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# Biological Monitoring Experience of a Natural and Anthropogenic Ecosystems Ecological Stability on the «Spasskoye-Lutovinovo» Reserve Territory with Central Forest-Steppe Gray Forest Soils

E V Yakovleva<sup>1</sup>

<sup>1</sup>Ph.D., Associate Professor, Department of Technosphere Safety, N.V. Parakhin Orel State Agrarian University

E-mail: Elenavalerevna79@yandex.ru

**Abstract.** Presently, a large volume of anthropogenic heavy metals enters the biosphere, a significant part of which is accumulated in the soil. To predict the environmental hazard of heavy metal contamination, it is necessary to know not only the extent of their flow but also the patterns of their behavior in various soil and geochemical conditions. The source of numerous pollutants: dust, poisonous substances, heavy metals, etc., are manufacturing industry dumps, exhaust gases of vehicles, residues of oil products (gas stations), mineral fertilizers, meliorants, pesticides, the effects of heavy agricultural equipment on the density and structure of the soil. Their accumulation in the environment leads to a disruption of ecological equilibrium, which along the chain can spread to sizable territories. Industrial centers are especially marked by soil pollution.

## 1. Introduction

In the Oryol region one of them belongs to the city of Mtsensk, where the emissions of an aluminum plant and the storage of waste production account for almost half of the total waste in the district, which harms the ecological condition of biogeocenosis and the living conditions of the population. There is a big problem with soil degradation, associated with recreational burden, the fertilizers and pesticides use, the movement of agricultural machines.

The geochemical characteristics assessment of a soil cover exposed to technogenic contamination and the influence study of the soil properties and processes on the ecological stability of gray forest soils is relevant for predicting the substances and energy redistribution in landscapes and changes in the barrier and tread function of these soils.

The research purpose is to establish the main types and factors of the Oryol region soil degradation and methods for assessing and predicting the ecosystems ecological state and the degree of their degradation under the influence of anthropogenic and natural impacts.

In this regard, we have undertaken the following tasks:

- Establish the degree of influence of various anthropogenic impacts (degradation factors) on an environmental assessment of soils.



- Study the impact of soil and soil formation processes on the ecological status of biogeocenosis and their resistance to degradation.
- to determine the location and content forms of heavy metals in the gray forest soils profile in the northern forest-steppe, depending on regional characteristics and anthropogenic impacts.
- to make a comprehensive assessment of the elemental composition and properties of soils for organizing and conducting regional and local works related to environmental monitoring.

Practical significance: based on the research, the content of heavy metals in soil, plants, water was established, the species diversity of living organisms was described, sensitive and relatively pollution-resistant plant species were identified.

The obtained database on the progress of natural reproduction of gray forest soils in technologically disturbed areas can be used to justify the ecological rehabilitation of anthropologically disturbed landscapes.

## 2. Theoretical part

The natural soil formation processes occurring in the soil vary in intensity and degree of dominance. Soil formation processes such as podzolization, lessivage, gleying, salinization, alkalization lead to degradation of cultivated soils.

The different intensity of individual soil formation processes in local areas conducts to the formation of different soils.

Formed soils largely determine the resilience of ecosystems to degradation. At the same time, not one soil is found on each field and a certain territory, but a combination of different soils. The nature of the land cover structure has a significant impact on the environmental situation. In this regard, the environmental assessment of land needs to consider not only processes associated with anthropogenic effects on the soil, but also natural soil formation processes.

Soil podzolization is caused by acidic hydrolysis of the mineral and organic part of soils and washing out decomposition products to the lower part of the soil profile and beyond the soil profile. Soil is formed with poor nutritional elements, an acidic eluvial horizon, and, in some cases, a compacted illuvial horizon, which has low fertility for crops. The process is certainly a factor in the degradation of cultivated soils.

One of the most important and interesting problems in genetic and applied relations of soil formation in forest landscapes is the analysis of the causes of two such different types of soils (grey and podzolic) close to each other (at a distance of several meters or tens of meters) on the same genesis and composition of soil-forming rocks, in the same climatic conditions, under the canopy of a light-water forest. Given the relevance of the problem, the research of the features of the formation of podzolic and submerged horizons in the profile of soils of light granulometric composition in the conditions of the territory of the Spasskoye-Lutovinovo reserve acquires important environmental importance.

Of great interest is the conservation zone of the Spasskoye-Lutovinovo reserve of the Mtsensky district, located 25 km from the industrial slag dump. In 2018, soil samples were taken around the Spasskoye-Lutovinovo reserve (the territory of the reserve), in the parking lot of vehicles, arable land.

As can be seen from the data of Table 1, grey forest soils located 25 km from slag dump on arable land are characterized by an average medium-acid environment throughout the profile (pH 4.7-4.9) and base saturation (86.2-89.0%). The content of phosphorus and exchange potassium mobile forms is average 9.5-8.2 mg per 100 g of soil, respectively, the humus content was 1.8%.

The sum of exchange bases reaches 19.2 meq per 100g of soil, and the cationic exchange capacity of 21.56 meq per 100g of soil, down the profile, these indicators decrease.

In gray forest soils on the parking area, the humus content and absorption capacity practically do not change compared to arable soils.

However, in arable gray forest soils, the value of hydrolytic acidity is greater, it is 1.6 times higher than the values of acidity in soils in a parking lot. This is due on the one hand to the use of physiologically acidic mineral fertilizers on the arable land, and on the other hand to the effects of

vehicle emissions in the parking lot.

**Table 1.** Change of gray forest soils physicochemical properties on the territory of Spasskoye-Lutovinovo.

Section No.	Sample depth, cm	Hydrolytic acidity, meq per 100g soil	Sum of bases, meq per 100g soil	Cation-exchange capacity meq per 100g soil	Base saturation (%)	P <sub>2</sub> O <sub>5</sub> , mg per 100g soil	K <sub>2</sub> O, mg per 100g soil	Humus (%)	pH (κcl)
reserve territory									
7	12-22	1,58	27,6	29,18	94,5	7,2	28,9	4,4	5,6
7	22-32	1,8	26,0	27,8	93,5	4,6	13,8	2,06	5,8
7	mix.	3,71	38,8	42,51	91,2	10,6	33,7	4,7	6,1
arable land									
8	0-20	2,36	19,2	21,56	89,0	9,5	8,2	1,8	4,7
8	20-30	2,5	15,6	18,1	86,2	12,7	9,6	1,2	4,8
8	mix.	2,1	23,2	25,3	91,6	11,4	11,7	1,8	4,9
parking									
9	0-10	1,44	20,0	21,44	93,2	22,2	38,0	1,8	5,7
9	10-20	1,58	18,0	19,58	91,9	11,0	12,0	1,2	5,5
9	20-30	1,45	15,6	17,05	91,4	11,5	12,0	1,02	5,1

The soils of the reserve are represented by well-humus gray forest soils with a humus content of 4.4-4.7%, close to the neutral reaction of the medium and high saturation of the bases. Since the soils of the protected area are not anthropogenic, their properties can be taken as background indicators for monitoring.

Intensive human exposure to arable land without replenishing the necessary organic loss results in significant humus loss in arable gray forest soils and these losses amount to 2.6% or 85.8t of organic matter from 1 hectare of arable land, which leads to a sharp decrease in the ecological resistance of soils to degradation factors.

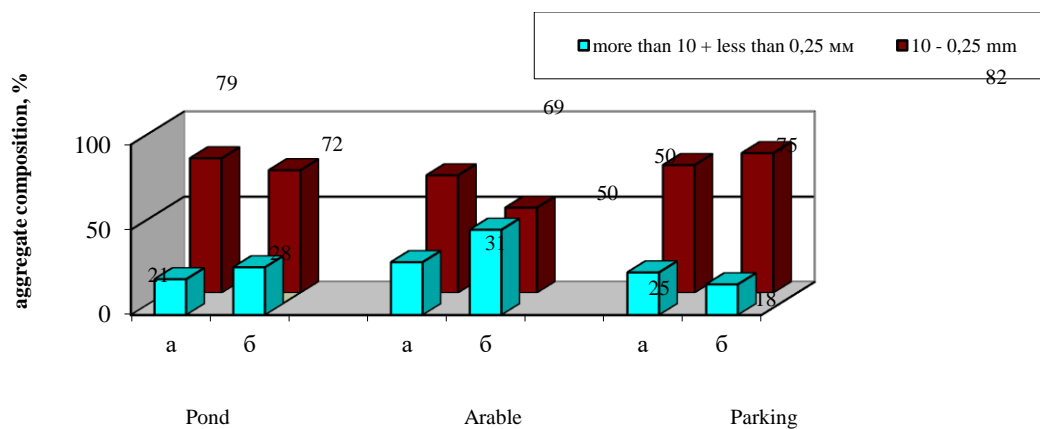
On the territory of the Spasskoye-Lutovinovo reserve, there is no noticeable change in the content of aggregates larger than 10 mm and smaller than 0.25 mm in the humus layer. The content of agronomically valuable aggregates 10-0.25 mm in the soils of the protected area varies as follows: in the upper 0-20 cm humus layer, their amount reached 79%, and in the sub-humus layer, the content of aggregates decreased to 72.0%. The aggregates >10 and < 0.25 in humus horizon is 21%, and in under humus horizon 28% (Fig. 1).

The aggregate composition of arable soils undergoes significant changes.

On the territory of the arable land, the content of agronomically valuable aggregates in the arable layer amounted to 69.0%, and in the underground, it decreased to 50%. Aggregates > 10 and < 0.25mm in the arable layer amounted to 31%, in the under-sugar layer increased to 50% (Fig. 1).

At the parking lot, the content of agronomically valuable aggregates of 10-0.25 mm was 75% in the humus horizon and 82% in the sub-humus layer. The number of aggregates >10 and <0.25 mm was 25% in the layer 0-20 cm and 18% in the layer 20-30cm, that is, in terms of indicators they approach

the indicators of the aggregate composition of the soils of the reserve.



**Figure 1.** Influence of land usage intensity on aggregate composition of gray forest soils, and - 0-20 cm, b - 20-30 cm.

Thus, the aggregate state of the soil is characterized by a high content of agronomically valuable aggregates, which characterizes the structural state of the soil as good. However, the intensity of mechanical treatments of gray forest soils and low humification level lead to a significant change in the aggregate composition of arable gray forest soils and, as a result, a decrease in porosity and an increase in density, which is a factor in changing the intensity of accumulation and migration of substances in the soil profile.

The granulometric composition of the soils under study in the upper horizons is dominated by a fraction of large dust of 48.6-53.2%, which causes low resistance of structural units to mechanical action and low absorption capacity. In all studied soils, the pattern of the particle distribution of less than 0.001 mm and physical clay is estimated as eluvial-illuvial. The granulometric structure in the soil profile is heterogeneous, it varies from medium-grained in the upper horizon to heavy- and light-loam in the lower illuvial part of the soil profile. (tab. 2)

Formed soils largely determine the resilience of ecosystems to degradation. At the same time, not one soil is found on each field and a certain territory, but a combination of different soils. The nature of the land cover structure has a significant impact on the environmental situation. In this regard, the environmental assessment of land needs to consider not only processes associated with anthropogenic effects on the soil, but also natural soil forming processes.

The degree of influence of the pollution source on the entry of heavy metals into soils was studied depending on the removal from the studied source, and on the territory of the reserve not subject to anthropogenic effects.

On the territory of the reserve, the content of gross and mobile forms of lead, copper, zinc, nickel does not exceed the TLV. The gross copper content varied from 16-20 mg/kg in the soil profile, zinc content ranges from 50 in the upper horizon to 58 mg/kg at a depth of 50-60 cm. Some redistribution of nickel in the soil profile was noted, namely, down the profile, its amount increases from 25 mg/kg in the upper humus horizon to 41 mg/kg in the illuvial horizon at a depth of 50-60 cm. Some increase in the amount of gross lead is observed in the illuvial part of the profile of gray forest soils.

The observed patterns are confirmed by the values of the total accumulation coefficient of heavy metals in the soil profile, it changed from 1.6 in the upper part to 3.6 in the illuvial horizon. This pattern characterizes the eluvial - illuvial type of distribution of substances in the profile of gray forest soils.

**Table 2.** Granulometric composition of dark gray forest soils.

Section, horizon	The size of the mechanical elements, mm, their name, content, %								
	1 – 0,25 coarse and medium- grained sand	0,25 – 0,05 fine sand	0,05 – 0,01 coarse dust	0,01 – 0,005 medium- grained dust	0,005 – 0,001 fine dust	<0,001 silt	<0,01 physical clay	Zn mobile	Zn gross
reserve territory									
Section 7 0-2	10,5	1,8	53,2	11,98	10,2	12,4	34,5	16,4	1,6
Section 7 12-22	5,3	33,4	30,9	1,22	13,5	15,6	30,3	2,1	1,3
Section 7 50-60	0,9	37,5	5,4	11,2	16,4	28,6	56,2	2,6	2,5
arable									
Section 8 0-20	4,0	12,9	51,6	11,5	7,7	12,3	31,5	6,9	0,6
Section 8 30-40	0,9	6,8	50,6	21,9	5,6	14,2	41,7	2,9	1,6
Section 8 50-60	1,0	29,7	27,1	8,3	10,7	23,2	42,2	2,7	1,3
parking									
Section 9 10-20	3,4	15,5	48,6	10,1	6,4	16,6	32,5	5,3	1,7
Section 9 30-40	1,5	37,7	13,6	9,0	8,4	29,8	47,2	2,3	1,3
Section 9 50-60	1,0	25,0	30,8	13,6	5,1	24,5	43,2	11,3	1,2

In the profile of low-content humus gray forest soils, the value of the total accumulation coefficient was 2.5-3 times lower than the value of the accumulation coefficient of gross forms of heavy metals compared to the soils of the reserve, but in this case, the nature of the distribution of substances remains the same, that is, it is eluvial-illuminating.

In gray forest soils of the parking area, the coefficient of total accumulation of metals is the largest in the upper 10 cm layer of soil, it amounted to 2.3 due to the higher content of gross forms of copper and zinc. At the same time, nickel compounds are characterized by the greatest redistribution in the soil profile.

On the territory of the arable land, the gross copper content according to the soil profile decreases to 18-16 mg/kg. The amount of zinc, nickel, and lead in the lower horizons in the soil profile is increasing, which indicates the migratory ability of these metals.

Of interest are the data in the parking lot. The amount of gross copper increased 1.8 times in comparison with the data of the reserve and 1.6 times with arable land in the horizon 0-10. Zinc content decreases in soil profile from 50 to 44 mg/kg. The gross cobalt content did not differ.

The value of the gross copper concentration coefficient practically did not change and is 1.1 over the entire soil profile of the reserve, the zinc concentration coefficient varies from 1.3 in the upper

horizon to 1.5 in the lower. The lead concentration coefficient in horizons 0-2 and 2-12 cm was 1.8, and at a depth of 50-60 cm increased to 2.2.

In arable land soils, the coefficient of lead concentration with soil profile depth increased, so in the arable horizon 0-20 cm it amounted to 1.3, and in the horizon 50-60 cm -1.8 units.

In the parking lot, the copper concentration coefficient was 1.8 and this value decreased in the soil profile. The zinc and lead concentration factor also vary, and the nickel concentration factor with depth increased to 1.2-1.5 units (Table 3).

**Table 3.** Concentration coefficient of heavy metals gross forms.

Section	Depth, cm	Cu	Zn	Ni	Pb
	reserve territory				
7	2-12	1,1	1,5	1,5	1,8
7	12-22	1,1	1,1	1,4	1,5
7	22-32	1,1	1,3	1,7	1,8
7	50-60	1,3	1,5	2,1	2,1
	Arable				
8	0-20	1,1	1,0	1,1	1,3
8	20-30	1,0	1,1	1,3	1,5
8	30-40	0,9	1,1	1,4	1,6
8	50-60	1,0	1,2	1,4	1,8
	Parking				
9	0-10	1,8	1,3	1,2	1,8
9	10-20	1,4	1,2	1,2	1,8
9	20-30	0,7	0,7	0,6	0,9
9	30-40	1,0	1,1	1,4	1,6
9	50-60	0,9	1,1	1,5	1,5

The environmental significance of heavy metals can be estimated by the number of mobile forms of heavy metals.

According to the data of the annex showing the content of heavy metals mobile forms in the soils of the reserve, no excess of TLV for all the analyzed metals was established, but the accumulation of mobile forms of metals is shown mainly in the upper humus layer of gray forest soils. On the arable land, there was an excess of TLV on nickel in the horizon of 30-40 cm almost 2 times, on lead, copper, and zinc there were no exceedances.

On the territory of the parking lot, the amount of mobile nickel exceeded the TLV by 1.1 times in the soil horizon 0-10 cm, in the horizon 20-30 cm 1.3 times. With depth, the number of mobile forms of nickel increases, in comparison with other objects, the number of mobile forms of nickel in the soils of the parking lot exceeded 1.4 times the amount of nickel in the soils of the reserve and 1.2 times in the soils of arable land.

The maximum content of mobile forms of zinc in gray forest soil is noted in the upper 10 cm layer and is 15.9 mg/kg. According to the soil profile, the amount of zinc decreases to 1.6 mg/kg.

The content of mobile forms in gray forest soils of cadmium in the parking lot in the upper horizons is 0.7-0.6 mg/kg, and in the lower horizons, it decreases to 0.1 mg/kg.

By the value of the total accumulation coefficient of mobile forms of heavy metals in the profile of the studied gray forest soils, it can be concluded that in the soils of the parking lot the number of mobile forms of copper, nickel, lead and cadmium in the humus horizon increases significantly, in the soil of the arable land in the arable layer the amount of nickel and copper increases. In this regard, the value of the coefficient of total accumulation of mobile forms of heavy metals in gray forest soils of the protected area was 2.9 units, in soils of arable land 6.9 units, and the territory of the parking lot 18.2 units.

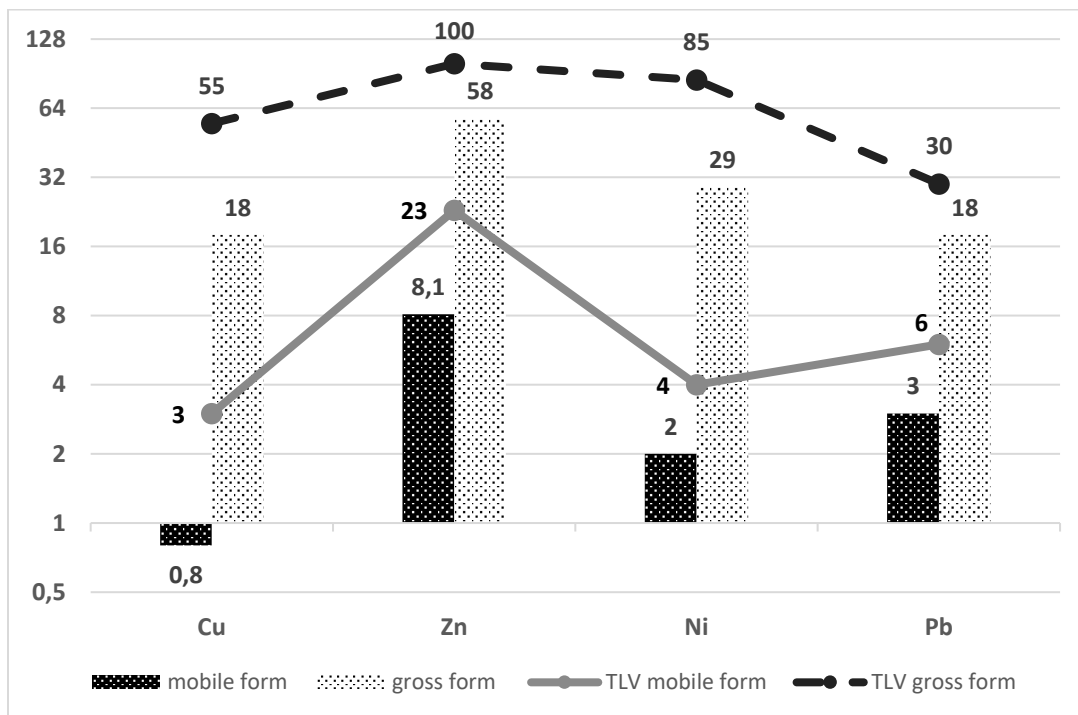
**Table 4.** Concentration coefficient of heavy metals mobile forms.

Section	depth	Cu	Zn	Ni	Pb	Cd
Reserve territory						
7	2-12	0,4	0,5	0,6	0,6	0,7
7	12-22	0,2	0,3	0,6	0,4	0,3
7	22-32	0,6	0,2	0,6	0,4	0,2
7	50-60	0,7	0,1	1,2	0,4	0,2
Arable						
8	0-20	0,5	0,4	1,2	0,6	0,5
8	20-30	0,2	0,3	0,7	0,4	0,3
8	30-40	0,2	0,1	2,1	0,4	0,2
8	50-60	0,3	0,3	1,2	0,4	0,2
Parking						
9	0-10	1,2	0,9	1,4	0,8	1,2
9	10-20	0,2	0,6	1,1	0,4	1,0
9	20-30	0,2	0,6	1,7	0,4	1,2
9	30-40	0,2	0,1	1,5	0,4	0,3
9	50-60	1,0	0,1	1,8	0,6	0,2

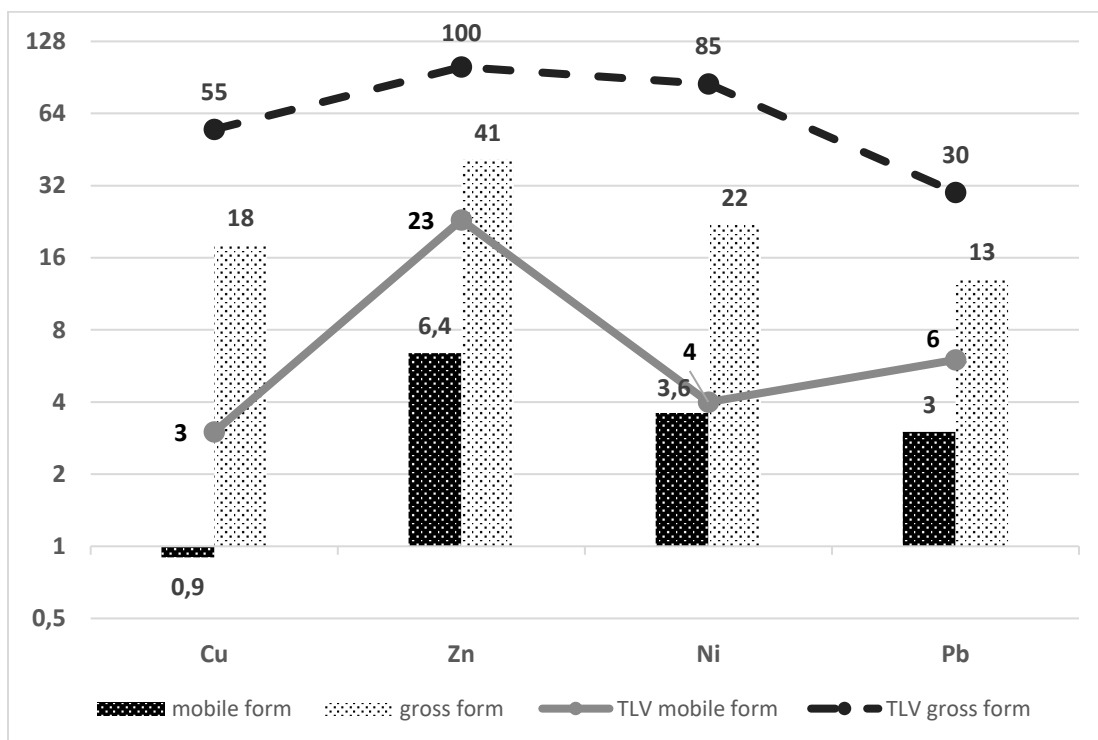
**Table 5.** Total accumulation factor.

Section, depth	Zn gross form	Zn mobile form
Reserve territory		
7(2-12)	2,2	2,9
7 (12-22)	1,3	2,1
7(22-32)	2,1	4,3
7 (50-60)	3,6	6,1
Arable		
8 (0-20)	0,6	6,9
8(20-30)	1,0	0,8
8 (30-40)	1,2	3,3
8 (50-60)	1,6	2,9
Parking		
9 (0-10)	2,3	18,2
9 (10-20)	1,7	5,3
9 (20-30)	-	6,7
9 (30-40)	1,3	2,3
9 (50-60)	1,2	11,3

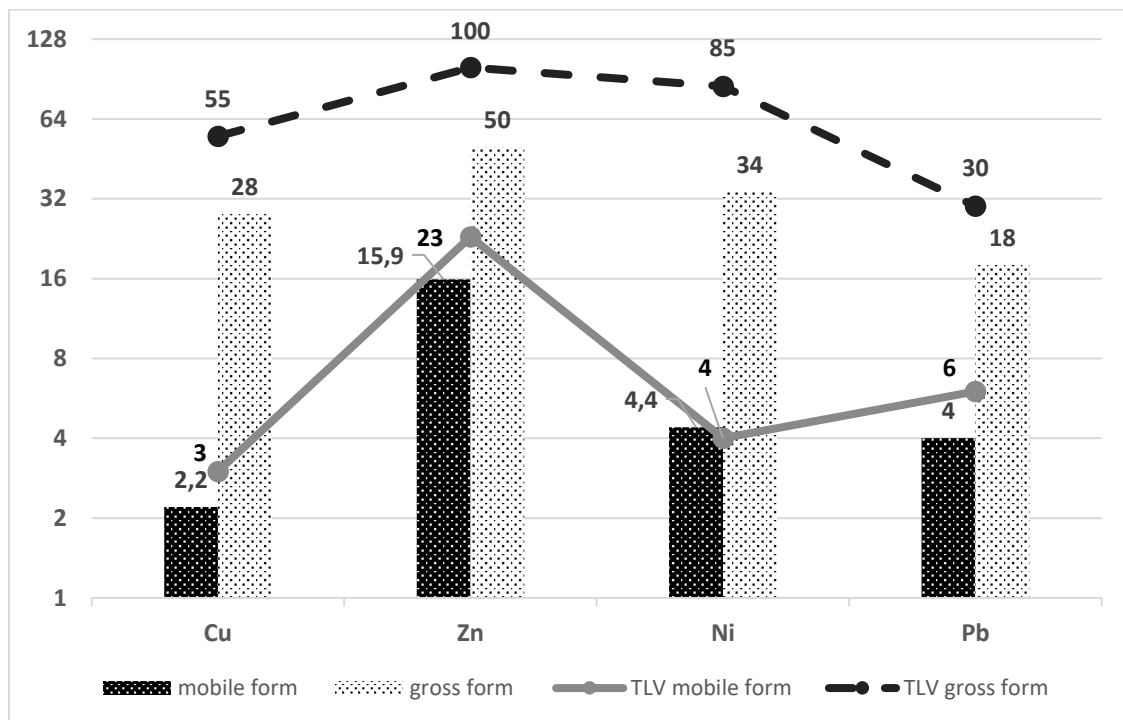




**Figure 2.** Content of gross and mobile forms of heavy metals in the arable layer of gray forest soil on the territory of the reserve.



**Figure 3.** Content of gross and mobile forms of heavy metals in the arable layer of light grey forest soil on the arable land.



**Figure 4.** Content of gross and mobile forms of heavy metals in the arable layer of light grey forest soil on the parking lot.

Thus, the usage of mineral fertilizers and pesticides, as well as vehicle emissions, contribute to the contamination of gray forest soils with heavy metals and their migration in the soil profile.

#### Conclusions:

1. Since the soils of the protected area are not anthropogenic, their properties can be taken as background indicators for monitoring.

2. The heavy human impact on arable land without replenishing the necessary organic losses results in significant humus losses in arable gray forest soils, and these losses amount to 2.6% or 85.8 tons of organic substances from 1 hectare of arable land, which causes a dramatic decrease in the ecological resistance of soils to degradation factors.

3. The intensity of mechanical treatments of gray forest soils and low humification lead to a significant change in the aggregate composition of arable gray forest soils and, as a result, a decrease in porosity and an increase in density, which is a factor in changing the intensity of accumulation and migration of substances in the soil profile.

4. In all test soils, the particle distribution pattern of less than 0.001 mm and physical clay is estimated as eluvial. The granulometric composition in the soil profile is heterogeneous, it varies from medium-carbon in the upper horizon to heavy-carbon and light-clay in the lower illuvial part of the soil profile, which changes the intensity of migration and accumulation of substances in the soil profile.

5. In the gray forest soils of the parking lot, the number of mobile forms of copper, nickel, lead and cadmium in the humus horizon increases significantly, in the arable land soil in the arable land layer the number of mobile forms of nickel and copper increases, in comparison with the soils of the reserve. The value of the coefficient of total accumulation of heavy metals mobile forms in gray forest soils of the protected area was 2.9 units, in soils of arable land 6.9 units, and the territory of the parking lot 18.2 units. The use of mineral fertilizers and pesticides, as well as vehicle emissions, contribute to the contamination of gray forest soils by heavy metals and their migration in the soil profile.

Based on the data obtained, which indicate the need to improve the environmental situation in the research area, we propose:

1. The obtained database on the natural reproduction progress of gray forest soils in technogenically disturbed territories can be used to justify the ecological rehabilitation of man-made landscapes.
2. The ecological state of the soil-plant system is recommended to be evaluated by the species composition of growing plants, their ability to accumulate heavy metals, and the species resistance to soil contamination with heavy metals.
3. Apply a systematic ecological approach to the geochemical characterization of the soil cover of anthropologically disturbing territories.
4. Creation of waste-free process production.
5. To develop a procedure for methods and techniques of recycling waste from the metallurgical industry, the consumption of their fertilizing properties in agriculture.
6. Ensure the creation of protective forest plantations both along roads and near the production waste territory.

### 3. References

- [1] Jakovleva E V 2006 Ecological assessment of gray forest soils degradation factors and ways of their optimization Abstract of dissertation for the degree of Ph. D. (Agricultural science)] (Orel) 23 (In Russ.)
- [2] Stepanova L P, Jakovleva E V, Koren'kova E A, Pisareva A V 2015 Fertility restoration agro-economic assessment of anthropologically disturbed and recultivated gray forest soils *Scientific notes of Oryol State University* **3** 256-261 (In Russ.)
- [3] Pisareva A V, Belopuhov S L, Savich V I, Stepanova L P, Jakovleva E V, Gukalov V V, Shajhiev I G 2017 Heavy metals migration from the source of pollution depending on the relationships in the landscape *Bulletin of Kazan Technological University* Vol 20 **6** 160-163 (In Russ.)
- [4] Stepanova L P, Jakovleva E V, Pisareva A V 2017 Ecological assessment of the phytotoxicity degree of soils on anthropogenic transformed territories *Bulletin of Michurinsk State Agrarian University* **2** 10-15 (In Russ.)
- [5] Stepanova L P, Jakovleva E V, Pisareva A V 2016 Ecological characteristic of anthropogenic-transformed soils contaminated with heavy metals *Agrochemistry* **12** 60-67 (In Russ.)
- [6] Stepanova L P, Jakovleva E V, Pisareva A V 2019 Spatial and temporal dynamics of soil-geochemical anomalies in the area of slag waste exposure *Ecology and industry of Russia* Vol 23 **3** 44-48 (In Russ.)
- [7] Pisareva A V, Stepanova L P, Jakovleva E V 2018 The impact of anthropogenic factors on the ecological properties of urban soils A collection of materials from a scientific and practical conference with international participation 20-25 (In Russ.)
- [8] Raskatov V A, Stepanova L P, Pisareva A V, Jakovleva E V 2018 Features of degradation changes of urban soils depending on the intensity of the anthropogenic impact **2(101)** 55-59 (In Russ.)