

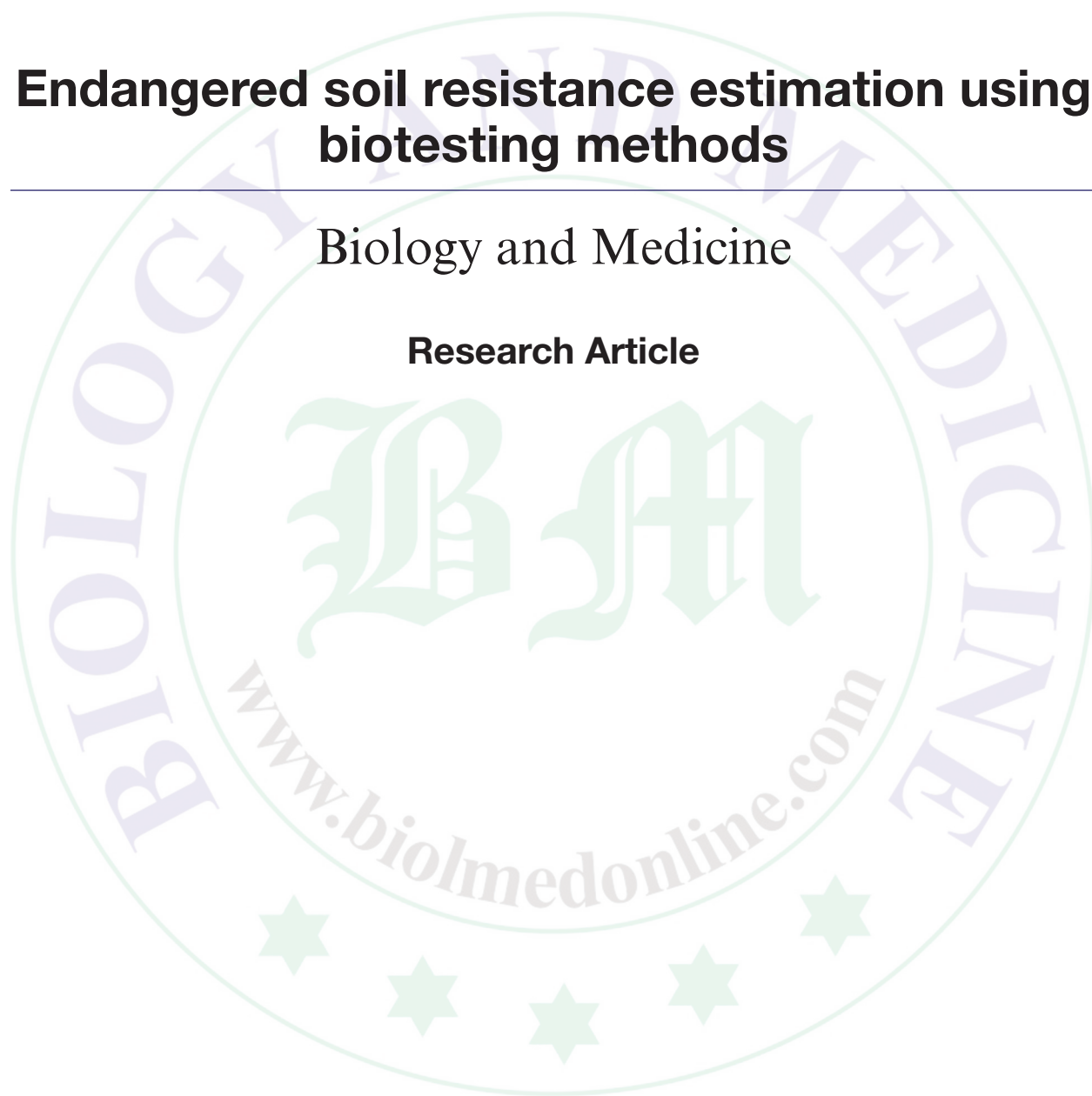
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# **Endangered soil resistance estimation using biotesting methods**

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## Endangered soil resistance estimation using biotesting methods

Eremchenko Olga Zynovievna, Shestakov Igor Evgenievich\*  
Perm State University, Bukireva Street, 15, 614990, Perm, Russia.

\*Corresponding author

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### Abstract

It has become impossible to recover the unique ecosystems of the northern areas of forest-steppe in Russia. The reason is the irreversible loss of grey forest soils and chernozems due to agricultural impact and water erosion in Perm Krai. We have singled out several soil types that should be specially protected. The objective of the research is the estimation of resistance of Kungur forest-steppe endangered soils, using the methods of biotesting. Soil samples were contaminated by Cd and Pb. Soil resistance estimation was done by testing with watercress cultivation *Lepidium sativum*. Later, the indexes of growth, biomass, generation of H<sub>2</sub>O<sub>2</sub> in the overground plant organs, catalase activity, and soil 'respiration' were measured. Also, the content of organic carbon and pH in soils was measured. The results of the research were processed by dispersion and regression procedure methods. The reliable connection between the studied biological indexes and elements of soil fertility was established. It is established that the height and mass of test-culture are connected with humus content. There is also close connection between catalase activity and respiration. All the indexes studied, apart from respiration, had connection with pH. Thus, biological indexes tested, changed according to basic elements of soil fertility, which are humus content and exchange acidity. The relation between basic soil properties (humus, pH) and biotests can be used for estimation of future soil condition. Increased generation of H<sub>2</sub>O<sub>2</sub> by test-culture can indicate the contamination of soils. Even if the mass of plants does not differ from control samples, this significant index revealed the influence of high dose of lead and cadmium on intracellular processes. The approved testing methods, using biological indexes, are recommended to the further usage under estimation of the ecological soil function deformation in forest-steppe landscapes of Perm Krai.

**Keywords:** Biotesting of soils; soil conservation; cadmium; lead; heavy metals; soil resistance.

### Introduction

Contemporary science has not estimated the contribution of each natural phenomenon on general biosphere condition. Humanity evolution depends on the state of ozone screen, atmosphere thermal balance, air and natural land water quality. Along with these, soil mantle refers to the endangered zones of the planet.

Living organisms (plants, fungi, animals, microorganisms) are tightly connected with each other in ecosystems. They use matter cyclically to reproduce life and transmit energy through food chains. Both biogenic matter and biogenic energy pass through soil, the properties of which have been precisely correlated to the corresponding complex of organisms in the process of evolution. Therefore, large diversity and life density on land are at the most connected to ecological functions of soils, including its fertility.

Soil ecological functions guarantee soil capability for biosphere steadiness in general and certain landscapes in particular. Any soil, being a natural historic body, has general biospheric ecological functions. It takes part in formation of global matter, energy, and information circulation in biosphere. Straight or implicit, soil controls a lot of processes in lithosphere (biochemical transformation of its upper layers and sun energy penetration into its lower layers), hydrosphere (underground waters formation, transformation of surface waters into ground waters and processes of river sink formation), atmosphere (regulation of matters, heat and energy streams of ground atmosphere and atmosphere chemical composition), and also biosphere in general, being a habitat for animals and plants, source of matter and energy for land organisms [1].

At present, soils of the Earth are exposed to anthropogenic impact of different extent: from air

pollution impact to almost complete soil destruction over mining operations or construction site works. The total area of degraded and destroyed lands makes up approximately 2 billion hectares. In Russia over 1 million hectare of soils are destroyed. Transformed arable soils occupy 1,476 million hectares in the world, in the Russian Federation – 124 million hectares [2,3].

Ecological functions performance and retention of soil characteristics over anthropogenic impact depends on soil resistance. In order to steady state of soil and preserve ecogenetic soil diversity, a number of measures are needed, including soil conservation. Soil conservation is apparently necessary not only as an object of agricultural production but also as an integral part of land ecosystems – as a habitat of living organisms. The system of living organisms' preservation will be effective only in case of soil diversity conservation as the existence of more than 90% of species on Earth closely depends on soils. Self-reproduction of rare and endangered species of living organisms is realized in ecosystem, in which ecological soil functions are fulfilled [1,4].

According to the “environment protection law” of Russian Federation, Article 62, it is stated that rare and endangered soils should be secured by government. They are listed in the Red Data Books of soils of the regions and of Russian Federation. The primary aiming of special soil protection is the preservation of the most possible variability of soil types, structures of soil cover, and their biocenoz. It is suggested to protect the soils that are endangered by considerable transformation, degradation or disappearance under the influence of anthropogenic factors. Moreover, rare soils that are formed on rare parent rocks, not typical to the zone and formed in unusual ecological conditions should be specially protected [1].

Due to global processes of environment pollution, the problem of biological soil testing has become relevant today. Studying soils, it is important to reveal and forecast the reaction of soil cover on anthropogenic contamination. The analysis of elemental soil structure cannot provide with the needed information on influence of negative factors, connected with agricultural human influence on soils. Only the usage of living organisms that are plants and microorganisms and indexes of their activity provide the necessary efficient data about the influence of complex of negative factors. The role of biological

methods in the estimation of ecological state of soil cover is perspective quite significant. Biotesting estimates the current contamination with test-objects and the objective is to get a quick signal on toxicity [5-7].

In Perm Krai, several categories of soils were segmented that should be specially protected due to agricultural transformation of soil cover [8]. Under the influence of agriculture, soils change the characteristics and functionality, and soils become less fertile. Fertile soils of Perm Krai are considered to be forest grey soils and chernozems of forest-steppe areas. Practically all the areas convenient for usage are ploughed up. The progression of water erosion (relative density of eroded agricultural lands is from 15 to 70%) leads to practically irreversible loss of forest grey soils and chernozems. That means the recovery of soils as well as unique ecosystems of the northern areas of forest-steppe in our country has been becoming less and less possible [8].

## Materials and Methods

The object of the research is the soils of Perm Krai that have special ecological status are recommended to be included into the regional Red Soil Data Book. These are the soils of unique Kungur forest-steppe that are chernozem clayey-illuvial, dark-grey, and grey soils. High percentage of ploughed soils (up to 72% of the occupied area) and intensive development of water erosion make it possible to estimate the soils as endangered and recommend the special protection procedures. For comparing the analysis of soil reaction to pollution by heavy metal, sod-podzol soil was studied.

The object of the research was the estimation of chernozem and grey soils steadiness by testing height and mass of watercress, peroxide hydrogen content in the overground plant organs, catalase activity, and respiration (by carbonic acid gas emission) of soil.

## Results and Discussion

Grey forest soil type dominates the soil cover of forest-steppe part of Perm Krai. It includes three subtypes: light-grey forest, grey-forest, and dark-grey forest soils. Dark-grey soils differ by more density of humus profile, reduction of eluvial thickness and less illuvial profile part.

The studied dark-grey forest soil had the following morphological structure.

AU – dark-humus, 0-26/26 cm, has a sod 2 cm thick; brownish dark-grey colour; wetting, loose; structure is cloddy, light-clayey, thin-porous and porous, loose, light-sticky, there are worm-holes and coprolite. There are rich roots; the transition to the next horizon is visible and wavy.

AUe – dark-humus podzolic, 26-40/14; dark-grey, but lighter than AU; wetting; structure is cloddy-plastic; light-clayey, thin-porous, of high thick, sticky; there are worm-holes and coprolite. There are less roots; the transition to the next horizon is visible and wavy.

BEL – sub-eluvial, 40-58/18 cm; consists of colour combinations: huge pale-yellow stains, dark-grey humus leaks, at the bottom there are ginger-brownish salients; wetting; the structure is cloddy-nuciform; of high density; there is vertical parting; slightly sticky; light-clayey; there are not many roots; the transition to the next horizon is even/flat/level and gradual.

BT – textured, 58-118/60 cm; brown-brownish; wetting; the structure is large-format-prismatic; thin-porous; thin-split; of high density; light-sticky; light-clayey, with single roots; the transition to the next horizon is level, very gradual.

C1 – transitional to soil-formation rock horizon, from 120 cm (slit to 160 cm); brown-brownish colour; wetting; structure is large-prismatic, similar to large-columnar; thin-porous; thin-split; thick, sticky, light-clayey, there are single roots.

Dark-grey soil is characterized by high humus content in dark-humus horizon (about 10%) and the content is lower by 1.6% in sub-eluvial soil. High capacity of cation exchange in top horizon is connected with the content of humus (66-55 mg- $\mu$ Eq/100 g of soil), in sub-eluvial horizon it is two times lower. The profile is characterized by subacid reaction of soil solution. Exchanging acidity form is distinctly evident; hydrolitic acidity is maximum in dark-humus horizon, that is, 15-17 mg- $\mu$ Eq/100 g. The base saturation percentage is minimum in dark-humus horizon (73-74%), it gradually becomes higher. The soil has light-clayey structure; in dark-humus and sub-eluvial horizons the content of silt is lower almost 2 times comparing to lower horizons [8].

The grey forest soil subtype of Perm Krai forest-steppe is characterized by accumulation of organic matter and cindery elements in the

upper horizon, clear eluvial-illuvial differentiation of profile according to silt, ferrum oxides, and aluminium.

The studied grey soil had the following morphological structure:

AY – grey-humus (sod), 0-12/12 cm; in the upper layer the capacity of sod is about 2 cm; brownish-light-grey, cloddy-dusty, of high density, non-sticky, loamy; with worm-holes and roots; there are few roots; the transition to the next horizon is wavy and gradual.

AEL – humus-eluvial, 12-20/8 cm; colour is heterogeneous; light-grey stains on light-brownish background; slightly wetting; platy-dusty, of high density, non-sticky, clayey; the transition to the next horizon is wavy and gradual.

– grey and light-brownish, sometimes dark fragments (humus tongues, roots, molhills); wetting, nutty, of high density, light-sticky, clayey, contains many wormholes and roots; living roots are few; the transition to the next horizon is gradual and level.

BT – textured, 40-66/26 cm; colour is red-brownish, yellowish; the structure is large nuciform and large prismatic, structural inclusions are covered with clear films; of high density, sticky, clayey, heavily wetting, contains humus tongues, ferrum-manganese concretions, rare roots, the transition to the next horizon is gradual and level.

BC – transitional to maternal rock, 66-104/38 cm; red-brownish, yellowish, wetting, large-nuciform-prismatic, of high density, sticky, silty, there are dark fragments that are roots and molehills; contains ferrum-manganese concretions (less than BT), single roots; the transition to the next horizon is very gradual.

C – silty soil-formation rock, from 104 cm (slit to 145 cm); colour, structure, granular structure are similar to BC horizon, but the stickiness is higher and density is lower.

Humus content in grey-humus and sub-eluvial horizons of grey soil is 6-7%. Soil horizons are characterized by acid reaction of soil solution. Hydrolytic acidity had most indexes in sub-eluvial horizon, that is, 8.6 mg- $\mu$ Eq/100 g of soil. The sum of exchange cations in grey-humus horizon is 2 times lower than in sub-eluvial (24 mg- $\mu$ Eq/100 g of soil). Saturation percentage was 81-85% in humus and sub-eluvial horizons and it increased by 90% in texture horizon. Soil structure was clayey in upper horizon and clayey in all the other horizons [8].

Chernozems of Perm Krai forest-steppe are characterized by dark colour, almost black humus horizon, that is, on average 38 cm high. There is cremnium powder on the surface of structure aggregates in clayey-illuvial horizon. The profile of the studied soil has the following structure:

AU – dark-humus, 0-28/28 cm; has loose sod on the surface of grey-brownish colour 3 cm thick, consisting of grass litter of different erode degree and grass roots together with soil mass; upper part of the horizon is loose, cloddy-seedy, brownish; in the average part colour is dark-grey, structure is nutty-cloddy, coming apart to seeds; in the lower part the horizon is thick, large prisms coming apart to seedy, nutty and cloddy parts; podzol is not registered; thin-porous, light-sticky, light-clayey; contains large roots and the signs of earthworms activity. Coprolites and brown mottles are the material of the lower horizon; transition to the next horizon is very tongued.

Bi<sub>1</sub> – clay-illuvial, 28-63/35 cm; very tongued, the colour is heterogeneous, from dark-grey in the upper part of the horizon and in ‘tongues’ to grey, grey-brownish and red-brownish in the lower part; the structure of brownish mass is nutty, of dark-grey is cloddy-seedy; on the whole the construction is thick; new formations are revealed in humus tongues and weak whitish powder along the dark-grey sides of structural partings; there are wormholes and molehills; rich roots.

Bi<sub>2</sub> – clay-illuvial transitional, 63-98/35 cm; brown-brownish; by structure the horizon in the upper part is nutty-prismatic, in average part is large prismatic. It is close to large columnar, in the lower part the structure is thin-prismatic; thin-porous; there is a rare net of vertical and diagonal splits; It is thick. Light-clayey and sticky; there are rare humus tongues; the transition to the next horizon is very gradual and level.

C1 – transitional to mother rock, 98-143/45 cm; brownish with ginger or yellowish shade; unstructured, thin-porous, thick, sticky, clayey; there are dark-grey silty plates; brown clayey-humus cutans that cover the walls of pores; carbonate mycelium is along pores; the transition to the next horizon is very gradual, level; soil effervescence from 113 to 118 cm depth.

C2ca – carbonate clay, from 143 cm (split to 177 cm); the ginger shade is more intensive compared to the higher horizon; clay-humus cutans are present; there is more carbonate mycelium; soil very effervescence from 143 to 153 cm.

In dark-humus horizon of clay-illuvial chernozem the content of humus is high, that is, 9.6-13.0%, at the depth of about 0.5 m there is 4% of humus additionally. Soil has weak acid reaction of soil solution to the depth of 50 cm, lower are neutral horizons, in the carbonate maternal the reaction is alkali. Dark-humus horizon is characterized by high hydrolytic acidity, that is, 6.7-12.3 mg- $\mu$ Eq/100 g with the maximum value in the upper part of the horizon. The lowest base saturation percentage is in the upper part of dark-humus horizon, that is, about 80%, it increased up to 95% in the clayey-illuvial horizon. Chernozem has a high cation-exchange capacity, in the dark-humus horizon of the upper part it is 66 mg- $\mu$ Eq/100 g of soil and in the lower part it is 50 mg- $\mu$ Eq/100 g. Soil horizons are heterogeneously different in granulometric composition. Dark humus horizon is clayey, clayey-illuvial horizon is light-clayey and the transitional to the rock is clayey [8].

Sod-podzol soil in grey-humus horizon of 12 cm capacity contained 4.3% of humus and eluvial – 1.4%. The reaction of soil solution is acid. Exchange and hydrolytic forms of acidity are high, in grey-humus horizon base saturation percentage is less than 50%. The capacity of cation exchange in grey-humus and eluvial horizons is 23-28 mg- $\mu$ Eq/100 g of soil. Granulometric composition of soil is differentiated according to the horizons. Grey-humus and eluvial horizons are clayey and sub-eluvial and textured horizons are clayey [8].

Bioavailability of heavy metals depends on the soil type, it reduces with the growth of pH, presence of other metals and helators [9]. In cohesive soils, contamination elements are absorbed by mineral and organic matters, do not come to living organisms, and do not reveal toxicity. The behavior of ecotoxicants in different soils is reflected by plants and microorganisms, which is revealed in reaction of test-cultures and in the indexes of biochemical soil activity. Lead and cadmium refer to the group of toxic elements with high technogenic and low biogenic activity. Their influence on ecosystem condition, living organisms refract through buffer soil properties. This is the reason why plant reaction to high level of lead and cadmium contamination of different soils that have ecosystem value is of great scientific interest [10].

The soils were studied in natural conditions, so their natural composition of profile and main properties has been maintained.

For fitotesting the samples were taken from the upper and lower parts of dark-humus horizons of chernozem and dark-grey soil, from grey-humus and sub-eluvial horizon of grey-soil and from grey-humus horizon of sod-podzol soil. Soil samples were eroded with cadmium sulfatum on the basis of 500 mg/kg of soil and lead nitratum on the basis of 1,000 mg/kg of soil. Lead was inserted in the quantity corresponding to the high level of contamination that is registered in technogenic landscapes of Perm Krai. Cadmium toxicity is 2-10 times higher comparing to other heavy metals. That is why, its dose was decreased in two times comparing to lead.

Watercress *Lepidium sativum* of Kurlud variety had been cultivated in small vessels for 14 days, after that growth indexes, biomass and generation of hydrogen peroxide were measured. General content of hydrogen peroxide was defined by ferroticionate method [11]. Catalase activity was determined in air-dry samples of soils by gasometric method. Respiration was estimated by the content of carbonic acid gas emitted by soil in 24 h under the temperature of 28°C and humidity of 60% of total moisture capacity by adsorptive method. The content of organic carbon in soils was estimated by Turin method and salt pH – by potentiometer method. The results of the research are elaborated by dispersion and regression methods.

High chernozem fertility provided high resistance of test-culture to the contamination by heavy metals. Watercress plants cultivated on samples from upper part of dark-humus horizon, the samples with high contamination of lead salt had higher growth indexes due to nutritious

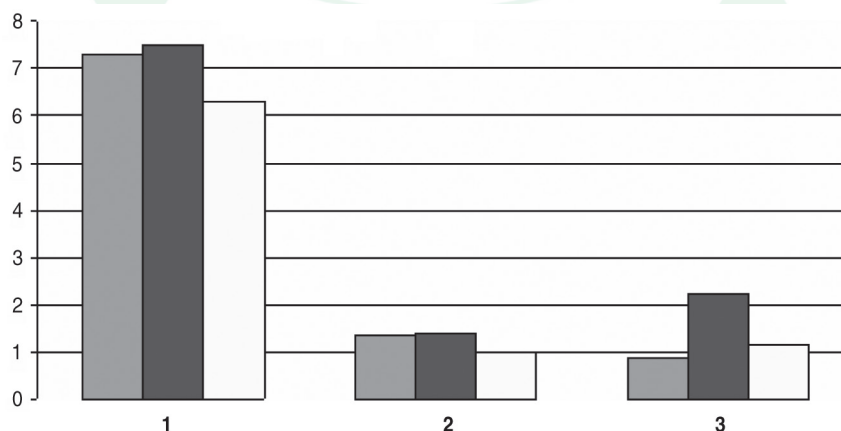
significance of nitrate-ion. The biomass of plants did not differ from control samples (Figure 1). At the same time the plants revealed high level of generation of hydrogen peroxide, 72% higher than control state. Extreme factors of soil environment influence on plants, disrupting intracellular mechanisms. To define the initial target/element which is influenced by different stress factors sometimes can be a difficult task. Generally, the influence of factors integrates in a way that provokes overexpression of reactive oxygen species. Reactive oxygen species including  $H_2O_2$  have high reactivity and can damage intracellular components. At present, reactive oxygen species are considered as not only destructive molecules but also important signal/warning molecules in cellular regulation [12]. Apparently, in watercress cultivated in chernozem contaminated with lead salt, overexpression of reactive oxygen species activated antioxidant protection system.

Plants that grow on samples from lower part of dark-humus horizon on the whole revealed similar reaction, at the same time generation of peroxide increased 2.6 times comparing to control.

It is known that cadmium is characterized by higher toxicity for living organisms than lead. Against the background of high contamination of chernozem by cadmium salt, the growth of plants reduced by 14%. Biomass decreased by 28% being cultivated on the samples from lower part of dark-humus horizon, at the same time generation of  $H_2O_2$  by plants intensified, although to a lesser degree than at the background of lead insertion (Figure 2).

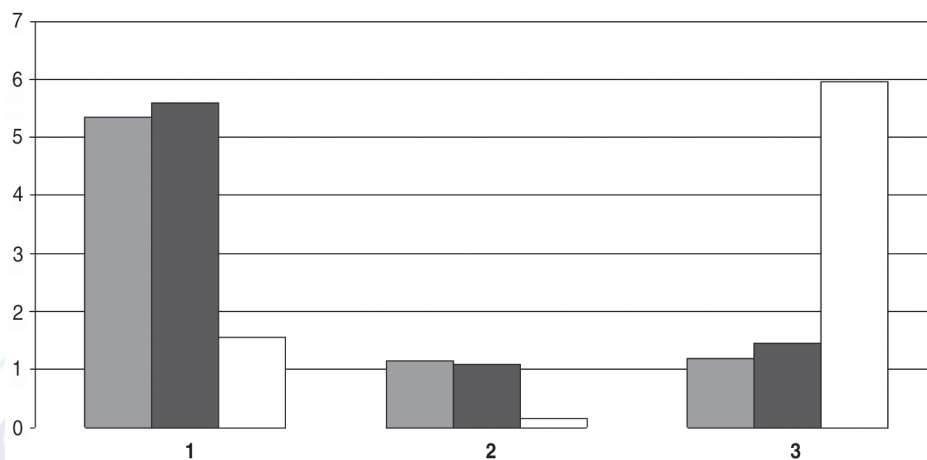
**Figure 1: Indexes of test-culture condition on chernozem.**

1 – plant growth, cm; 2 – plant mass, g; 3 –  $H_2O_2$  content, mM/100 g  
(from left to right: control, Pb 1,000 mg/kg, Cd 500 mg/kg).



**Figure 2: Indexes of test-culture condition on grey soil.**

1 – plant growth, cm; 2 – plant mass, g; 3 – H<sub>2</sub>O<sub>2</sub> content, mM/100 g  
(from left to right: control, Pb 1,000 mg/kg, Cd 500 mg/kg).



Dark-grey soil as well as chernozem due to favourable properties secured stability/steadiness of test-culture under contamination by heavy metals. On the samples from the upper part of humus horizon, contaminated by lead, the plants revealed increased growth and biomass that is not different from that of control. In both versions the content of hydrogen peroxide in plants increased by 78.5% and in 3 times correspondingly.

Under the contamination of dark-grey soil samples by cadmium, growth indexes reduced significantly, at the same time generation of H<sub>2</sub>O<sub>2</sub> by watercress plants noticeably intensified.

On the sample of grey soil contaminated by lead salt, the growth and mass of the plants changed insignificantly, but generation of H<sub>2</sub>O<sub>2</sub> increased by 22-31% comparing to control sample. Test-culture suffered more noticeable from contamination by cadmium, as in acid soil heavy metals mobility increase as well as their accessibility to the plants. Apart from that, in that soil, comparing to the ones considered, apparently absorption of metals decrease because of less content of humus and absorption capacity. Growth and mass of watercress decreased in several times, increasing hydrogen peroxide content in 4-5 times. Intensive generation of reactive oxygen species by plants, apparently, influenced destructively the cellular constructions, including membrane components.

On low fertile sod-podzol soil, plants of watercress suffered considerably by the heavy metal contamination. Indexes of growth and biomass significantly decreased, especially under

the contamination of soil by cadmium. Generation of H<sub>2</sub>O<sub>2</sub> on the lead sample increased by 62%. At the background of insertion of cadmium salt biomass was minimal that did not allow to determine hydrogen peroxide generation in it.

All the biological processes connected with transformation of substances and energy in soil are carried out with the help of enzymes. Enzymatic activity of soil is used as a diagnostic index of soil fertility, as the enzyme activity reflects changes of biological soil properties under the influence of ecological factors [8]. In chernozem, the catalase activity in sample with lead nitrate does not significantly differ from control sample. Catalase activity in sample with cadmium decreased by 23.3-32% comparing to the control sample (Table 1).

In sod-podzol soil, the catalase activity is 3 times lower comparing to chernozem. Under the influence of lead salts the reaction of soil on catalase activity is similar to chernozem. Catalase activity in cadmium samples is lower by 16.6% in humus horizon and by 25% in eluvial horizon.

In upper and lower parts of humus horizon of dark-grey clayey/loamy soil respiration intensity in control sample did not differ from the sample with lead. Apparently, this is connected with nitrate-ion influence. In the sample with cadmium 'respiration' intensity is slightly reduced in the upper part of the humus horizon.

In the humus horizon of sod-podzol soil the 'respiration' intensity is increased in the sample with lead comparing to the sample with cadmium, apparently, because of nitrate-ion

**Table 1: Biological indexes change under contamination of soil samples by lead and cadmium salts.**

Soil	Testing option	Plant mass (mg)	Catalase activity, O <sub>2</sub> cm <sup>3</sup> /g of soil per minute	'Respiration' intensity, CO <sub>2</sub> /100 g of soil per 24 h
Chernozem	Control	1,950	6.3	30.8
	Pb 1,000 mg/kg	2,260	6.2	29.2
	Cd 500 mg/kg	1,412	4.6*	26.1*
Dark-grey soil	Control	1,337	4.5	27.6
	Pb 1,000 mg/kg	1,125	3.5*	33.3
	Cd 500 mg/kg	687*	3.4*	21
Grey soil	Control	1,180	3.8	14.1
	Pb 1,000 mg/kg	1,047	3.6	13.5
	Cd 500 mg/kg	373*	2.9*	13.8
Sod-podzol soil	Control	1,002	1.9	24.2
	Pb 1,000 mg/kg	319*	1.9	29.3
	Cd 500 mg/kg	78*	1.5*	21.2*

Note: \*Significant differences from control value.

influence. Between control and lead samples as well as control and cadmium samples there are no reliable differences.

In light-grey forest soil, the influence of factor to the reaction is not observed. There are no reliable differences concerning respiration intensity in all the samples (Table 1).

By regression analysis methods connection between the studied biological indexes and soil fertility elements was established (Tables 2 and 3). The height and mass of test-culture is connected with humus content. More relative connection is studied/observed with catalase activity and respiration, in accordance with

coefficient of determination, 60-70% of their unsteadiness depend on humus concentration in soils. All the studied indexes apart from respiration, are related to pH salt. At the same time, the lower acidity is (higher than pH), the more the height and mass of the plants is and the more active catalase in soil is (Table 3). The concentration of hydrogen peroxide in the plants with the growth of exchange acidity of soil increase; it is possible that acid soil environment influence the cation-anionic balance of cellular solution, disrupt transportation of proton and electron through cell membrane, causing overexpression of reactive oxygen species. Thus, the probationer

**Table 2: Dependence between humus concentration in soils and bioindicative indexes.**

Index	Regression equation
Test-culture height, mm	$y = 4.47 + 0.17x; F = 3.37; p = 0.0119; R^2 = 0.32$
Green weight of test-culture, mg	$y = 381 + 132x; F = 9.26; p = 0.00015; R^2 = 0.57$
Peroxide concentration in test-culture, mM/g green weight	No
Soil 'respiration', CO <sub>2</sub> /100 g of soil per 24 h	$y = 8.88 + 1.51x; F = 10.7; p = 0.000093; R^2 = 0.61$
Catalase activity, O <sub>2</sub> cm <sup>3</sup> /g of soil per min	$y = 0.603 + 0.397x; F = 17; p = 0.000027; R^2 = 0.71$

**Table 3: Dependence between pH salt of soils and bioindicative indexes.**

Index	Regression equation
Test-culture height, cm	$y = 0.68 + 1.16x; F = 7.39; p = 0.00036; R^2 = 0.51$
Green weight of test-culture, mg	$y = -0.0029 + 963x; F = 18.8; p = 0.000021; R^2 = 0.73$
Peroxide content in test-culture, mM/g green weight	$y = 0.0455 - 0.0072x; F = 8.51; p = 0.0004; R^2 = 0.59$
Soil 'respiration', CO <sub>2</sub> /100 g of soil per 24 h	No
Catalase activity, O <sub>2</sub> cm <sup>3</sup> /g of soil per min	$y = 1.14 + 0.59x; F = 6.51; p = 0.00061; R^2 = 0.48$



biological indexes changed in connection with basic elements of soil fertility, which are humus concentration and exchange acidity.

The derived relations/dependences between the main characteristics of soils (humus, pH) and biotests can be used for prognosis estimation of ecological state of soils. It is known that under agricultural usage of chernozems and grey soils the processes of dehumification and acidification have been developing that decrease soil fertility. According to the calculation data (regression equation), under the decrease of humus concentration in soil from 14% to 8%, the mass of one plant of test-culture, catalase activity, and isolation of carbonic acid gas decrease by 30-40%. By the drastic decline of humus concentration from 14% to 5%, we expect decrease by 50-60%.

Equation calculations revealed that under the change of pH salt of soils from 5.1 to 3.6, the mass of one plant of test-culture and catalase activity can decrease by 20-30%. The indexes of peroxide concentration in green parts of the plants at the same time increase in 1.2 times.

### Conclusions

- The soils of Kungur forest-steppe that have economic and ecological value are characterized by significant steadiness to contamination by heavy metals. On chernozem, dark-grey and grey soils insertion of lead salt on the basis of 1,000 mg/kg was not revealed in height and mass of the plants. The contamination of chernozem and dark-grey soil by cadmium (500 mg/kg) practically did not influence the mass of the plants and only the indexes of the growth reliably decreased. On grey soil with the cadmium insertion the plants were significantly suppressed.
- Increased generation of  $H_2O_2$  by test-culture can indicate the contamination of soils. Even if the mass of plants does not differ from control samples, this significant index revealed the influence of high dose of lead and cadmium on intracellular processes.
- Decrease of catalase activity of soil mainly revealed on samples contaminated by cadmium salt. Soil respiration was a stable

value, did not changed under soil contamination by lead; it reliably decreased only in chernozem on the background of cadmium salt insertion.

- The approved testing methods, using biological indexes, are recommended to the further usage under estimation of the ecological soil function deformation in forest-steppe landscapes of Perm Krai.

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