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Ecological Dangers of Chemical Contamination of Urban Areas Soils: Casestudy of Tomsk

N.A. Osipova*[a], L.V. Zhornyak[a], E.G. Yazikov[a], A.A. Syskina[a]

[a]*National Research Tomsk Polytechnic University, Lenina ave. 30, Tomsk 634050, Russia*

Abstract

The elemental composition of soils in Western Siberia industrial center – Tomsk city is studied. The content of 28 elements in soils of the four administrative districts is determined by the instrumental neutron activation analysis method. The value of calculated total pollution index indicates a high degree of soil contamination, and dangerous levels of human health risk. The main contributors to the total pollution index value are elements: Tb, Br, Sb and Ta. The districts were ranked by the accumulation level of some elements, and it is shown that increased concentration values are confined to industrial enterprises and fuel cycle. The specificity of city districts soil cover is the increased values of relative to the city average values of several elements contents: Kirovsky district- Na and Ba, Oktyabrsky - Hf, Sc, Tb, Sm, La, Ce, Yb, Lu, and Br, Leninsky - Ca, Rb, Sr. The main sources of chromium and barium in the Tomsk city environment are analyzed.

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1. Introduction

Storage medium such as soil, snow cover and etc. is assessed for complex characteristics of aerogenic impact pollution. On the one hand, the soil is a major factor in the formation of natural and artificial biogeochemical provinces, playing a leading role in the occurrence and prevention of endemic diseases, and, on the other hand, soil is the environment which provides the circulation of exogenous chemicals in the "external environment - people". The migration and exchange of all chemical elements take place in the soils[1].

* Nina A. Osipova. Tel.: +7-906-949-4369
E-mail address: osipova@tpu.ru

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Accumulation of various chemical contaminants in soils of Tomsk and its suburbs was studied previously[2]. The observed spatial heterogeneity of pollutants, especially heavy metals and radioactive fissile elements indicate that the chemical composition of the soil material of Tomsk region reflects the specific character of production activities associated with the operation of heat and power facilities, petrochemical complexes, and with nuclear fuel cycle enterprise located nearby[2].

The aim of this work is to establish the levels of chemical elements in soils of Tomsk districts.

2. Experimental technique

215 soil samples were selected and studied within the research program of soils at Tomsk administrative districts and the areas of industrial enterprises. Among them 204 soil samples were selected by the net in the Tomsk city with 103 samples taken in the areas of currently and previously functioning industrial enterprises[3].

The elements were quantitatively determined by atomic emission method with inductively coupled plasma (ICP, Laboratory of Kara-Balt mining plant, Kyrgyz Republic), multielement instrumental neutron activation analysis (INAA) in nuclear and geochemical laboratory of the Department of Geoecology and Geochemistry of TPU.

3. Results and discussion

According to the studies of the Tomsk soils, the levels of rare, rare earth, and other radioactive elements accumulation are measured (Table 1)

Table 1. Average content of elements in soils of Tomsk city districts, mg / kg

Elements	District				Tomsk city	Background[2]
	Kirovsky (57 samples)	Sovietsky (48 samples)	Oktyabrsky (61 samples)	Leninsky (38 samples)	(204 samples)	
Na. %	**1.3±0.04**	1.1±0.05	1.1±0.03	1.1±0.04	1.1±0.02	0.46
Ca. %	1.3±0.03	1.5±0.06	1.5±0.1	**1.7±0.1**	1.4±0.04	0.43
Fe. %	2.9±0.1	3.2±0.1	3.2±0.1	3.2±0.1	3.2±0.04	1.3
Br	8.9±1.1	8.5±0.7	**9.5±0.7**	8±1.5	8.8±0.5	1.24
Ba	**608.7±31.1**	576±19.8	542.6±16.3	560±29.4	550±12.3	124
Co	14.5±1.1	13.1±0.4	14.7±0.3	13.8±0.5	14.3±0.3	6.5
Cr	109±6.3	113.2±4.9	102.4±14.7	109±5.4	103.6±5	43.2
Sb	1.7±0.4	1.8±0.2	1.6±0.2	1.6±1.7	1.6±0.3	0.3
As	< d.l.	< d.l.	0.5±0.36	1.2±0.6	0.4±0.2	< d.l.
			Rare elements			
Rb	72.8±2.9	71±3.6	79.4±3.2	**85.7±3.4**	76.7±1.7	17.2
Cs	3.5±0.1	3.8±0.2	3.7±0.1	3.5±0.1	3.6±0.1	1.25
Sr	30.1±13.3	44.7±22	44.4±18	**188.4±41.6**	67.3±12	164
Hf	6.5±0.2	6.6±0.2	**7.1±0.2**	6.1±0.2	6.6±0.1	3.8
Ta	0.92±0.05	0.83±0.05	0.91±0.04	0.86±0.06	0.85±0.02	0.16
Sc	10.9±0.3	10.8±0.3	**12.1±0.3**	11.2±0.4	11.3±0.2	8.3

			Rare earth elements			
Tb	0.97±0.04	0.97±0.04	**1.1±0.03**	1±0.04	1±0.02	0.13
Sm	5.5±0.2	5.6±0.2	**6.2±0.2**	5.5±0.3	5.7±0.1	3.9
Eu	1.3±0.04	1.2±0.05	1.4±0.04	1.4±0.05	1.3±0.02	1.4
La	25.1±0.7	24.7±0.8	**27.6±0.6**	24.6±0.9	25.7±0.4	17.3
Ce	55.3±1.4	59.1±3.1	**59.8±1.1**	55.6±1.1	58.6±0.9	33.4
Yb	2.6±0.1	2.5±0.1	**3±0.1**	2.6±0.1	2.7±0.05	0.9
Lu	0.39±0.01	0.38±0.01	**0.43±0.01**	0.38±0.02	0.4±0.01	0.16
			Radioactive elements			
U	2.6±0.2	2.7±0.1	2.2±0.1	2.4±0.2	2.4±0.1	0.5
Th	7.2±0.3	7.4±0.3	**7.8±0.2**	7.1±0.2	7.5±0.1	3.7

Note: This table shows the results of instrumental neutron activation analysis (INAA); mean ± standard error; < d.l. - value which is below the detection limit of the analysis; values in boldface are above the average for the Tomsk city and other areas

Relative to background concentrations in soils, there is the accumulation of almost all investigated elements except strontium and europium. Minimum excess above the background is 1.4 times for Sc, maximum - 7 times for Br and 8 - for Tb.

Industrial anomalies are often connected with multielemental composition, the total pollution index Z_c characterizing the effect of a group of elements is calculated with the formula:

$$Z_C = (\sum_{i=1}^{n} CC) - (n-1)$$

where CC - the concentration coefficient of i- element; *n* - accounted number on anomalous elements.

According to the indicative scale of assessment of airborne pollution centers, there are four values of the total interval indicator of pollution. The magnitude from 1 to 15 units characterizes a low degree of contamination with non-hazardous incidence; from 16 to 31 units correspond to the average, moderately dangerous level; Values range from 32 to 127 units shows a high degree of contamination with dangerous levels of morbidity, especially for children. Very high contamination with extremely dangerous incidence is characteristic for values of SDRs more than 128 units.

Value of the total soil pollution index calculated relatively to the background content for the city is on average 51 units, which corresponds to a high degree of pollution and dangerous level of morbidity. It was previously noted that districts heterogeneity in the distribution of the total pollution index is observed. The elements: Tb (CC=7.7), Br (CC=7.1), Sb (CC=5.4) and Ta (CC=5.3) contribute mostly to the total pollution index.

According to the results of studies, the areas with maximum number of elements were identified relative to the background and the mean values of the city. On allocation patterns of elements contents in soils, their elevated contents especially in the central, north-western and north-eastern parts of the city are clearly visible.

Kirovsky district is characterized by higher contents of Na and Ba in soils relative to other areas, and the city average values (statistically significant difference from the average values). Soil geochemical specifics of Oktyabrsky district is the presence of increased concentrations of Hf, Sc, Tb, Sm, La, Ce, Yb, Lu and Br (statistically significant difference between the averages). This can be explained by the possible impact of emissions from Tomsk state district power station chimneys, which are distributed (according to the prevailing

annual average wind direction) in the northern part of the city, as well as the influence of the activities of construction enterprises.

Specificity of Leninsky district soil is the increased average content of Ca, Rb and Sr (significant differences from the city and other areas average) that can be explained by the influence of the detached houses and local boilers burning coals. The average content of the studied elements in soils of Sovietsky district is common for those of Tomsk.

Thus, the presence of elements in urban soils of I - III Hazard Class at their concentrations exceeding the maximum permissible concentrations creates a risk to the public. Soil particles can enter the body by ingestion or breathing, as well as a transition of harmful substances from soil into food grown on it. The presence of a wide range of highly toxic elements in urban soils causes concern. In addition, a significant part of the city occupy areas with individual buildings, and it does not exclude the possibility of transition of pollutants from agricultural farmlands[4,5].

Environmental impact of heavy metals (chromium, barium, in particular) on the biota and, above all, a man is insufficiently studied. Hazard levels of toxic elements impact are relatively well studied in the production contacts, especially in the workshops via skin or air of the working area, etc., and at much smaller scales their dispersal in the environment.

Notions of the transition processes of trace elements from passive forms into contact, i.e. active form of biota remain particularly uncertain. Limit values of elements in soils, water and air are not enough to address the issue of the degree of toxic hazard. For example, extremely high concentrations of many trace elements in the bound state do not have toxic effects on the biota. But these elements are released, for example, by burning, in microdispersed state in soils, and become dangerous for the whole biota moving into an accessible (mobile) form and moving up along the food chain[1,6].

Sources of chromium in the environment in Tomsk (presumably the nature of production activities of local businesses and the fuel cycle) are manufacturing gears, bearings and technically important parts for pneumatic tools of high quality alloy and heat-treated structural steel; bichromate used to reduce corrosion, chromium in the fuel burned at state district power station “GRES-2”. The increased concentrations of chromium comparing to the background and the mean values are recorded around the city near “Electric-bulb”, “Instrumental” and “Manometer” enterprises. Chromium is typomorphous for these enterprises, as it is contained in raw materials, and, therefore, there are emissions into the environment while processing. Increased risk levels from chromium exposure is accounted in the area of state district power station “GRES-2” location and its ash dump (in the floodplain of the River Ushayka), which indicates the need to study the composition of the fuel burned in terms of impact on the human. The metalworking enterprise “Tomsk Instrumental Factory” which is located in the city center also contributes to the soil contamination with chromium. The human exposure to chromium results in the reduced immunity, affects the liver, skin, mucous membranes of the nose, leads to fibrosis, gastritis, gastric ulcer, duodenal ulcer, chrome steatosis, the vascular tone regulation violation , cardiac activity. Chromium accumulates in the liver, kidney, spleen, bones and bone marrow[1,6].

Barium compounds are used in many industries: electronics, petroleum, glass, paper, textile, ceramics, paint, rubber, metallurgy, printing. In soils sampled near industrial enterprises in Tomsk, elevated concentrations of barium relative to the background, and the average values of the city are identified in the areas of Tomsk instrumental and nanometer factories.

Thus, the accumulation of chemical elements in soils is the result anthropogenic multi-years impact, their release during combustion and industrial activities, which are historically closely related to areas of residential development.

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