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Anthropogenic Influence on Heavy Metals' Content in Natural Flora

Tatiana L. Egoshina[1, 2], Lyudmila N. Shikhova[1], Eugene M. Lisitsyn[1, 3] and **Olga L. Voskresenskaya[4]**

[1]Vyatka State Agricultural Academy, Kirov (Russia); **E-mail:** paiis@bk.ru

[2]All-Russian Institute of Game and Fur Farming, Kirov (Russia);

[3]North-East Agricultural Research Institute, Kirov (Russia);

[4]Mari State University, Yoshkar-Ola (Russia).

ABSTRACT

The content of heavy metals in phytomass of plants in natural habitats and habitats subject to various degrees of anthropogenic influence was estimated by a method of atomic-absorption spectrometry. Concentration of manganese in phytomass of plants in polluted habitats changes from 46.42 to 158.94 mg/kg of dry matter. At semi-aquatic and water plants of polluted habitats concentration of manganese in green mass is on average 111.05…190.34 mg/kg. Average concentration of copper for plants of polluted habitats is 3.47…5.96 mg/kg, for background – 3.27 mg/kg. Plants of semi-aquatic habitats are not inclined to copper accumulation. All terrestrial and semi-aquatic plants in technogenic territories contained iron in insignificant amount. Statistically significant invert correlation between content of iron and such metals, as cadmium, manganese, lead, and magnesium is noted. The value of zinc concentration in plants of technogenic habitats varied from 21.12 to 44.01 mg/kg of dry matter, slightly exceeding that at plants of background habitats (28.75 mg/kg). Zinc content in phytomass of water plants is twice lower than of terrestrial plants (17.05…19.51 mg/kg). Concentrations of nickel in plants of background and technogenic habitats are close - 1.93 and 1.69 mg/kg of dry matter accordingly. Concentration of cadmium in plants from technogenic habitats exceeds maximum allowable concentration (MAC). On the average for plants of polluted habitats the lead content is 1.11…1.15 mg/kg, for background – 0.6 mg/kg. Average concentration of chrome in phytomass changes almost 50 times - from 0.21 mg/kg to 11.56 mg/kg.

Keywords: hydrophyte, hygrophyte, macrophyte, maximum allowable concentration, pollutant, technogenic habitat

Mathematics Subject Classification: 92F05

Journal of Economic Literature (JEL) Classification: Q57

1. INTRODUCTION

The problem of saturation of biosphere with pollutants, including heavy metals, attracts special attention recently. Rapid population growth and global changes that have occurred in the last century in society have dramatically increased the production of waste and new types of pollutants among which the heavy metals play a leading role. The technogenic share of heavy metals in atmosphere increases constantly and is now 75% for copper and zinc approximately, cadmium - 50%, nickel - 30%, lead – 50…80% (Chernykh, Milashchenko, & Ladonin, 1999). The main sources of soil and water contamination by heavy metals are fertilizers (phosphate fertilizers), and also pesticides, fungicides, and sewage (Chen, Sun, Sun, Chao, & Guo, 2007; Hadlich & Ucha. 2010; McGrath & Tunney, 2010; Vamerali et al., 2012) Contamination of soil and water by heavy metals is connected with its uptake by plants – crops and vegetables – cultivated for human consumption (Chang Zhang et al., 2014; Khodaverdiloo, Dashtaki, & Rezapour, 2011; Moustakas, Akoumianaki-Ioannidou, & Barouchas, 2011). Toxicity of heavy metals for plants includes inhibition of many enzymes involving in disruption of physiological processes including photosynthesis and growth alterations (Chaffei-Haouari, Carrayol, Ghorbel, & Gouia, 2009; Rivelli, De Maria, Puschenreiter, & Gherbin, 2012), synthesis of phytochelatins and antioxidants (Cherif, Mediouni, Ben Ammar, & Jemal, 2011; Yadav, 2010).

Annual technogenic input of the most dangerous heavy metals in Kirov region is also significant and reaches 4.5 tons of cadmium and 451.64 tons of lead (Burkov, 2005). Anthropogenic activity influences a change in chemical composition of biological objects. Accumulation of heavy metals by food plants and animals is especially dangerous as about 75…80 % of heavy metals get to a human body with food. The increased concentration of heavy metals is one of the reasons of the decrease in general health standards of the population of Russia.

Heavy metals play a special role in biosphere. Being mainly in dispersion condition, they can form local accumulations where their concentration is hundreds and thousand times higher than regional average level. Metals being present at living organisms in small amounts, carry out rather important functions being a part of biologically active substances. The ration of metals' concentrations in organisms was developed throughout the evolution of the organic world. Considerable deviations from these ratios cause negative often pernicious effects. Being one of the main natural resources, an indispensable condition of modern civilisation development, metals form group of the most dangerous pollutants of biosphere.

Certain plants called hyperaccumulators absorb unusually large amounts of metals in comparison to other plants (e.g. up to 0.1% chromium, cobalt, copper or nickel or 1% zinc, manganese in the aboveground shoots, dry weight). Such hyperaccumulators are taxonomically widespread throughout the plant kingdom (different genera and families of plants) (Cunningham, Berti, & Huang, 1995). Search of such plants for the purpose of phytoremediation of polluted areas is urgent and significant problem which botanists and ecologists face.

2. MATERIAL AND METHODS

To study the change of element structure of plants from natural habitats and the habitats subject to various degrees of anthropogenic impact, vegetative samples were selected on the following technogenic sites:

1. Drilling waste disposal site of factory on processing of nonferrous metals (FPNM), Kirov city
2. Municipal waste treatment facilities, Kirov city
3. Floodplain of the Vyatka River near municipal waste treatment facilities, Kirov city

4. Vicinities of Lake Ivanovskoe in which cleared sewage from Kirovo-Chepetsk chemical industrial complex and municipal clearing facilities is emitted, Kirovo-Chepetsk city

5. Vicinities of the Lake Prosnoe in which sewage from Kirovo-Chepetsk chemical industrial complex and thermal power station is emitted, Kirovo-Chepetsk city

6. Territory of Kirov and Kirovo-Chepetsk cities and their vicinities

lant samples were collected in dry weather conditions. Plants of the same species from the different trial areas were in one phenophase. Green mass was collected according to the rules of gathering of raw materials for each species (Rules of gathering …, 1989). Not less than 30 individuals of each species of plants of grass-and-subshrub layer were selected in regular intervals within the trial area. At preparing plant samples their pollution by soil was excluded. Plant samples (shoots and roots) were rinsed briefly in deionized water and dried with tissue paper, then processed for heavy metals quantification by drying at 70 ^{o}C. After reducing particle size with a ball mill samples were dry-ashed at 500 ^{o}C for 5 h in a muffle furnace and the ash was dissolved in 3.3% (v/v) HCl (Risser & Baker, 1990). Definition of the content of heavy metals was conducted with a method of atomic-adsorption spectrophotometry (Methodical instructions…, 1992). All measurements were taken in at least triple replicate. Statistical data processing was done with Statistica 10 software.

3. RESULTS AND DISCUSSION

It's known, the chemical composition of plants depends on two primary factors: 1) ecological (landscape-and-geochemical) defining geochemical conditions of plants growth, content of elements in the environment, forms of elements (including mobile, accessible to plants), and 2) genetic, causing biogeochemical specialization of separate families, genera and species as well as formation of physiological barriers or thresholds of absorption of elements in connection with systematic position of species and their physiology (Il'yin, 1991; Kabata-Pendias, 2010; Shkol'nik, 1974).

1. Manganese. Concentration of manganese in phytomass from the polluted habitats changes largely. The highest concentration of manganese is noted in average sample of aboveground green mass of the plants growing in a coastlandof Ivanovskoe lake (158.94 mg/kg of dry matter). The lowest content of manganese is noticed at plants from a dam of drilling waste disposal site of FPNM (46.42 mg/kg of dry matter) (Figure 1) which is close to the one for non-polluted habitats.

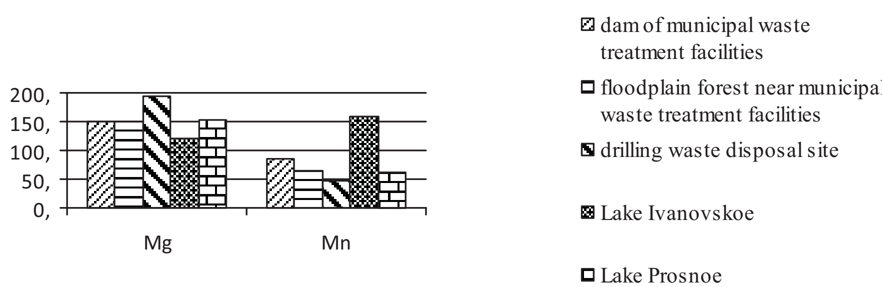

Figure 1. Magnesium and manganese concentrations in phytomass of plants in technogenic habitats (mg/kg of dry matter)

At semi-aquatic and water plants of the polluted habitats concentration of manganese in green mass on the average reaches 111.05…190.34 mg/kg. It is almost 3 times higher than in background habitats – 47.01mg/kg (Figure 2).

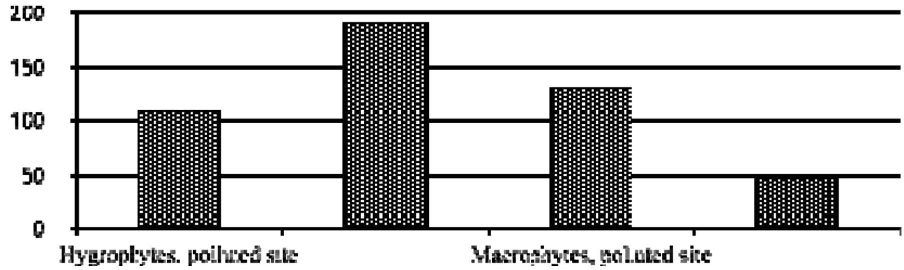

Figure 2. Manganese content in plants of different ecological groups in background and polluted habitats

(mg/g of dry matter)

The highest accumulation ability in relation to manganese, possibly, has tripartite bur-marigold (*Bidens tripartita* L.). Concentration of manganese in green mass of the given species in floodplain of the lake Ivanovskoe reaches 766.49 mg/kg that is above the level which is considered to be phytotoxic (500.0 mg/kg). The majority of plants of central floodplain of the lake Ivanovskoe are characterized by the content of manganese less than 100 mg/kg of the dry matter. Only a bay-leaf willow (*Salix pentandra* L.) and meadow foxtail (*Alopecurus pratensis* L.) contained high quantities of manganese. Among hygrophytes there are more species inclined to accumulation of manganese: common club-rush (*Schoeneoplectus lacustris* (L.) Palla.), batter dock (*Potamogeton natans* L.), water-torch (*Typha latifolia* L.), hornweed (*Ceratophyllum demersum* L.), Old-World arrowhead (*Sagittaria sagittifolia* L.), and tripartite bur-marigold. This fact possibly indicates genetic predisposition of hygrophytes to accumulation of manganese and high degree of solubility of manganese compounds.

2. Copper. The highest content of copper is noted in green mass of the plants growing in territory of drilling waste disposal site of FPNM – 40,23 mg/kg of dry mass (Figure 3). This is 10 times higher than in plants of other technogenic territories. This fact probably indicates high copper content (up to 10…15%) in soils of the area.

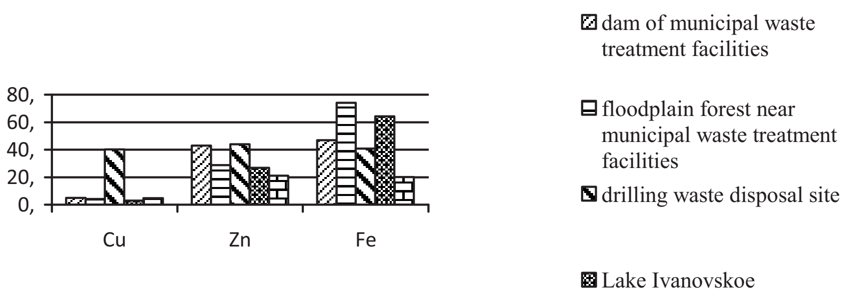

Figure 3. Copper, zinc, and iron concentrations in phytomass of plants in technogenic habitats (mg/kg of dry matter)

Average concentration of copper in green mass of plants of terrestrial polluted phytocenoses reaches 12.57 mg/kg which is almost 3 times higher than in background habitats. Average concentration of copper in plants from polluted habitats is 3.47…5.96 mg/kg, background – 3.27 mg/kg. Possibly plants in semi-aquatic habitats are not inclined to copper accumulation because all distinctions in the copper content in silt on the polluted and background habitats are rather considerable. The most considerable accumulation ability in relation to copper is marked for common tansy. In aboveground green mass of tansy growing on a dam of drilling waste disposal site of FPNM, concentration of copper reaches 241.66 mg/kg of a dry matter that is almost 50 times higher than MAC for foodstuff.

3. Iron. The highest content of iron is noted in average sample of green mass of the plants collected in floodplain forest at municipal waste treatment facilities of Kirov city (74.00 mg/kg of dry matter). This value is only 30% below that for plants of background habitats. The lowest concentration of iron is revealed in samples of the plants collected in a coastal strip of Prosnoe lake (20.15 mg/kg of dry matter) (see Figure 3).

Table 1 demonstrates that all investigated species of terrestrial plants in technogenic areas contained iron in insignificant amounts (58.02 mg/kg of dry matter) - almost twice below that in background territories (98.55 mg/kg of dry matter) and almost 3 times lower than the clark (Bowen, 1979). Concentration of iron in green mass of semi-aquatic plants in polluted ecosystems was hardly higher (56.92 mg/kg). The low content of iron in samples of plants in technogenic habitats is connected with antagonism of some other heavy metals to iron. There is statistically significant (P = 0.05) negative correlation between iron and cadmium (r = -0.76 …-0.89), manganese (r = -0.57 …-0.73), lead (r = -0.76 …-0.81), magnesium (r = -0.63 …-0.79) content. Possibility of such replacements is marked in literature (Lozanovskaya, Orlov, & Sadovnikova, 1998; Shikhova & Egoshina, 2004).

Table 1. Chemical composition of aquatic plants in polluted and non-polluted habitats (mg/g of dry matter)

Ecological group of plants	Mg	Cu	Ni	Cd	Pb	Zn	Fe	Cr	Mn
Hygrophytes, polluted habitats	49.91	3.47	2.04	0.24	1.15	19.51	56.92	2.96	111.05
Hydrophytes, polluted habitats	42.32	5.96	1.34	0.39	1.12	17.05	58.98	3.77	190.34
Macrophytes, non-polluted habitats	34.50	3.27	1.60	0.12	0.60	12.35	98.55	1.67	47.91
Macrophytes, polluted habitats	47.39	4.38	1.82	0.28	1.11	18.59	58.02	3.02	130.38

Among species which accumulate iron in technogenic territories it is possible to mark a cinnamon rose (*Rosa majalis* J. Herrm.), some species of genus *Salix* (sharp-leaf willow (*Salix acutifolia* Willd.), bay-leaf willow, almondleaf willow (*Salix triandra* L.), tea-leaved willow (*Salix phylicifolia* L.)), and common club-rush. But concentration of iron in them is low and exceeds the level of obviously underestimated world clark (Bowen, 1979) only in of cinnamon rose fruits.

4. Zinc. Zinc concentration in average sample of plants in technogenic habitats varied from 21.12 mg/kg of dry matter in a coastal zone of Prosnoe lake to 44.01 mg/kg within the territory of the drilling waste disposal site of FPNM (Figure 4), averaging 33.86 mg/kg of dry matter. This value only slightly exceeds the one in plants of background habitats (28.75 mg/kg of dry matter).

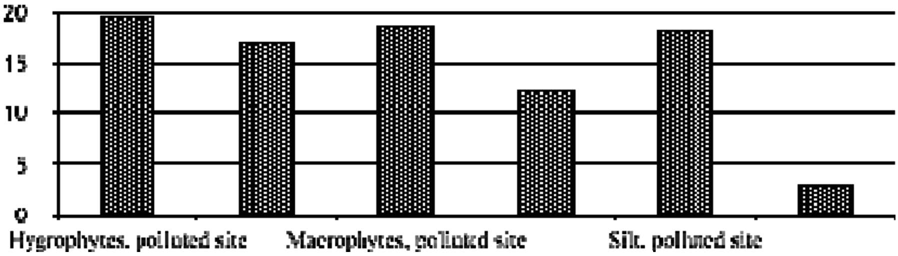

Figure 4. Zinc content in silt and plants of different ecological groups in background and polluted habitats (mg/g of dry matter)

The highest concentration of zinc is noted for forest plants - in shoots of *Salix* species (56.80…83.30 mg/kg) in floodplain of the Lake Ivanovskoe and fruits of mountain ash (*Sorbus aucuparia* L.). Possibly, it is caused by deeper root system of forest species allowing them to take zinc which under conditions of the studied region concentrates in layers more than 1 m deep. Zinc content in green mass of water plants from technogenic habitats is almost twice lower than one of terrestrial plants and reaches 17.05…19.51 mg/kg in plants from polluted habitats (see Figure 4.). Average concentration of zinc in green mass of herbaceous plants from technogenic habitats reaches 32.17 mg/kg. The zinc content in plants from polluted habitats almost equals the one in silts, while plants from not polluted ecosystems possess strongly expressed ability of zinc accumulation.

5. Nickel. Nickel content in average sample of plants from technogenic habitats varies from 1.59 mg/kg of dry matter in a coastal zone of Prosnoe lake to 2.03 mg/kg in the territory of drilling waste disposal site of FPNM (Figure 5). Concentration of nickel in plants of background and technogenic habitats are close and reach 1.93 and 1.69 mg/kg of dry matter accordingly

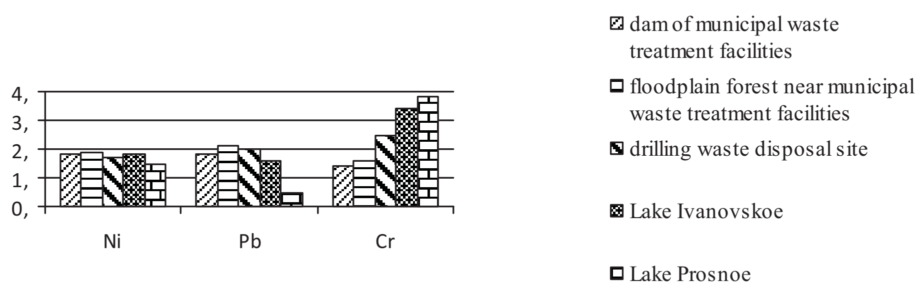

Figure 5. Nickel, lead, and chrome concentrations in phytomass of plants in technogenic habitats (mg/kg of dry matter)

The average content of nickel is higher in forest mesophytes and reaches the maximum level in shoots of white willow (*Salix alba* L.) (5.84 mg/kg of dry matter). In herbaceous plants it changes from 0.28 mg/kg (water-torch) to 5.40 mg/kg in shoots of a common club-rush, average for hygrophytes is 2.04 mg/kg, for hydrophytes – 1.34 mg/kg (Figure 6.). The last figure is close to the one for semi-aquatic plants of non-polluted habitats. Concentration of nickel in green mass of macrophytes in technogenic habitats is usually below the one in silts.

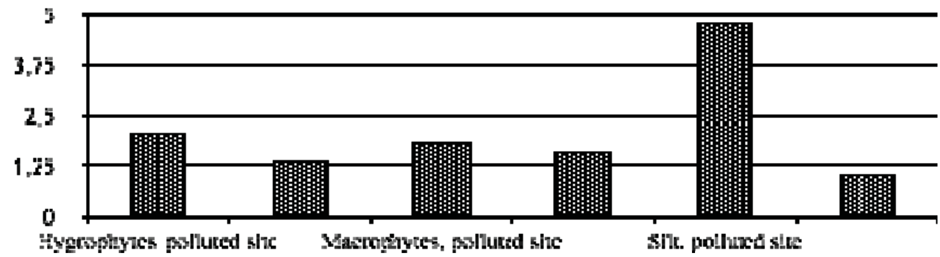

Figure 6. Nickel content in silt and plants of different ecological groups in background and polluted habitats
(mg/g of dry matter)

6. Cadmium. Maximum concentration limit of cadmium for vegetative products reaches 0.30 mg/kg of dry weight. Sauerbeck (1982) indicated that a critical content of 5-10 mg Cd per g (shoot, dry matter) might affect plant growth. According to Brandle, Labbe, Hattori, and Miki (1992) the concentration of available Cd in soil solution might induce plant uptake rates that exceed the binding capacity of the metal-protected proteins (metal-thioneins, MT) produced by the plants. Levels of MT accumulation were likely not sufficiently high to allow the MT to compete with the other, more mobile, Cd-binding molecules.

Large genotypic differences in Cd contents were found (Guo, 1995) between plant species and even between cultivars and inbred lines of the same species (e.g. lettuce, wheat and barley, maize and tobacco). Uptake of Cd by plants differs between species and cultivars of the same species. In many cases however, it is not clear whether the observed differences are due to a different uptake or a different internal distribution of Cd between roots and shoots..

In our researches concentration of cadmium in the majority of samples of plants in technogenic habitats exceeds MAC. The maximum content of cadmium is revealed in the plants growing on the dam of drilling waste disposal site of FPNM. It reaches 0.97 mg/kg of dry matter, which is 3 times higher than the content of the element in plants from relatively non-polluted habitats and level of MAC for vegetative material (Figure 7). Possibly, the fact indicates the considerable content of cadmium in soil of the drilling waste disposal site containing waste of electroplating shop. The lowest concentration of cadmium is noted in green mass of plants in a coastal zone of Prosnoe lake (0.18 mg/kg)

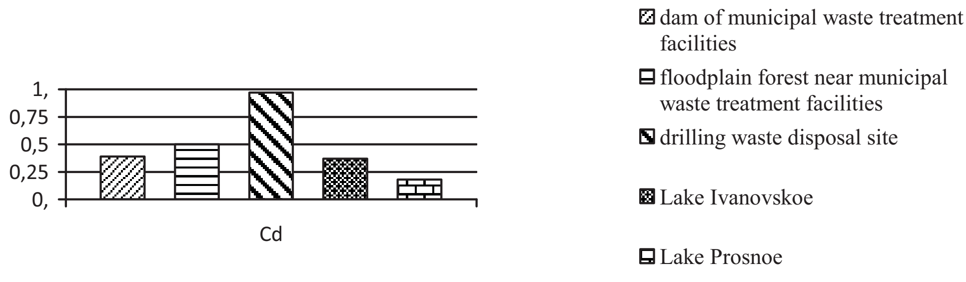

Figure 7. Cadmium concentrations in phytomass of plants in technogenic habitats (mg/kg of dry matter)

Concentration of cadmium in green mass of hydrophytes in all polluted habitats also exceeds MAC and reaches 0.39 mg/kg (Figure 8) on the average. The cadmium content in green mass of semi-aquatic plants in all investigated ecological groups in vicinities of Ivanovskoe lake considerably exceeds background values more than 1.5 times. Possibly, it indicates significant anthropogenic pollution of vicinities of Ivanovskoe lake with cadmium. According to Burkov (2005) basic sources of cadmium income into environment in the Kirov region are its dump in ponds with sewage (3.5 t/year), placing of silt deposit of municipal waste treatment facilities (0.44 t/year), emission of fuel burning products from thermal power station of joint-stock company "KirovEnergo" (0.108 t/year) to the atmosphere. The investigated territory is under the influence of all above specified sources of anthropogenic pollution.

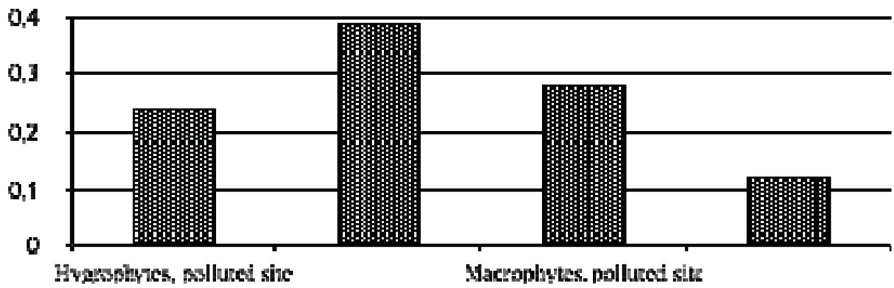

Figure 8. Cadmium content in plants of different ecological groups in background and polluted habitats
(mg/g of dry matter)

He greatest ability of cadmium accumulation is marked for goat willow (*Salix caprea* L.), sharp-leaf willow, common club-rush, and common tansy.

7. Lead. MAC of lead for vegetative products reaches 0.5 mg/kg of raw matter. The highest concentration of lead is typical for plants collected in floodplain forest at Municipal waste treatment facilities of Kirov city (2.23 mg/kg), the lowest - for plants from a coastal zone of Prosnoe lake (0.57 mg/kg) (Figure 9).

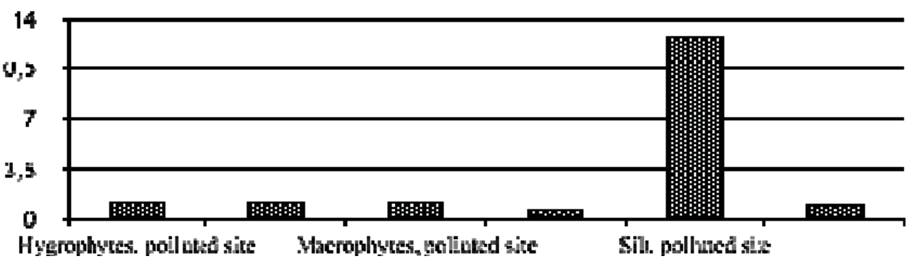

Figure 9. Lead content in silt and plants of different ecological groups in background and polluted habitats
(mg/g of dry matter)

Lead content fluctuates considerably even in the same plant species. Concentration of lead in horn weed in background habitats reaches 0.05 mg/kg, in vicinities of Kirov city - 1.80 mg/kg. However, the lead content in green mass of water and semi-aquatic plants of polluted habitats is below the one for terrestrial plants. For example, lead content in shoots of almondleaf willow from Ivanovskoe lake reaches 4.50 mg/kg, while it is 1.12 kg/kg in macrophytes. On the average plants from the polluted habitats contained 1.11…1.15 mg/kg of lead, and background areas – 0.6 mg/kg. Possibly, macrophytes do not possess bias to considerable accumulation of lead. The content of the given element in silts in polluted habitats is always significantly higher than in water plants (Figure 9). Burkov (2005) marks the following sources of lead emission to the environment of Kirov region: dump in ponds with sewage (0.372 t/year), placing of silt deposits of municipal waste treatment facilities (1.494 t/year), emission of lead with shot (33.0 t/year), emission of lead with the storage batteries non returned for processing (416.1 t/year), emission to the atmosphere of fuel burning products from thermal power station of joint-stock company "KirovEnergo" (0.678 t/year). The studied region is subject to all above specified kinds of anthropogenic pollution.

At the given stage of studies is not revealed statistically that lead content in plants significant depends on its concentration in soil and volumes of lead income to the environment. Probably lead accumulation is determined by species-specificity of a plant. Significant differences in lead content in green mass of plants of background and technogenic habitats are not revealed as well.

8. Chrome. Normal content of chrome in plants is 0.74 mg/kg (Il'yin, 1991; Kabata-Pendias, 2010). Chrome content of more than 1.3 mg/kg is considered toxic in plants (Tarabrin, 1980). The highest concentration of chrome is marked for plant samples from Prosnoe lake (3.88 mg/kg) and Ivanovskoe lake (3.51 mg/kg), the lowest - on the dam of municipal treatment facilities of Kirov city (1.45 mg/kg) (Figure 10). Average concentration of chrome in green mass of plants of polluted habitats reaches 2.49 mg/kg of dry matter which is almost twice higher than the one for plants from non-polluted habitats.

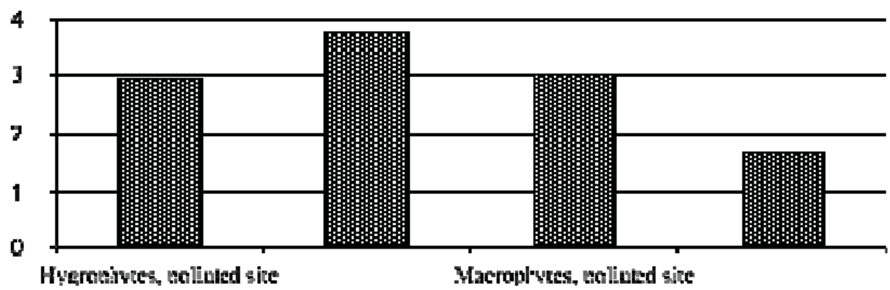

Figure 10. Chrome content in plants of different ecological groups in background and polluted habitats (mg/g of dry matter)

The content of chrome in different plant species diverge almost 50 times - from 0.21 mg/kg for lady's-laces (*Digraphis arundinacea* (L.) Rausch) in non-polluted habitats to 11.56 mg/kg in shoots of water-torch in floodplain of the Lake Ivanovskoe, average - 1.94 mg/kg for herbaceous mesophytes and almost twice higher (3.77 mg/kg) for hydrophytes of polluted habitats. High concentration of chrome in plant samples can be explained by considerable pollution of soils and habitats of the studied habitats with the element. So, the content of mobile chrome in floodplain soils of the Lake Ivanovskoe exceeds the background values almost 7 times.

As a result of studying the element structure of plants green mass in all technogenic locations and background territories the greatest total pollution (except for iron) - more than 300 mg/kg - was marked for the plants growing in territory of drilling waste disposal site of FPNM and in a coastal zone of Prosnoe lake. Total pollution of green mass with pollutants (except iron) in vicinities of Kirov (163.63 mg/kg) and Kirovo-Chepetsk (207.01 mg/kg) cities has appeared to be slightly lower than on basic technogenic territories, but is considerably higher than background (121.01 mg/kg). A little less polluted plant samples were collected from vicinities of Kirov city, which indicates insufficient uniformity of specific structure of samples. Low concentration of iron in plant samples ,as it was already mentioned, can be an indirect indicator of higher pollution by other heavy metals.

It is possible to reveal 13 species of plants as the most active collectors of magnesium: Canadian thistle (*Cirsium arvense* (L.) Scop.), a black (*Carex nigra* (L.) Reichard) and acute (*Carex acuta* L.) sedges, some willows (sharp-leaf willow, eared willow (*Salix aurita* L.), goat willow, and white willow), purple loosestrife (*Lythrum salicaria* L.). Copper is accumulated by 11 species of wild plants. The highest concentration of copper in phytomass was marked for common tansy, white willow and sharp-leaf willow. 7 species of plants in technogenic habitats accumulate nickel: dogrose cinnamon, white willow, tea-leaved willow, bay-leaf willow, goat willow, eared willow, and common club-rush. 23 species from technogenic habitats are capable of cadmium accumulation in the amounts considerably exceeding MAC. These are all studied species of willow, especially goat willow, acute and black sedge, mountain ash, dogrose cinnamon, common club-rush, common reed (*Phragmites australis* (Cav.) Trin. ex Steud.), common tansy, meadow clover (*Trifoloum pratense* L.) and some other perennial herbaceous species of plants. Active collectors of lead are 9 plant species from technogenic habitats. Among them are stone bramble (*Rubus saxatilis* L.), common club-rush, common tansy and 6 species of willow: goat, common osier (*Salix viminalis* L.), almondleaf, bay-leaf, white, and tea-leaved willow. Arboreal plants are the only zinc collectors in technogenic territories - all studied species of willows and mountain ash. Nine species of plants are characterized by ability for iron accumulation, one of them is dogrose cinnamon which fruits contain almost twice that much of iron as the other species, the concentration reaches 196.40 mg/kg of dry matter. This is almost 4 times higher than theaverage concentration of iron in phytomass of plants in technogenic habitats and almost twice higher than in background habitats. Other species from technogenic habitats contain the amount of iron which is almost equal to the one for plants from background habitats. All investigated species of willow and mountain ash belong to this type of plants. 11 species were marked as chrome concentrators. Herbaceous plants in semi-aquatic lands present the highest degree of chrome accumulation: water-torch, common reed, acute and black sedge. Manganese was accumulated by 13 species of plants in technogenic habitats, among which the highest concentration of manganese was in phytomass of hydrophytes: water-torch, common reed, three-part bur-marigold.

Detected species of plants in technogenic habitats - collectors of pollutants - can be used for phytomelioration and sanitation of polluted territories.

It is known that some plant species show constant element composition. 14 species of plants not accumulating some pollutants were revealed (Table 2). Concentration of one or several elements in their phytomass is stable even in technogenic territories.

Table 2. Plant species having stable content of some chemical elements (+)

Plant species, part of plant	*Mg*	*Cu*	*Ni*	*Cd*	*Zn*	*Cr*	*Mn*
Cirsium arvense (L.) Scop.	+		+				
Vicia cracca L.	+		+				
Salix viminalis L.		+					
Trifolium pratense L.	+	+		+			
Nuphar lutea (L.) Smith*, leaves*	+		+		+		
Populus tremula L.*, shoots*				+			
Populus tremula L.*, bark*	+	+	+	+		+	
Tanacetum vulgare L.					+		
Sorbus aucuparia L.*, shoots*			+				
Phragmites australis (Cav.) Trin. ex Steud.		+			+		
Achillea millefolium L.			+	+	+		
Bidens tripartita L.	+						
Rosa acicularis L.*, fruits*		+		+			
Rosa majalis J. Herrm.*, fruits*			+				+

These species having stable concentration of pollutants do not accumulate some heavy metals can help working out the basis for agricultural use of the polluted territories for the purpose of acquiring products suitable for use.

4. CONCLUSION

38 species of the plants accumulating pollutants in technogenic habitats of the North-East of the European part of Russia are revealed. Only 1 species of plants accumulated in rather considerable amounts all 8 elements at once; 1 species - 6 elements; 5 species - 5 elements; 3 species - 4 elements; 5 species - 3 elements; 12 species - 2 elements; and 10 species - 1 element. Copper is accumulated by 11 plant species; tansy, swamp willow, and six-staminate willow accumulate especially high amounts of copper. Dogrose cinnamon, six-staminate willow, almondleaf willow, laurel willow, goat willow, bulrush accumulate nickel in technogenic habitats. All studied species of willow, especially goat willow, sedge, mountain ash, dogrose cinnamon, cane, bulrush, tansy, meadow clover accumulate cadmium in the amounts considerably exceeding MAC. 9 species of plants of technogenic habitats are actively accumulating lead: lake cane, tansy and some species of willow:

goat, laurel, six-staminate, almondleaf, and tea-leaved. Only arboreal plants accumulate zinc in technogenic territories - all studied species of willow and mountain ash. Dogrose cinnamon possesses the ability to accumulate iron; the content of the metal in its fruits reaches 196.40 mg/kg of dry matter. All investigated species of willow and mountain ash in technogenic habitats may be considered as iron collectors. The greatest chrome accumulation was marked for herbaceous plants in semi-aquatic habitats: water-torch, bulrush, and sedges. Manganese was accumulated by 13 species of plants in technogenic habitats among which the highest concentration of manganese in green mass was marked for hydrophytes: tripartite bur-marigold, water torch, bulrush. At the same time in technogenic habitats 14 species of plants do not accumulate some pollutants. Concentration of one or several elements in their green mass is stable even in technogenic territories.

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