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Features of the Elemental Composition of *Syringa vulgaris* Cultivars in the Novosibirsk Urban Ecosystem

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Abstract

The data on the content of 20 elements determined by means of X-ray fluorescence analysis using synchrotron radiation (SRXRF) in the leaves and stems of three *Syringa vulgaris* cultivars “Nadezhda”, “Olimpiada Kolesnikova”, “Pamyat o Kirove” growing under the conditions of transport-caused and industrial pollution in Novosibirsk and under background conditions (reference). The concentrations of Mn, Fe, Co, Cr, Br, Rb, Nb in plants increased as a result of the technogenic impact, while the concentrations of Zn and Mo decreased (in comparison with the reference). The plants of “Nadezhda” cultivar were distinguished by the increased content of microelements under urban conditions. As a consequence of environmental pollution, changes in the relations between physiologically essential chemical elements were observed in the leaves and stems of the plants. The smallest changes were detected in the Fe/Mn and Zn/Cu ratios in the plants of “Pamyat o Kirove” cultivar. It was determined that the K/Rb ratio decreased under technogenic load in the plants of “Olimpiada Kolesnikova” and “Pamyat o Kirove” cultivars due to an increase in Rb content in the leaves and stems, while, quite contrary, this ratio increased in “Nadezhda” cultivar with respect to the reference. On the basis of the calculated biogeochemical transformation coefficient, the most significant changes in the microelement composition are recorded for leaves and stems of the “Nadezhda” cultivar, compared to others, which indicates its lower resistance to anthropogenic pollution in comparison with other cultivars. Common lilac plants of “Pamyat o Kirove” cultivar were determined to tolerant to pollution under urban conditions.

Keywords: *Syringa vulgaris*, anthropogenic impact, X-ray fluorescence analysis with synchrotron radiation (SRXRF), elemental composition

INTRODUCTION

The relevance of the studies of an urban ecosystem is due to the acuteness of the environmental pollution problem, which is urgent in many Russian cities [1].

Novosibirsk is the third largest city in Russia, an important industrial centre of West Siberia, and the ecological situation in this city remains uneasy within the recent 20–30 years. Moreover, a trend to its worsening is traced, mainly due to an increase in the number of automobiles and power plants, with their continuously increasing emissions [2]. Suspended matter (dust), nitrogen oxides, ammonia, carbon (II) oxide, formaldehyde, 3,4-benz(a)pyrene are major air pollutants, with the content in the air exceeding the maximal permissible concentrations (MPC) in Novosibirsk [3, 4]. In general, the level of atmospheric pollution in the city is evaluated as increased, however, since 1996 Novosibirsk is not included into the priority list of cities with the highest level of air pollution in Russia [3].

To keep the health of the population under the conditions of substantial technogenic impact, permanent monitoring of environmental quality is necessary. With an increase in the emission of pollutants into an urban environment, the use of biogeochemical data of the components started to be employed to provide an indication of the state of the environment. Information of the microelement composition of plants is important first of all for the evaluation of their vitality and for early diagnostics of the stress state [5]. Objective information on the state of the urban environment allows one to reveal and analyze responses of the biota to technogenic pollution. Many authors use woody plants or their parts as bioindicators for the studies of the urban environment [6–9]. Depending on plant species, different levels of stability to the action of pollutants are exhibited by plants, so it is an important task to search for species and cultivars of plants, either tolerable to the presence of pollutants or sensitive to the technogenic stress, to reveal the effect of an anthropogenic factor on plant objects.

The species of the *Syringa* genus are ecologically plastic, gas-resistant, they grow and blossom well under urban conditions [10]. The bioindicator properties of these plants for the evaluation of environmental pollution were reported in a number of works [7, 9–12].

Since 1986, works with the cultivars of the *Syringa* genus have been carried out at the Central Siberian Botanical Garden SB RAS (CSBG SB RAS, Novosibirsk) in the Laboratory of Dendrology, for the purpose of creating a collection for subsequent selection of the most promising cultivars resistant to anthropogenic pollution in the urban ecosystem. During these years, 126 *Syringa vulgaris* cultivars of foreign and home selection have been tested. At present, there are 26 cultivars in the collection of *Syringa vulgaris* that are recommended for planting in Siberian cities [13, 14]. They are characterized by high winter resistance, gas stability, ecological plasticity. and may be used for planting in the cities of cold climatic zones in Russia.

In 2003, researchers from the CSBG SB RAS Lyakh E. M. and Chindyaeva L. N. planted 17 syringa bushes in the public garden near the Glory Monument (Novosibirsk). Three landscape groups contained three most promising cultivars of *Syringa vulgaris* – "Nadezhda", "Pamyat o Kirove" and "Olimpiada Kolesnikova". As a result of annual observations, these cultivars demonstrated stability to urban conditions and are recommended for use in planting at public areas under design and construction [14].

The goal of the work was to determine the changes in the elemental composition in the plants of three cultivars of *Syringa vulgaris* under the effect of technogenic stress, to reveal the response of plants to pollution for the evaluation of the quality of the environment and to formulate recommendations for planting.

EXPERIMENTAL

The objects of the investigation were woody plants of the *Syringa* genus (Oleaceae family) – three cultivars of *Syringa vulgaris* L.: "Nadezhda", "Pamyat o Kirove" and "Olimpiada Kolesnikova", which are included in the list of most promising cultivars for their economic and biological indices [14].

The objects chosen for investigation were plants growing in the Lenin district of Novosibirsk (the Glory park), one of the most unfavourable regions from the ecological viewpoint (urban conditions). According to the data of the West Siberian Department of Meteorology and Environmental Monitoring, the Lenin district is one of the leading sites in the emissions of carbon (II) oxide, sulphur dioxide, nitrogen oxides, and solid pollutants into the atmosphere as a result of technological and other processes. The most substantial contribution to environmental pollution is made by benz(a)pyrene, suspended matter, formaldehyde, ammonia and nitrogen dioxide. It should be stressed that the maximal monthly average concentrations of metals did not exceed the permissible standard levels but still the level of atmospheric pollution in the city is considered as increased [3]. The park is in the centre of the Lenin district near power plants No. 2 and 3, and the ground is surrounded from three sides by automobile roads (Stanislavkiy str., Plakhotniy str., Parkhomenko str.) with intense traffic, related to the rank of dangerous pollution of atmospheric air [4]. Syringa bushed were planted at a distance of 15–17 m from the road (Parkhomenko str.,) and are separated from the road by a grass lawn, sidewalk and a shrubbery. The reference plants were the bushed of the same age growing in a forest land at the territory of CSBG SB RAS, situated in the Sovetskiy district of Novosibirsk (Academy town), a territory which is relatively favourable from the viewpoint of ecological situation.

Plant samples were collected during the generative phase in late August 2017 uniformly over the perimeter of the crown and simultaneously at both sites.

Average samples were formed by collecting 10 yearly sprouts from each plant. The leaves and stems of plants were analyzed, along with soil samples from each site. An average plant sample included the material collected from 5–10 plants at the stage of fruiting. Soil samples were taken from the root zone (10–25 cm) using the envelope method.

Determination of elements in plant and soil samples was carried out by means of X-ray fluorescence analysis using the synchrotron radiation (XPA SR) at the station of elemental analysis (VEPP = 3 storage ring) at the Shared Equipment Centre of the Siberian Centre for Synchrotron and Terahertz Radiation based at the INP SB RAS (Novosibirsk). A weighted portion of air-dry plant material or soil (1 g) was ground in an agate mortar. Then the samples were pressed as tablets ~1 cm in diameter, with a mass of 30 mg (with the surface density of 0.04 g/cm^2). Measurements were carried out with the energy of exciting radiation 23 KeVB. The time of each measurement for plant and soil samples was 300 to 500 s. The synchrotron radiation was monochromatized with the help of a butterfly-type monochromator based on silicon crystal with (111) working planes. Fluorescence was recorded with the help of a PentaFET detector (Oxford Instruments, Great Britain) with an energy resolution of ~135 eV (with the K_α line of iron – 5.9 KeV). The major characteristics of the experimental station and details of the procedure were described in [15–17].

The recorded spectra were processed using AXIL software intended for energy-dispersive spectrometric analysis with the help of the non-linear least-squares method. Element concentrations were determined with the help of an external standard. The detection limit was 10^{-8} g/g. Reference samples were the Russian standard samples of grass and cereal mixture GSO SORM1 and Baikal silt BIL-1 [18]. The error (reproducibility of analysis results) was calculated through ten parallel measurements of the standard SORM1 sample and five measurements of the standard BIL-1 sample repeated three times. For the majority of elements, reproducibility with respect to the SORM1 sample mainly varied within the range 5–11 %; for titanium, vanadium and yttrium – 19–26 %; for lead, cobalt, niobium and nickel it was 35–40 %, for chromium – 64 %. Detection limit for Co, Br, Mo, Rb and Pb was 0.01–0.07 ppm, doe Sr, Cu, Zn, Ni, Zr, Fe, Mn – 0.1–0.9 ppm, for other elements – more than 1 ppm. For the standard BIL-1 sample, reproducibility varied for the majority of elements within the range 3–12 %, for Pb and Mo – 14 %, Zr – 16 %. The detection limit for Mo, Nb, Co, Zr, Sr, Br, Y, Rb and Pb was 0.1–0.5 ppm, for other elements – more than 1 ppm.

Enrichment and dispersion of elements for plants growing under urban conditions in comparison with the plants growing under background conditions were evaluated by calculating local enrichment factor (EF_l) and dispersion factor (DF_l): $EF_l = C_u/C_b$ and $DF_l = C_b/C_u$, where C_b, C_u are the concentrations of an element in background and urban samples, respectively [19].

To reveal the changes in the chemical composition of plants under the effect of dust and gas emissions under urban conditions, an integrated parameter was used: the total index of biogeochemical transformation Z_v [19], which was calculated using the equation:

$$Z_v = \sum_1^{n_1} EF_l + \sum_1^{n_2} DF_l - (n_1 + n_2 - 1),$$

where n_1, n_2 are the amounts of elements with $EF_l > 1.5$ and $DF_l > 1.5$, respectively.

RESULTS AND DISCUSSION

A comparative analysis of soil from plant sampling sites showed that the differences in the concentrations of elements are insignificant (Table 1). Insignificant excess of vanadium, zinc, bromine, lead was recorded along with a decrease in manganese content in urban soils in comparison with the reference. In general, it may be stressed that the content of chemical elements in soil samples under investigation almost does not exceed the background level in the soils of Novosibirsk and the Novosibirsk Region, as reported in [20–23]. An exclusion is bromine: its concentration in sampling sites was 1.9 times higher than the background level; vanadium and lead concentrations are also increased by 10–30 %. This is most probably a consequence of the position of the sampling site near heat plants and automobile roads. In the opinion of G. A. Konarbaeva [24], increased bromine content is due to emissions from coal combustion at Power Plants No. 2 and 3, which are among the oldest power engineering works in the city operating for more than 60 years. Increased bromide content in soil is also possible along roads: bromine in the form of dibromoethane is added to petrol so that lead oxide formed from the combustion of tetraethyl lead was trans-

TABLE 1

Element content in the soils of the sites where *Syringa vulgaris* samples were collected under urban and background conditions

Element	Element content in soils, μg/g per air-dry mass		
	City	References (CSBG SB RAS)	Background value according to literature data [20–23]
K	13 430±671[1]	13 335±667	– [2]
Ca	30 336±2427	31 087±2487	–
Ti	3558±178	3213±161	4100[4]
V	73±4	64±3	60[3]
Cr	37±2	41±2	80[3]
Mn	715±36	931±47	750[3]
Fe	20 300±1015	22 380±1119	38 000[6]
Co	9±1	10±1	12[3]
Ni	31±3	34±3	35[3]
Cu	17±1	21±1	30[3]
Zn	73±5	46±3	70[3]
As	3.4±0.3	3.0±0.3	15[3]
Br	7±1	7±1	1.2–3.6[5]
Rb	52±6	49±6	–
Sr	163±21	158±20	170[3]
Y	20±3	20±3	–
Zr	166±33	228±46	250[3]
Nb	10±3	8±2	15[3]
Mo	0.5±0.2	0.7±0.2	3[3]
Pb	19±2	18±2	15[3]

[1] Mean value ± standard deviation.
[2] Dash means the absence of data.
[3] Background content of heavy metals in the soils of the southern part of West Siberia [21].
[4] Background content of heavy metals in the soils of the southern part of West Siberia [22].
[5] Background content of halogens in the soils of West Siberia [20].
[6] Background content in the soils of the Novosibirsk Region [23].

formed into volatile lead bromide, which enters soil from the atmosphere [24].

Investigation of the content of macro- and microelements in the above-ground parts of the S. vulgaris cultivars showed that the concentrations of macroelements (potassium and calcium) are higher in leaves than in stems, independently of cultivar and growing site (Table 2). The highest K content in the leaves was detected in the "Pamyat o Kirove" cultivar; in urban samples, it was 1.2 times higher than in background samples. K content varied in the leaves of two other syringa cultivars practically at the same level independently of the growing site but it was lower by a factor of 1.4–1.7 than in the "Pamyat o Kirove" cultivar (Fig. 1). Potassium was accumulated in stems mainly in the plants of the "Nadezhda" cultivar (11–12 mg/g). As a rule, calcium content is higher in the leaves of syringa from urban conditions, independently of the cultivar. For instance, the maximal concentration of calcium was detected under urban conditions in the leaves of the "Olimpiada Kolesnikova" cultivar (19 mg/g); it was slightly lower in the plants of two other cultivars (16–17 mg/g). Differences in Ca content were statistically insignificant in the stems of different syringa cultivars.

The total content of microelements is higher in the leaves of syringa than in stems (Fig. 2) independently of the level of technogenic load. The maximal content in the leaves (607 mg/kg) was detected in the "Nadezhda" cultivar from urban conditions, the minimal content (317 mg/kg) was detected in this cultivar under background conditions. It should be noted that depending on growing conditions leaves exhibited stronger differences in total microelement content than stems. For instance, microelement content in the leaves of the "Nadezhda" cultivar under urban conditions is 1.9 times higher than in the refer-

TABLE 2

Element content in the leaves (l) and stems (st) of *Syringa vulgaris* plants of the cultivars growing under urban and background conditions, Novosibirsk

Element	Plant organ	Content, mg kg of air-dry mass					
		City			Reference (CSBG SB RAS)		
		1	2	3	1	2	3
Ti	L	8±0.4[a]	9±0.5	4±0.2	14±1	8±0.4	2±0.1
	St	13±1	8±0.4	4±0.2	27±1	9±0.4	2±0.1
V	L	0.18±0.01	0.56±0.05	0.27±0.02	0.70±0.1	0.36±0.03	0.16±0.01
	St	0.56±0.05	0.39±0.03	0.25±0.02	1.01±0.1	0.45±0.04	0.16±0.01
Cr	L	0.2±0.01	2.9±0.16	3.1±0.18	N. d.[b]	0.7±0.04	1.3±0.08
	St	0.3±0.02	N. d.	2.6±0.15	2.7±0.2	N. d.	N. d.
Mn	L	152±6	189±7	261±10	74±3	54±2	75±3
	St	62±2	103±4	59±2	42±2	61±2	41±2
Fe	L	173±8	228±10	169±8	93±4	127±6	75±3
	St	179±8	73±3	67±3	156±7	73±3	44±2
Co	L	0.08±0.01	0.08±0.01	0.08±0.01	0.05±0.005	0.05±0.01	0.05±0.004
	St	0.07±0.01	0.05±0.01	0.07±0.01	0.06±0.01	0.04±0.00	0.03±0.003
Ni	L	0.7±0.03	0.8±0.04	1.0±0.04	0.9±0.04	0.6±0.03	0.5±0.02
	St	1.1±0.05	0.9±0.04	1.0±0.04	1.3±0.06	1.0±0.04	0.6±0.02
Cu	L	10±1	11±1	11±1	10±1	4.6±0.24	4.4±0.230
	St	11±1	12±1	12.5±1	12±1	8.6±0.45	9.5±0.495
Zn	L	35±2	25±1	74±4	101±5	61±3	80±4
	St	36±2	40±2	48±2	44±2	57±3	54±3
As	L	0.6±0.02	0.6±0.02	0.0±0.0004	0.5±0.02	0.6±0.02	0.4±0.01
	St	0.4±0.01	0.7±0.02	1.2±0.0363	0.6±0.02	0.4±0.01	0.6±0.02
Br	L	6±0.5	9±1	8.8±1	2.0±0.2	4.4±0.3	2.5±0.2
	St	0.2±0.02	0.4±0.03	1.5±0.1	0.2±0.02	0.4±0.03	0.3±0.02
Rb	L	12±1	14±1	9±1	7±1	7±1	12±1
	St	6±1	13±1	10±1	3±0.3	7±1	12±1
Sr	L	117±8	79±6	61±4	131±9	68±5	60±4
	St	64±5	74±5	76±5	76±5	68±5	62±4
Y	L	0.39±0.04	0.33±0.04	0.17±0.02	0.30±0.03	0.11±0.01	0.6±0.1
	St	H. o.	0.17±0.02	0.31±0.04	H. o.	0.14±0.02	0.9±0.1
Zr	L	1.0±0.2	1.5±0.2	1.2±0.2	0.8±0.1	0.5±0.1	0.4±0.1
	St	0.4±0.1	0.5±0.1	0.5±0.1	0.6±0.1	0.5±0.1	0.4±0.1
Nb	L	1.9±0.2	2.3±0.2	1.6±0.1	0.5±0.0	1.1±0.1	0.5±0.0
	St	0.8±0.1	1.1±0.1	1.6±0.1	2.9±0.3	H. o.	1.0±0.1
Mo	L	0.2±0.03	0.5±0.1	0.9±0.1	2.0±0.3	3.6±0.5	2.9±0.4
	St	0.2±0.02	0.2±0.03	0.3±0.04	0.7±0.1	1.5±0.2	1.5±0.2
Pb	L	1.5±0.2	1.5±0.2	1.0±0.1	1.3±0.2	1.6±0.2	1.3±0.2
	St	1.0±0.1	1.1±0.1	1.5±0.2	1.3±0.2	1.0±0.1	1.2±0.2
Fe/Mn	L	1.1	1.2	0.6	1.3	2.4	1.0
	St	2.9	0.7	1.1	3.7	1.2	1.1
Zn/Cu	L	3.3	2.2	6.9	10.0	13.4	18.3
	St	3.2	3.4	3.8	3.7	6.7	5.7
Ca/Sr	L	144	247	260	125	215	217
	St	128	116	90	94	131	129
K/Rb	L	1995	1109	1738	3128	2229	1412
	St	1650	809	1135	2635	1487	994

Note. *S. vulgaris* cv plants: "Pamyat o Kirove" (1); "Olimpiada Kolesnikova" (2); "Nadezhda" (3).

[a] Mean value ± standard deviation.

[b] N. d. – content below detection limit.

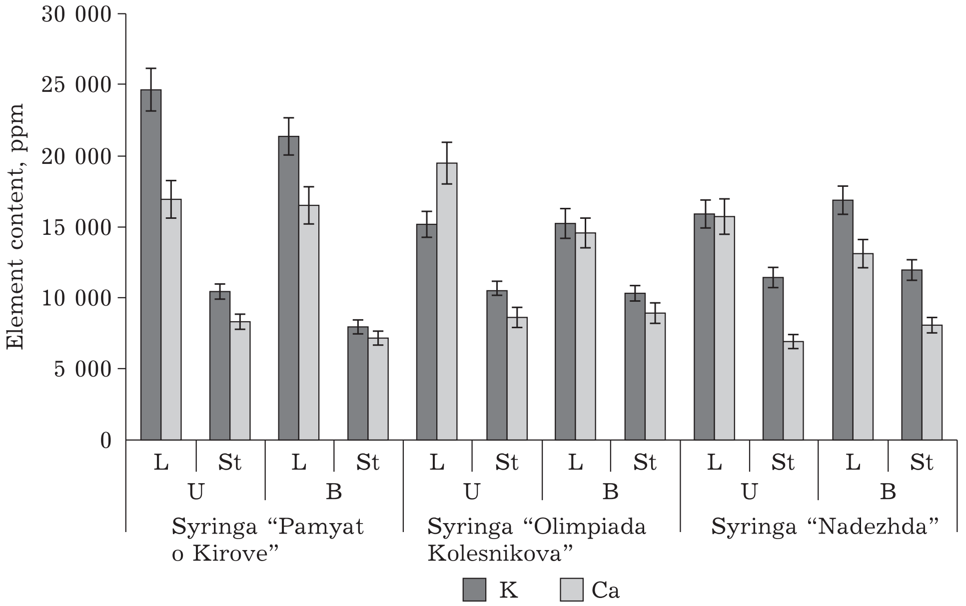

Fig. 1. K and Ca content in the leaves (l) and stems (st) of the plants of *Syringa vulgaris* cultivars growing under urban (U) and background (B) conditions.

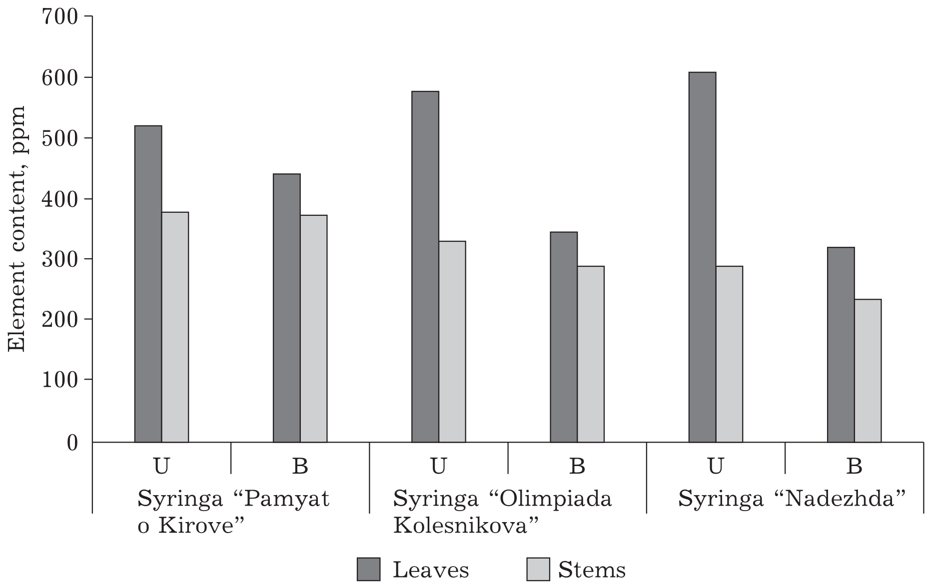

Fig. 2. Total content of elements in the leaves and stems of *Syringa vulgaris* cultivars growing under urban (U) and background (B) conditions.

ence sample, and in stems – 1.2 times higher. Depending on growing conditions, the least detectable changes of total microelement content are observed for the leaves and stems of the "Pamyat o Kirove" cultivar in comparison with the plants of other cultivars.

Analysis of the content of other microelements in above-ground organs of different cultivars of syringa revealed increased concentrations of Mn, Fe, Co, Cr, Br, Nb and decreased concentrations of Zn and Mo in plants under urban conditions in comparison with background ones (see Table 2). For the other ten elements, no clear connection with growing conditions could be revealed. For example, Ti and V were accumulated to a maximal extent in stems and leaves of the "Pamyat o Kirove" cultivar at the background site, and the content of these elements in the stems is 2–3 times higher than in the leaves. Under urban conditions, their content in the leaves is 1.8–3.9 times lower, and in the stems, it is 2 times lower in comparison with the background. No substantial changes in Ti and V content were detected for two other cultivars. The content of Cu increased by a factor of 1.3–2.5 in the leaves and stems of the "Olimpiada Kolesnikova" and "Nadezhda" cultivars growing under the conditions of anthropogenic load, while this parameter remained almost at the same level for the "Pamyat o Kirove" cultivar. A similar trend was detected for Ni. The highest As accumulation was revealed in the stems of the "Nadezhda" cultivar from urban conditions, while this element was not detected in the leaves. The content of Rb increased by a factor of 2 in the leaves and stems of the "Pamyat o Kirove" and "Olimpiada Kolesnikova" cultivars under urban conditions; a decrease in the concentration of this element was detected in the "Nadezhda" cultivar in comparison with the reference. The highest Sr content was detected in the leaves and stems of the "Pamyat o Kirove" cultivar from background conditions; it slightly decreased under technogenic action. Changes were statistically insignificant in other cultivars. The highest Y content was detected in the stems of background samples of the "Nadezhda" cultivar, for other cultivars the accumulation of this element was detected for urban samples. The content of Zr is higher in the leaves of urban plants. Changes in Pb content are statistically insignificant.

Physiologically essential are changes in the relations between biophilic elements. A shift of the ratios of some elements may be evidence of unfavourable growing conditions [19, 25–29]. The Fe/Mn ratio decreased in the leaves of plants of the "Olimpiada Kolesnikova" and "Nadezhda" cultivars from urban conditions in comparison with the reference, though this ratio remained almost unchanged in the leaves of the "Pamyat o Kirove" cultivar (Fe/Mn = 1.1–1.3), which is the evidence of the normal course of processes involved in photosynthesis (see Table 2). Antagonistic relations between zinc and copper are well known; they are expressed as braking of the absorption of one of these elements under the action of the other element [26]. The the Zn/Cu ratio in leaves varies from 2.2 to 18.3, in stems from 3.2 to 6.7. The maximal value of the Zn/Cu ratio was detected in the leaves of the 'Nadezhda' cultivar from the reference, while under urban conditions it decreased to 6.9. Less substantial differences in Zn/Cu ratios are characteristic of the plants of "Pamyat o Kirove" cultivar. The ratio of Ca/Sr is very important in the soils and plants [28]. This ratio is used as an additional parameter for the biogeochemical evaluation of the ecological state of territory. For Ca/Sr <100 in plant hay crop, the situation is acknowledged as relatively satisfactory, 1 < Ca/Sr < 10 means ecological emergency, while Ca/Sr <1 means ecological disaster [30]. The Ca/Sr value in soils and plants investigated by us is higher than 100, which is evidence of a relatively satisfactory situation at sampling sites. An exception was the stems and leaves of the "Pamyat o Kirove" plants from the reference site and the "Nadezhda" cultivar from urban conditions, for which the Ca/Sr ratio was somewhat lower than 100 and was equal to 90 and 94, respectively. In the opinion of some authors, the K/Rb ratio may be connected with feed balance in woody plants [26, 27, 31]. Rubidium may partially substitute potassium in plants but not in metabolism processes, so high rubidium concentration is toxic for plants [26]. The authors of [27] stress that the value of the K/Rb ratio is two times higher for trees from a more heavily polluted locality and remains constant for a separate tree. According to our data, there are differences in the K/Rb ratio independently of the syringa cultivar. The value of the K/Rb ratio is lower by a factor of 1.6–2 in the leaves and stems of the "Olimpiada Kolesnikova" and "Pamyat o Kirove" cultivars from urban conditions, while for the "Nadezhda" cultivar it is, quite contrary, higher than in the reference plants.

Worsening of environmental conditions causes plant responses involving either accumulation or a decrease in the concentrations of microelements, which is due to changes in the intensities of biological processes [1, 19, 25, 26].

The index of biogeochemical transformation (Z_v) depicts distortion of the normal ratios of elements in plant organs, characteristic of their phylo- and ontogenetic specialization, and provides a quantitative description of the imbalance of microelements arising as a result of increased anthropogenic load [1, 17, 19, 25]. Under the conditions of technogenic load, Mo is considered as the scattered element: its highest scattering is detected in the leaves of the "Pamyat o Kirove" plants (DF_1 = 9), while its lowest scattering is detected in the plants of the "Nadezhda" (DF_1 = 3). Scattered elements also include Zn. Thus, its content in the leaves of the "Pamyat o Kirove" and "Olimpiada Kolesnikova" cultivars from urban conditions decreases by a factor of 2.4–2.9 in comparison with the background. A decrease in zinc concentration was also detected for stems and leaves of the "Nadezhda" plants, but the changes are less substantial.

The elements related to priority pollutants in the leaves of syringe plants of all cultivars under study are Nb, Mn and Br, the local enrichment

TABLE 3

Index of biogeochemical transformation (Z_v) for above-ground organs of *Syringa vulgaris* plants of different cultivars growing in Novosibirsk

Syringa vulgaris cultivar	Z_v	
	Leaves	Stems
"Pamyat o Kirove"	22.8	8.3
"Olimpiada Kolesnikova"	23.6	9.4
"Nadezhda"	26.3	15.1

factor are higher than 3 as a rule. Increased content of Fe and Co in the leaves was established (EF_1 > 1.5). In addition, the elements accumulated in the leaves of the "Olimpiada Kolesnikova" and "Nadezhda" plants are Cr, Zr, V and Cu, the leaves of "Olimpiada Kolesnikova" and "Pamyat o Kirove" plants accumulate Rb, the leaves of the "Nadezhda" cultivar accumulate Ni and Ti. Accumulation of elements in stems is mainly characteristic of the plants of the "Nadezhda" cultivar (Br, Co, As, Ni, V, Fe).

The index of biogeochemical transformation (Z_v) is formed mainly from EF_1 and is characterized by the values from 22.8 to 26.3 in leaves and from 8.3 to 15.1 in stems of syringa plants (Table 3), which corresponds to the high (25–35), medium (15–25) and low (<15) level of biogeochemical transformation according to ranking for woody plants as described in the monograph [19]. More substantial changes of the elemental composition of syringa leaves under technogenic action were detected in the "Nadezhda" cultivar. The values of Z_v for the leaves and stems of the plants of this cultivar are 1.1–1.8 times higher than those for two other cultivars. According to the calculated Z_v value, the plants most stable against pollution are the "Pamyat o Kirove" plants, which may be recommended for extensive planting in cities, while the "Nadezhda" cultivar plants are most sensitive to the anthropogenic factor. In general, the level of element accumulation in the leaves of *Syringa vulgaris* is comparable with the results reported by a number of authors for other plant species under urban conditions and is characteristic of the residential area [19, 25].

Differences in element contents in *S. vulgaris* of three cultivars correlate with the results obtained by us previously for the same samples over morphometric parameters. The largest changes in the morphometric parameters of leave plates and an increase in the coefficient of fluctuating asymmetry of leaves were established for *S. vulgaris* plants of the "Nadezhda" cultivar, while the smallest ones were detected in the "Pamyat o Kirove" cultivar [12].

CONCLUSION

The data on the content of 20 elements in the leaves and stems of three cultivars of *Syringa vulgaris* growing under the conditions of transport- and industry-related pollution and under background conditions are presented. It is established that technogenic load caused an increase in the concentrations of Nb, Br, Mn, Fe, Co, Cr and a decrease in the content of Zn and Mo in plants in comparison with the reference samples. A specific feature of the plants of the "Nadezhda" cultivar is a more intense accumulation of microelements; their total content in the leaves of plants from the transport-industry affected site was 1.9 times higher in comparison with the background.

As a consequence of growing under the conditions of anthropogenic load, changes in the relations between physiologically essential elements were observed in the leaves and stems of plants. The least substantial differences in Fe/Mn, Zn/Cu ratios are characteristic of the plants of the "Pamyat o Kirove" cultivar. It was revealed that a decrease in the K/Rb ratio due to an increase in Rb content in the leaves and stems is characteristic of the "Olimpiada Kolesnikova" and "Pamyat o Kirove" cultivars under technogenic action, while, quite contrary, this ratio increases under urban conditions with respect to the reference in the leaves and stems of the "Nadezhda" cultivar.

Biogeochemical transformation of the microelement composition of syringa leaves of different cultivars is characterized by the medium and high levels with Z_v = 22.8–26.3. The largest coefficient of biogeochemical transformation was detected for the plants of the "Nadezhda" cultivar, which is evidence of more substantial changes in the microelement composition for this cultivar than for two other cultivars. It was revealed that the "Pamyat o Kirove" cultivar is more tolerant to environmental pollution, so this cultivar may be recommended for extensive use in urban planting; the "Nadezhda" cultivar is more sensitive to the action of pollutants.

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