Пирсона (R) результатов оценки параметра флуктуирующей асимметрии и данных анализа образцов почвы (1), мха (2) и снега (3)

Analysis shows the prevalence of the edaphic sources of the high IFA values. The highest correlation was found for lead in snow (R = 0.75) indicating strong dependence of IFA from traffic. Final assessment of the elements origin was made on the basis of factor analysis. Three factors were recognized from the data obtained in 2013.

Factor 1 includes mostly elements in moss (Al, Sc, Ti, V, Fe, Co, As, Se, Zr, Hf, Ta, W, U, Th, alkali and alkali-earth metals, and rare earths). Also Al, Mg, and V in soil are associated with this component. These elements are all typical to the earth crust, and most probably this factor reflects the contamination of moss samples with soil particles. The maximum loadings of this factor situated at the south of town of Rodniki near asphalt plant. Despite of asphalt plant is closed to date the presence of V, As, and Fe indicates the air pollution by weathering of contaminated soil.

Factor 2 contains primarily elements measured in soil (Na, Sc, Fe, Co, As, Br, Rb, Cs, Ba, La, Sm, Hf, U, Th) and snow (Mn, Co, Pb). Ca, Cr, Sb, and Cd in moss as well as IFA also attributed to this component. High levels of the arsenic, heavy metals, and IFA found in the northern part of the town point out the machine-building plant as a most possible source of these elements.

Factor 3 comprises Mn, Ni, Br, Ba, Sr, Au from moss and Ti and Mn from soil. The maximum of this factor loadings is outside the town that evidences for the natural origin of these elements.

Factor 4 combines Zn in all media and soil Ca. The highest level of this factor located near the machine-building plant at the north of the town of Rodniki, which may be the most possible source of these elements.

CONCLUSION

The complex assessment of the air and soil quality of the town of Rodniki and its vicinity showed an acceptable level of the contamination. Combination of the statistical analysis and GIS technologies clarify the potential sources of elements. It was established that V has soil origin from southern part of the town. The highest growth of the concentration was marked for Zn originated from machine-building plant situated at the north of the Rodniki town. This plant also causes soil contamination by As, Fe, and Co. The IFA values successfully confirm the obtained concentration data. It was established that the soil contamination has a bigger influence on IFA than atmospheric pollution. The increasing of the concentration in all media from 2010 to 2013 was obtained for heavy metals and arsenic. Maximum concentrations were measured inside the territory of the town of Rodniki, however the influence of the anthropogenic impact was traced till 5 km distance.

The main recommendation is to develop in the town of Rodniki nature conservation measures for heavy metals emission (especially Zn). To prevent weathering of the contaminated soils it is suggested to lay out the lawns and grow trees and shrubs at the territory of the Rodniki town.

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