

THE CONTENT OF HEAVY METALS IN THE SOILS OF THE DRY-STEPPE BESKARAGAY RIBBON-LIKE PINE FOREST AND ITS POLLUTION LEVEL

**K.M. Satova¹, Sh.M. Zhumadina², Sh.B. Abilova^{3,*}, N.B. Mapitov⁴
and A.K. Jaxylykova⁵**

¹Department of Ecology, S. Seifullin Kazakh AgroTechnical University,
Nur-Sultan-010011, Kazakhstan

²Department of Biological Sciences, S. Seifullin Kazakh AgroTechnical University,
Nur-Sultan-010011, Kazakhstan

³Department of Microbiology and Biotechnology, S. Seifullin Kazakh AgroTechnical
University, Nur-Sultan-010011, Kazakhstan

⁴Department of Biology and Ecology, S. Toraighyrov Pavlodar State University,
Pavlodar- 140000, Kazakhstan

⁵Department of Biological Sciences, S. Seifullin Kazakh AgroTechnical University,
Nur-Sultan-010011, Kazakhstan

*E-mail: kazakhscience2000@gmail.com

ABSTRACT

This article deals with the problem of environmental pollution with heavy metals as one of the most acute environmental problems of our time. The survey presents the results of biogeochemical patterns regarding the content and distribution of some active forms of heavy metals within the soils of the Beskaragay pine forest, belonging to the Semey Ormany reservation in the East Kazakhstan region. The values of total soil contamination with heavy metals in the pine forest under consideration are calculated. The provided calculations and conclusions about the level of environmental pollution are based on the concentration coefficient value.

Keywords: Beskaragay Pine Forest, Soils, Heavy Metals, Ambient and Anthropogenic Zones, Total Pollution, Toxicity, Pollution Level.

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INTRODUCTION

Environmental pollution with heavy metals is one of the most acute environmental problems of our time¹⁻⁸, and particular attention is paid to the environmental safety of soils.⁹⁻¹⁵ Being a global geochemical regulator of cyclic mass flows of heavy metals, forest landscapes are essential to this process¹⁵⁻²¹. Such anthropogenic phenomena as fires and uncontrolled wood-felling also lead to dysfunction of the biogeochemical circulation of elements in forest ecosystems.²²

The object of the study is the Beskaragay ribbon-like pine forest belonging to the Semey Ormany reservation located in the East Kazakhstan region. According to the Kazakh Scientific Research Institute of Forestry and Agroforestry of the Republic of Kazakhstan, the studied forests belong to the area of the dry steppe Priirtysh ribbon-like pine forests.

The territory of these pine forests is located on the border of large industrial complexes of this area, which emit the waste of all existing aggregate compositions, causing great environmental damage to these natural landscapes. Therefore, we believe that the relevance of this work should not be in doubt.

The purpose of this work is to study the biogeochemical patterns of the content and distribution of some heavy metals in the forest soils of the Beskaragay pine forest.

EXPERIMENTAL

Soil samples were collected by the envelope method at a site of 1x1 m from a depth of 0-20 cm, thereafter the samples for analysis were mixed, and one average sample weighing at least 0.5 kg was compound by the quartering method. The content of heavy metals was determined from these samples.

The fluent contents of the chemical elements of these soils were determined at EcoNus LLP (Karaganda) by inductively coupled plasma atomic emission spectroscopy.

The concept of the total pollution index Z_c is used in the sanitary-hygienic assessment of soil pollution in the territory²³:

$$Z_c = (\sum K_c) - (n - 1) \quad (1)$$

Here K_c is the concentration coefficient; n is the total number of elements.

The average element content in the ambient area was used to calculate K_c ²⁴:

$$K_c = C_i / C_{\Phi i}, \text{ where} \quad (2)$$

C_i is the content of a chemical element; $C_{\Phi i}$ is the average element content in the ambient area.

When calculating such a total pollution index²⁵, it is proposed to take into account the toxicity of chemical elements. Then in formula (1) the concentration coefficient (K_c) is multiplied by the toxicity coefficient, and the formula will be as follows:

$$Z_c = (\sum K_c * K_{Ti}) - (n-1) \quad (3)$$

K_{Ti} is the toxicity coefficient of the i -th element; n is the total number of elements.

The data of hazard (toxicity) classes and coefficients of metals are presented in Table-1.

Table-1: Classes and Hazard (Toxicity) Coefficients of Elements

Hazard Classes	Elements	Toxicity Coefficient
I	Arsenic, cadmium, mercury, lead, zinc, fluorine	1.5
II	Boron, cobalt, nickel, molybdenum, copper, antimony, chromium	1.0
III	Barium, vanadium, tungsten, manganese, strontium	0.5

Table-2 shows the gradation of the total soil contamination level.

Table-2: The Total Soil Contamination Level

Contamination Level	Total Soil Pollution Index (Z_c)
Low	8 – 16
Medium	16 – 32
High	32 – 128
Very high	>128

RESULTS AND DISCUSSION

Table-3, Fig.-1 and Fig.-2 present the results of the chemical analysis of active forms of heavy metals in the soils of the Beskaragay pine forest.

As can be seen in Table-3, the content of none of the studied elements exceeds the MCL (maximum concentration limit) for active metals in the soil. The ambient content of heavy metals was taken as their content in the zone of barchans since they are subject to anthropogenic influence less than all other zones. According to the data in Table-3 and Fig.-1, manganese shows the highest content among all elements in the studied zones. But most of all, this metal is concentrated in the soils along the highway, and its content is 53.6 mg/kg. The second place is taken up by zinc with the content of 1.3-2.7 mg/kg, but the largest amounts are found in the ambient zone, 22.6 and 3.2 mg/kg, respectively.

Table-3: The Content of Active Forms of Heavy Metals in the Soils of the Beskaragay Pine Forest for Each Territory

Heavy Metals	MCL for Active Forms	Content, mg/kg			
		Barchans	Natural Plains	Along the Highway	Along Natural Soil Roads
Cadmium	0.5*	0.010	0.017	0.031	0.012
Cobalt	5.0	0.155	0.212	0.254	0.243
Chromium	6.0	0.082	0.086	0.101	0.100
Copper	3.0	0.415	0.249	0.283	0.194
Manganese	140.0	22.860	28.580	53.620	28.480
Nickel	4.0	0.058	0.250	0.531	0.146
Lead	4.0-6.0	0.599	0.785	0.794	0.738
Zinc	23.0	3.171	1.340	2.678	1.305

* – MCL for sandy soils²⁶, the rest are taken from²⁷

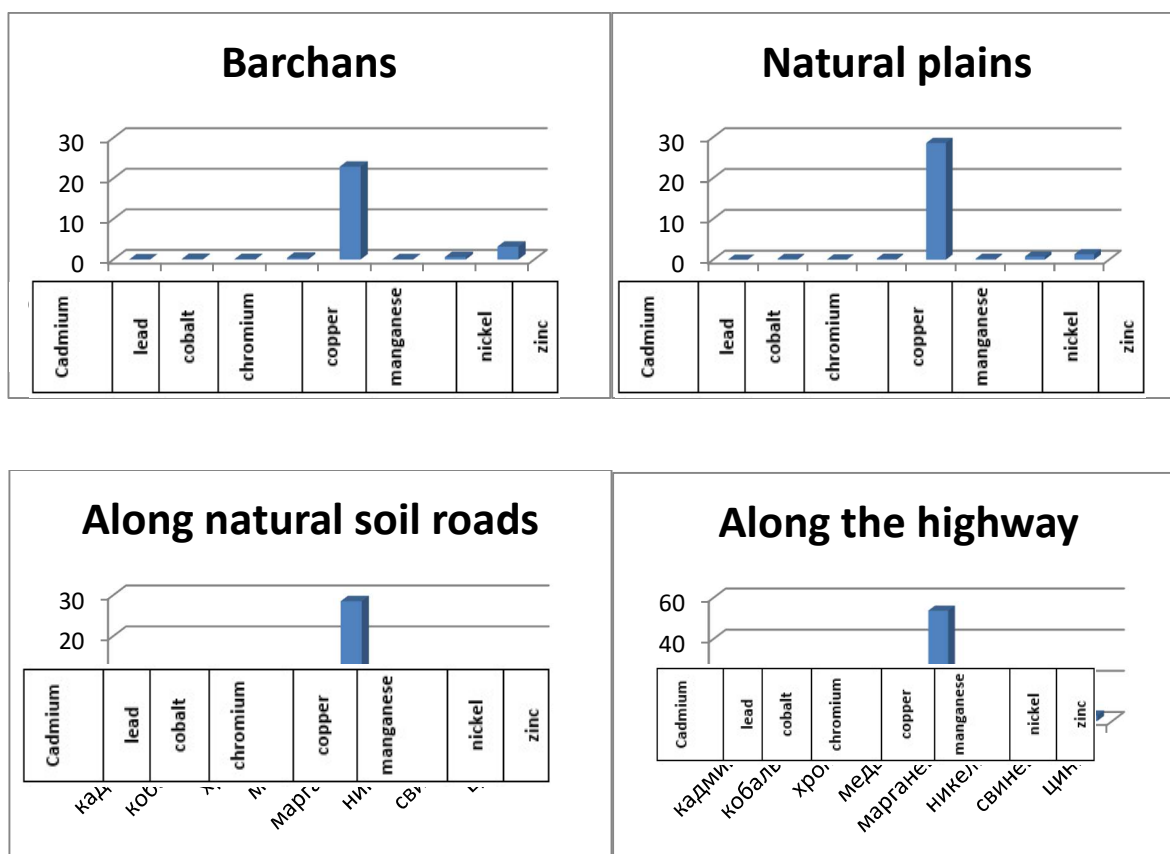
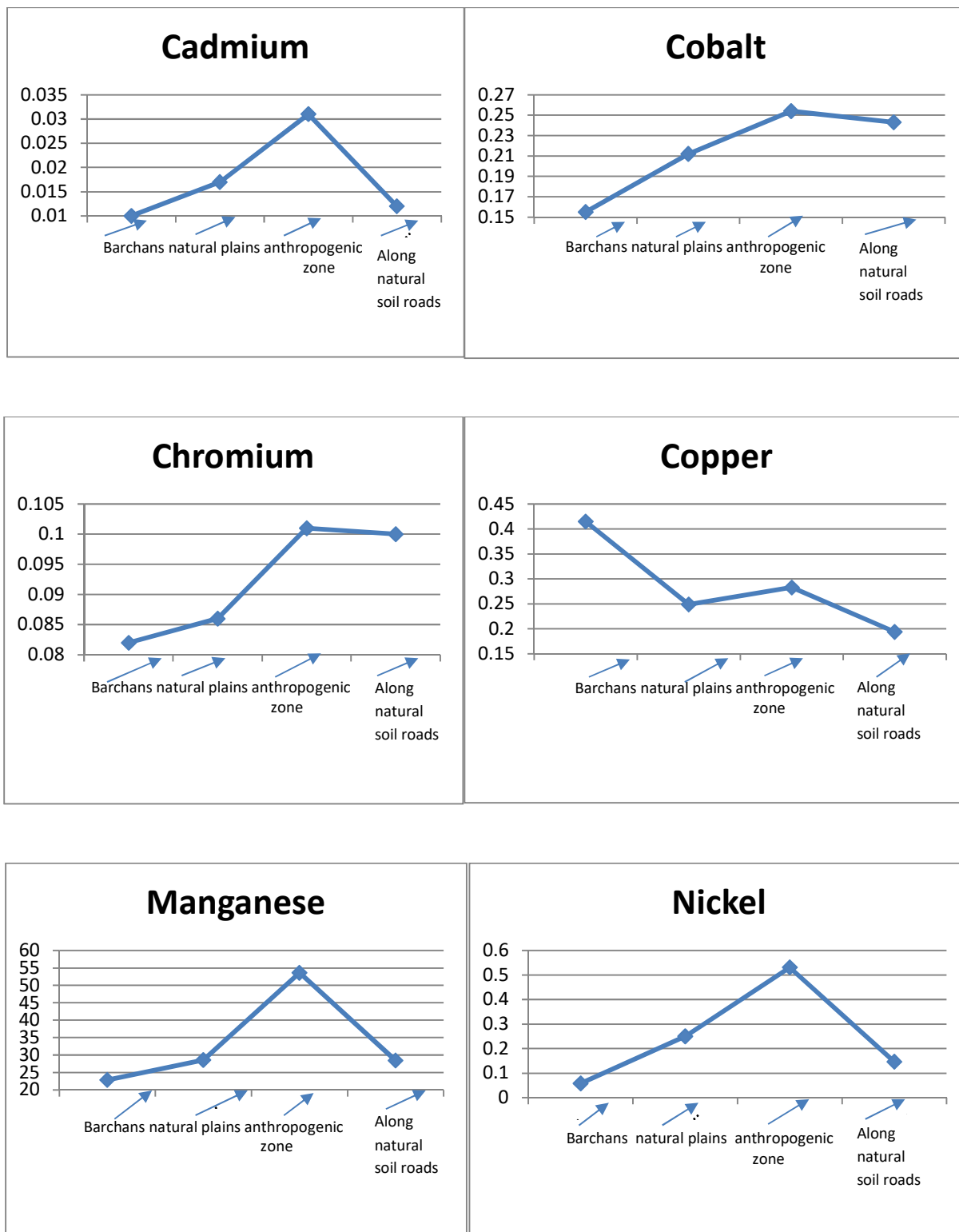


Fig.-1: Heavy Metals Distribution in the Beskaragay Ribbon-like Pine Forest Zones

Based on the data in Fig.-2, the soils of the anthropogenic zone along the highway have the highest content of heavy metals (cadmium, cobalt, manganese, lead, and nickel), which is to be expected. Chromium is more evenly distributed in all zones, but its content along the highways is 0.018 mg/kg higher than in the ambient zone. However, the ambient zone contains the most zinc, and its content is 3.17 mg/kg.

Graphs of the content of active heavy metals (mg/kg) for the Beskaragay ribbon-like pine forest zones are shown in Fig.-2.



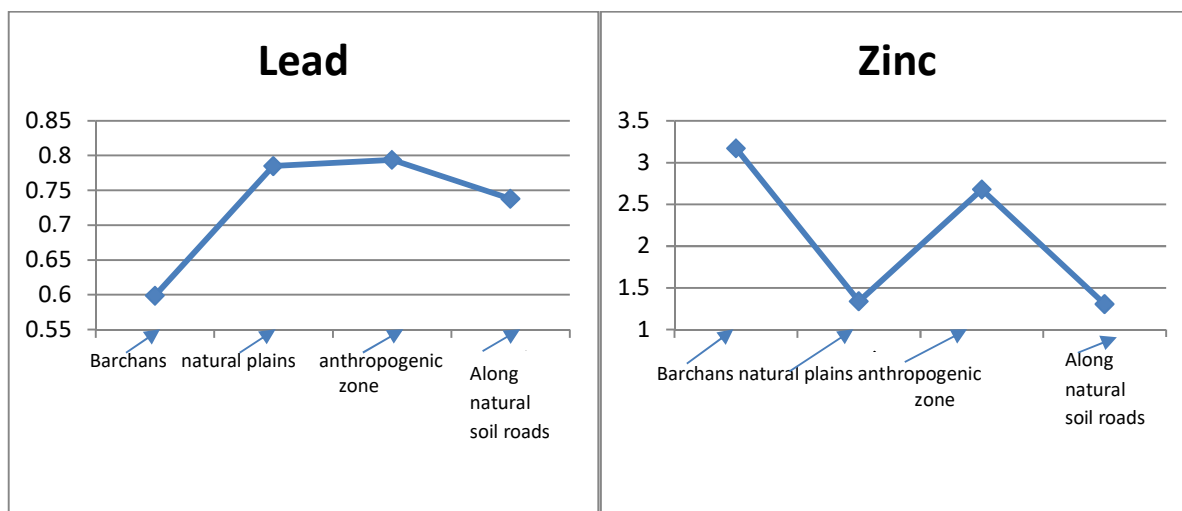


Fig.-2: The Content of Active Heavy Metals (mg/kg) for the Beskaragay Ribbon-like Pine Forest Zones

Table-4: Values of the Concentration Coefficient (K_c) of Heavy Metals in the Soils of the Beskaragay Pine Forest by Zones

Heavy Metals	The Element Content in the Ambient Area	K_c Values		
		Natural Plains	Along the Highway	Along Natural Soil Roads
Cadmium	0.010	1.70	3.10	1.20
Cobalt	0.155	1.36	1.63	1.56
Chromium	0.082	1.04	1.23	1.22
Copper	0.415	0.60	0.68	0.46
Manganese	22.860	1.25	2.34	1.24
Nickel	0.058	4.31	9.15	2.51
Lead	0.599	1.31	1.32	1.23
Zinc	3.171	0.42	0.84	0.41

The values of the concentration coefficient (K_c) in the soils of the Beskaragay pine forest by zones are shown in Table-4 and Fig.-3.

Calculations of the concentration coefficient (Table-4) and the data of Fig.-3 show that its value does not exceed unity only for copper and zinc. For all other elements, this coefficient is higher than unity. Following this, it can be concluded that in the zone of natural plains and along the highways of the Beskaragay pine forest, metals are ranked according to the degree of contamination as follows: nickel > cadmium > cobalt > lead > manganese > chromium. The nature of the pollution level along natural soil roads is as follows: nickel > cobalt > manganese > lead > cadmium.

According to V.B. Kadatskiy²⁸, the higher the pollution level, the greater the value of K_c . The maximum pollution level is observed for nickel along the highway (9.15) and in the zone of natural plains (4.31). The maximum value of the concentration coefficient for cadmium is 3.1 along the highway. The zone of natural soil roads is contaminated with nickel ($K_c = 2.51$). The same is observed for manganese, also along the highway, where the value of $K_c = 2.34$. Thus, the Beskaragay forest soils are heavily polluted with nickel, cadmium, and manganese and moderately polluted with cobalt, chromium, and lead. However, according to the calculation of the total pollution index Z_c , both with and without regard to toxicity, this is far from being the case. The calculation data of the total pollution index Z_c without regard to metal toxicity are given in Table-5 and Fig.-4.

As can be seen from Table-5 and Fig.-4, the area along the highway has the highest value of the total soil contamination of the studied pine forest (13.8). The second place belongs to natural plains (about 6), and the lowest value is shown by the natural soil road zone. However, a comparison of these data with the data of Table-2 allows us to conclude that the soils of this pine forest correspond to a low contamination level.

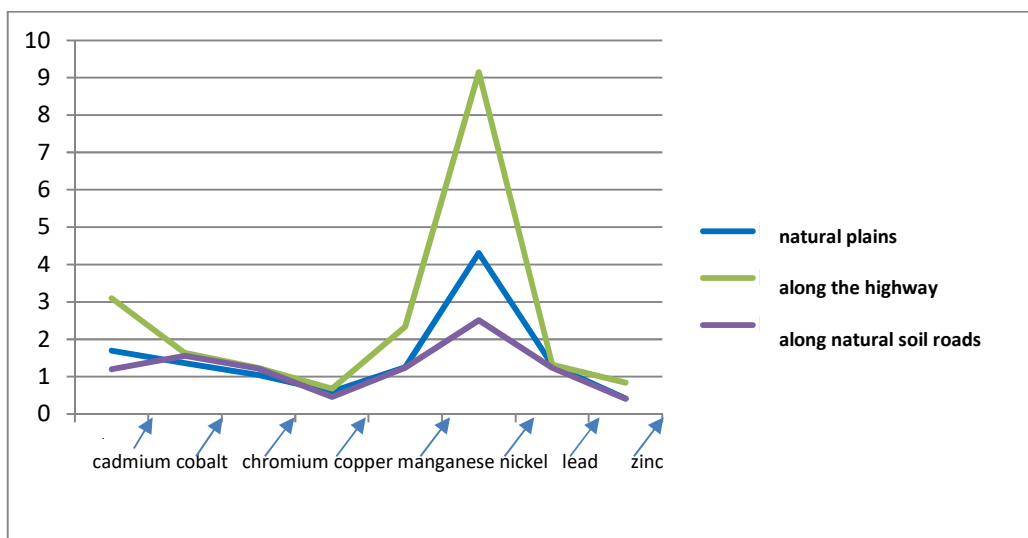


Fig.-3: The Concentration Coefficient of Heavy Metals by Pine Forest Zones

Table-5: Values of the Total Soil Contamination Indexes of the Beskaragay Ribbon-like Pine Forest

Z_c value	Zone		
	Natural Plains	Along the Highway	Along Natural Soil Roads
	5.97	13.77	3.96

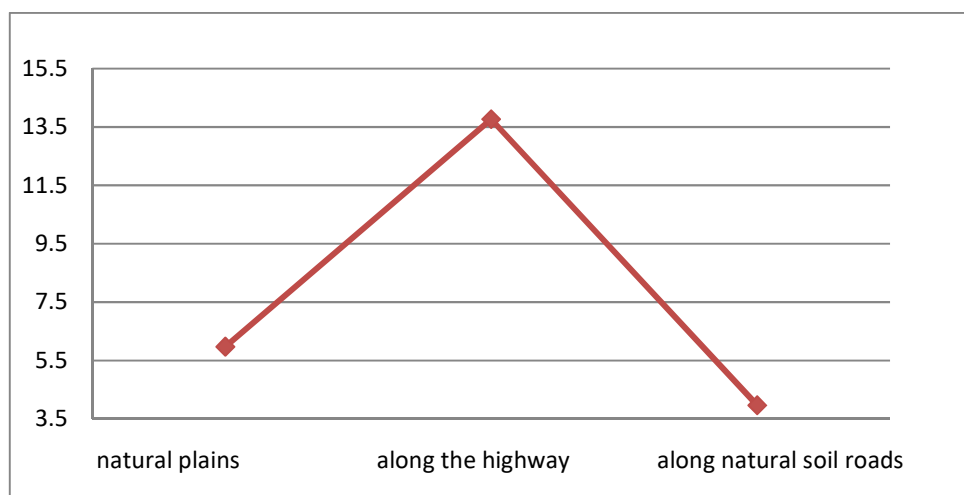


Fig.-4: The Soil Contamination Level of the studied Pine Forest without regard to Metal Toxicity

The values of the total soil pollution indexes of the Beskaragay ribbon-like pine forest concerning element toxicity are shown in Table-6 and Figure-5.

Based on the data in Table-6 and Figure-5, the following can be stated: the zone along the highway (10) has the maximum value of Z_c . About toxicity, this zone is contaminated with metals of toxicity class 2; natural plains are contaminated with metals of hazard classes 1 and 2, for which the values of the total pollution indexes are 3.5 and 4.7, respectively. The zone along natural soil roads is contaminated with metals of toxicity class 2; the value of Z_c is 3.3. Comparing the data in Table-6 and Table-2, one can also say that these soils correspond to a low pollution level, even about element toxicity.

However, forest ecosystems should be the most unpolluted on the planet, but in the present case, the pollution is still observed.

The pollution level of forest components will someday be high and very high.²⁹⁻³⁵ As is commonly known, the pollution of the Priirtysh'e forest ecosystems (Irtys River basin) is associated with technogenic emissions from industrial enterprises of this region.³⁶⁻⁴⁴ Let us consider the state of this issue only in recent years. According to statistics, the gross emission from stationary sources (enterprises, boiler facilities) in Ust-Kamenogorsk in 2017 was about 54,000 tons. The gross emission from unorganized sources (motor transport, private sector) was about 60,000 tons per year. Thus, in terms of gross emissions from stationary sources, the East Kazakhstan region ranked 5th out of 16 regions of Kazakhstan. Therefore, in terms of air pollution, Ust-Kamenogorsk came second after Lisakovsk in the Kostanai region. These emissions contain heavy metals. They also enter the environment from cement plant emissions in the East Kazakhstan region.^{29, 45-50}

Table-6: Values of the Total Soil Contamination Indexes of the Beskaragay Ribbon-like Pine Forest Concerning Element Toxicity

Toxicity Class	Z _c Value for Heavy Metals by Toxicity Zones		
	Natural Plains	Along the Highway	Along Natural Soil Roads
1	3.515	0.98	0.845
2	4.71	10.01	3.29
3	0.625	1.17	0.62

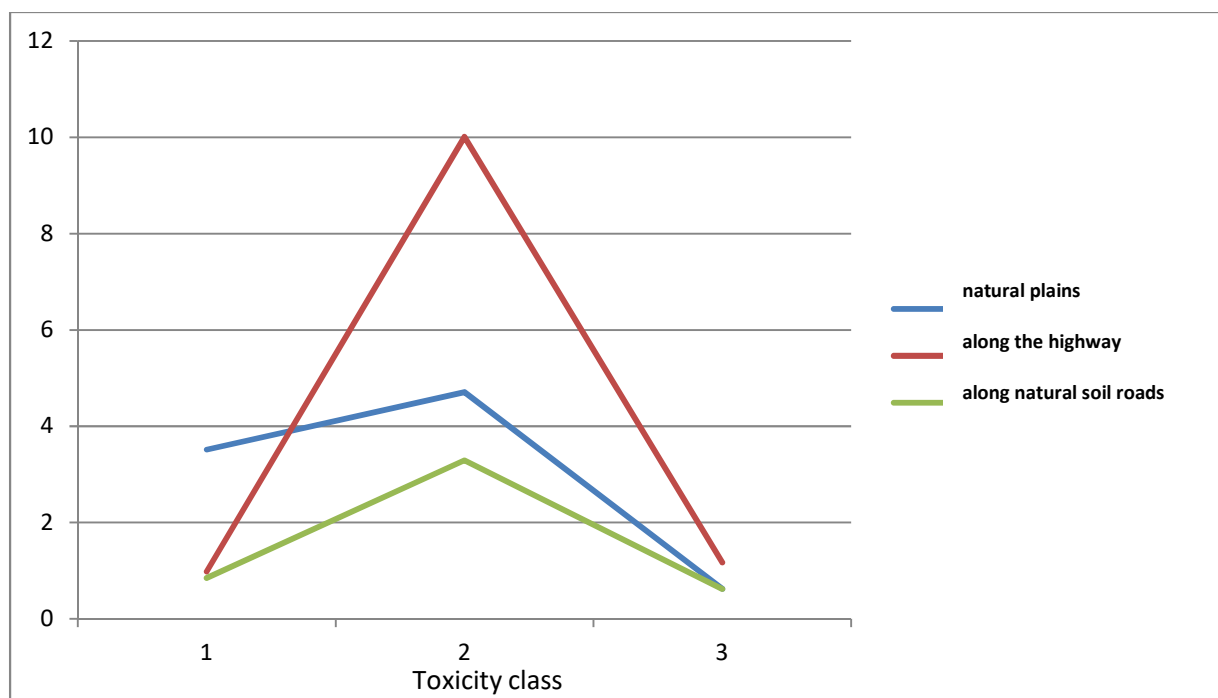


Fig.-5: The Total Soil Contamination of the Beskaragay Ribbon-like Pine Forest Concerning Element Toxicity

For the spring-autumn period of 2017, in the soil samples taken in various districts of the city of Ust-Kamenogorsk, the chromium content was in the range of 0.2-3.12 mg/kg, zinc – 11.4-93.0 mg/kg, lead – 9.8-694.6 mg/kg, copper – 1.0-19.5 mg/kg, and cadmium – 0.05-13.5 mg/kg. In the city of Semey, several enterprises were functioning for many decades that produced many heavy metals and other elements to the soil-plant system of pine forests. For example, for the spring-autumn period of 2017, the chromium concentration ranged from 0.3 to 4.9 mg/kg, zinc – 12.1-25.6 mg/kg, lead – 10.9-34.8 mg/kg, copper – 0.9-1.6 mg/kg, and cadmium – 0.1-0.52 mg/kg.^{30, 51-55}

CONCLUSION

The study of biogeochemical patterns of the content and distribution of some active forms of heavy metals in the forest soils of the Beskaragay pine forest showed that in the ambient zone, the value is higher than in the anthropogenic zone only for zinc. In other cases, the amount of heavy metals was higher in anthropogenic zones, especially in the highway zone. The values of total soil contamination with heavy metals of the studied pine forest were calculated based on the concentration coefficient value. The values of total soil contamination (both with and without regard to metal toxicity) showed that the contamination level of forest soils with heavy metals is permissible.

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