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SELENIUM IN THE SOILS AND AGRICULTURAL PLANTS IN THE SOUTH OF THE TYUMEN REGION

SUMMARY. This article presents the results of the research of selenium contents in soils and crops in the south of the Tyumen region. The patterns of selenium distribution in the soil of the region are discovered. Selenium is ascertained to concentrate in the humic and illuvial layers of soil. Selenium distribution in the top layer (0-20 cm) of the soil is examined. Also it is found that selenium content in the top layer of soil is primarily determined by the content of humic substances. The highest concentration of selenium is found on the outskirts of Roschino airport (0.413 mg/kg), perhaps due to the anthropogenic impact. Selenium content in plants is determined by its biological peculiarities and the content of this element in the soil and it is connected with such peculiarities of soil as acidity and the amount of humus. It has been determined that the large amount of selenium in oats found near Roschino airport is caused by high selenium content in the soil. It has been found that the content of selenium in the soils of the south of the Tyumen region is biogeochemically normal (0.2–0.7 mg/kg). Selenium content in the plants of the south of the Tyumen region is within the range from 0.182 mg/kg to 0.029 mg/kg that corresponds to its content in ecologically safe territories.

KEY WORDS. Selenium, soil, agricultural plants.

Selenium is a chemical element of the 16th group, 4th period of the Periodic system with atomic number 34 and symbol Se (Lat. Selenium). The vital necessity of this element for living organisms is observed only in animals when it occurs in Selenium-containing aminoacids, proteins, and in redox-enzymes. Selenium participates in such biological processes as methylation, hidrogen peroxide destruction and peroxy radicals, oxidation of sulfur compound and lipids.

Selenium is an indispensable element in animals' life. The scarcity of Selenium causes diseases as the white-muscle disease of sheeps and cattle, alimentary hepatitis of pigs, diathesis of cholera gallinarium. The nosogeny is probable when the dry weight of Selenium in fodder is 0.01-0.1 mg/kg, in soil – 0.05-0.1 mg/kg, in water – less than 10 mg/kg [1, 2, 3].

If the nutrient profile of an individual contains less than 20 mcg of Selenium per twenty-four hours, there are chances of contracting the Keshan disease, developing

a decrease in immunity, functional illness of liver, cataract, having unhealthy hair, skin and osteopathic diseases, subfertility augment.

However, a high concentration of Selenium is fairly toxic which is dangerous for living systems. Selenium is abundant in soil and environmental water of industrial regions which can appear naturally as well as due to the anthropogenic impact [4, 5].

The maximum acceptable limit of Selenium in fodder, according to the Russian standards, is 0.5–1.0 mg/kg in dry weight. The increased levels lead to poisoning symptoms in animals: anemia, heart trouble, extreme weight loss, deformity of hoofs and legs.

A high level of Selenium in humans provokes chronic fatigue, nail and hair disorders, epidermal disorders, dental enamel defects. It usually appears due to technogenic pollution. The daily demand in Selenium for humans equals to 0.02–0.20 mg [6]. This brief reference shows the significance of detection of Selenium in soils of agrocoenosis and in agricultural plants.

There are a lot of researches concerning Selenium, notably the fundamental research of [7]. A number of studies raise the question of Selenium health effect [8, 9, 10]. In West Siberia the occurrence of Selenium in soil-plant system is understudied. Particularly, a number of studies concerning this question are published in the Novosibirsk Region [11] and the Altai Territory [12, 13]. Consequently, similar researches are necessary in the Tyumen region, in the southern part of which agricultural activity has become a remarkable practice.

During the research* the topsoil (0-20 cm) from the south of the Tyumen Region (9 districts) was sampled. Four profile pits were formed to study Selenium partition in the soil profile as well as in the field-grown agricultural plants – wheat, barley, oats, and peas.

Topsoil samples' features are summarized in Table 1.

Table 1

Topsoil samples' features

District	Soil		Soil type	Soil subtype	Particle-size distribution
	zone	province			
1	2	3	4	5	6
Armizonskiy	forest-plain	West-Siberian forest-plain	chernozem	leached chernozem	medium-textured loam
Zavodoukovskiy	forest-plain	West-Siberian forest-plain	chernozem	leached chernozem	medium-textured loam
Isetskiy	forest-plain	West-Siberian forest-plain	alluvium	meadow	loam

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1	2	3	4	5	6
N-Tavdinskiy	southern taiga-forest	West-Siberian southern taiga- forest	grey forest soil	grey forest soil	medium-textured loam
Omutninskiy	forest-plain	West-Siberian forest-plain	chernozem	leached chernozem	medium-textured loam
Tyumenskiy	forest-plain	West-Siberian forest-plain	grey forest soil	grey forest soil	heavy loam
Tyumenskiy	forest-plain	West-Siberian forest-plain	chernozem	leached chernozem	medium-textured loam
Uporovskiy	forest-plain	West-Siberian forest-plain	grey forest soil	dark gray	medium-textured loam
Yarkovskiy	southern taiga-forest	West-Siberian southern taiga- forest	grey forest soil	cinereous	light loam

As follows from Table 1 the major part of the analyzed soils refers to the 2nd type of soil: leached chernozem and grey forest soil that is largely represented in the south of the Tyumen Region. There is one sample of alluvium from the Isetskiy District. The grey forest soils occupying an area of 889,000 ha are the second most widespread soils in the south of the region that is equivalent to 6.3% of the southern region's territory.

Table 2

Agrochemical indices of soil

Region	Humus, %	Labile soil nutrients		pH
		phosphorus	potassium	
		mg/gk		
Armizonskiy	7.7	60.5	109.0	5.2
Zavodoukovskiy	5.2	119.0	89.4	5.2
Isetskiy	5.8	100.7	87.1	5.3
N-Tavdinskiy	2.6	74.6	91.0	5.2
Omutninskiy	5.8	242.4	117.8	5.4
Tyumenskiy	3.8	226.6	80.7	5.3
Tyumenskiy	6.7	26.3	49.0	5.0
Tyumenskiy	5.9	256.8	70.7	4.7
Uporovskiy	2.6	37.9	92.7	5.0
Yarkovskiy	3.5	62.8	89.6	5.2

As it follows from Table 2 the grey forest soils have a high Ph level, some part of samples is low in humus and labile Phosphorus. Chernozems have environmental reaction close to neutral, some samples have a low level of labile Phosphorus and Potassium.

Selenium distribution in the soil profile is shown in Table 3.

Table 3

Selenium distribution in soil profile

District	Soil type	Depth, cm	Se, mg/kg
Armizonskiy	chernozem	0-20	0.217
		20-40	0.292
		40-60	0.246
		60-80	0.392
		80-100	0.288
Isetskiy	alluvium	0-20	0.248
		20-40	0.248
		40-60	0.224
		60-80	0.168
		80-100	0.224
Omutninskiy	gray forest soil	0-20	0.328
		20-40	0.22
		40-60	0.248
		60-80	0.3
		80-100	0.224
Nizhnetavdinskiy	gray forest soil	0-20	0.5
		20-40	0.34
		40-60	0.388
		60-80	0.304
		80-100	0.26

The topsoil of the Armizonskiy District has about 40 cm in depth. It has high concentration of Selenium that rises to 0.292 mg/kg. The highest concentration of Selenium is registered in humus and illuvial horizons. The illuvial horizon (the depth is 60-80 cm) has the highest concentration of Selenium – 0.392 mg/kg.

Since the Armizonskiy District is situated in forest-plain and plain zones that are characterized by low precipitation, Selenium is found in soils as selenates which is leached from humus horizon to illuvial horizon.

In the soil profile of the Isetskiy District concentration of Selenium falls down until the depth 80 cm where the concentration of Selenium is 0,168 mg/kg. The topsoil has 40 cm depth, Selenium is normally distributed in this part with the concentration value of 0.248 mg/kg. High Selenium content of humus horizon was influenced by the features of soil organic matter: to fix and to retain this element. The decrease in Selenium concentration in soil profile can be explained by natural fall of humus content in subsurface.

In the soil profile of the Omutninskiy District the highest level of Selenium is registered in humus horizon – 0.328 mg/kg. The concentration of this element considerably reduces to 0.220 mg/kg in the direction of leached horizon. In the illuvial horizon the increase in Selenium occurs gradually up to 0.300 mg/kg due to its fixation

by clay minerals. In the undesolum the Se concentration falls again and corresponds to 0.224 mg/kg.

The humus horizon of the Nizhne-Tavdinskiy District is also the most Selenium saturated one (0.500 mg/kg) due to fixation of this element by organic material. The illuvial horizon, that is limited to the depth of about 20-40 cm because of clay particles, has enhanced concentration of Selenium (0.388 mg/kg). Se concentration decreases to 0.260 mg/kg in undesolum.

Se concentration in topsoil (0-20 cm) and plants is shown in Table 4.

Table 4

Se concentration in topsoil (0-20 cm) and plants

District	Agricultural plants	Se content in soil mg/kg	Se content in plants, mg/kg
Uporovskiy	Wheat	0.179	0.035
N-Tavdinskiy	Wheat	0.194	0.038
Isetskiy	Wheat	0.333	0.033
Omutninskiy	Wheat	0.202	0.058
Armizonskiy	Wheat	0.291	0.083
Yarkovskiy	Oats	0.232	0.080
Roschino airport	Oats	0.413	0.182
Tyumenskiy	Barley	0.192	0.029
Zavodoukovskiy	Peas	0.288	0.074
M+m		0.179 -0.413	0.029- 0.182
Average grade		0.258	0.0622

In the soils of cultivated lands of the south of the Tyumen Region the average Se concentration equals to 0.258 mg/kg. The highest Se concentration was registered in the soils of the Roschino airport area – 0.413mg/kg that is the result of the anthropogenic impact. There is a relatively high Se content in the soils of the Isetskiy, Armizonskiy, Zavodoukovskiy Districts. On the basis of reported data it is possible to trace the dependence of Selenium concentration on the type of soils and to range the soils by the decrease in Se concentration: chernozems, alluvion – gray forest soil. Accumulation of Selenium in alluvion is obviously linked with the concentration in transported soil, and accumulation of Selenium in chernozems is linked with its concentration in organic material.

As a result of the research, it was found out that Selenium concentration in the plants of the south of the Tyumen Region is defined primarily by the level of this element in the soils and it is defined in a lesser degree by specific difference of plants. For example, the highest content of Selenium is registered in oats that are cultivated in the Roschino airport area – 0.182 mg/kg. The reason for this is obviously the anthropogenic impact. As a result of the anthropogenic impact the soils situated near the airport are rich in Selenium with the concentration of 0.413 mg/kg. Moreover, the lowest pH level in these soils that equals to 4.7 is found here, which can be also explained by pollution. The low pH level prevents from a still more intense absorption

of this element by plants whereas in sour lands Selenium is fixed by ferrum oxide forming insoluble compounds that are not influenced by flora. As it was mentioned before, the Selenium content in the soils of this territory has the highest value among the explored soils. At the same time large amplitude values of Selenium content in wheat, grown in different districts, have been recorded – 0.035-0.83 mg/kg, that can be explained mainly by the presence of Selenium in soils.

The wheat of the Armizonskiy District is rich in Selenium (0.083 mg/kg) due to high concentration of humic substances and rainless weather which is determined by the district location in forest-plain and plain zones. Since there is not plenty of water, Selenium concentration in soils reaches high levels in water-soluble compounds which are the most assimilable for plants. The high Selenium concentration in the soil of the Armizonskiy District (0.291 mg/kg) is conditioned by extremely high concentration of humus (7.7%) in comparison with humic acids' concentration in other explored districts.

The wheat of the Omutninskiy District has a sufficiently high level of Selenium content due to high concentration of humic substances (5.8 %) that enhances Selenium fixation, the content of which in soil equals to 0.202 mg/kg. In comparison with all explored soils the highest pH level is found here that is equal to 0.202 mg/kg 5, 4, which raises chances of Selenium compounds' creation that is the most assimilable for plants due to their high solubility.

The Nizhnetavdinskiy and Uporovskiy Districts have the lowest humus content in soil (2.8 %). That is why the Selenium concentration in soils is not high and is equal to 0.194 and 0.179 mg/kg respectively. The soils of these districts have the same type and refer to gray forest soils with middle loamy granulometric composition. The Selenium content in wheat has a similar range – 0.038 mg/kg in the Nizhnetavdinskiy District and 0.035 mg/kg in the Uporovskiy District.

The soils of the Isetskiy District having similar agrochemical indices with the soils of the Omutninskiy District have sufficiently high concentration of Selenium (0.058 mg/kg). At the same time the Selenium content in wheat of the Isetskiy District is lower than its content in the wheat of the Omutninskiy District and equals to 0.033 mg/kg. This difference can be explained by the peculiarities of soils' types. The soils of the Isetskiy District refer to alluvion but the soils of the Omutninskiy District refer to gray-forest type.

Selenium concentration in peas of the Zavodoukovskiy District equals to 0.074 mg/kg. This sufficiency high result can be explained by its plant's family having one of the most intense mechanisms for accumulating Selenium.

Oats grown in agricultural fields of the Yarkovskiy District have high Selenium concentration due to cultivation of this crop in soils with such particle-size distribution that is characterized by the lowest clay content among all the explored soils (light sandy loams). As a result, the Selenium is fixed less in these soils by clay minerals but it is more available for plants.

The barley of the Tyumen Region has the lowest Selenium concentration. The Selenium concentration in barley, that is grown on the gray forest soil with particle-

size distribution that is characterized as heavy loam, equals to 0.029 mg/kg. The reason for this is the low humus (3.8 %) and Selenium 0.192 mg/kg concentration in soil. Moreover, the heavy loamy soil content facilitates the fixation of Selenium presented in the soil due to fixation of this element by clay minerals.

The ecological assessment of Selenium concentration in the soils of the Tyumen region is complicated by the lack of safe standards that regulate the acceptable concentration limit for this element in the soils in Russia. In this regard it would be reasonable to refer to the limits of Selenium concentration that are given in scientific researches. Achieving the level of 2 mg/kg leads to a devastating effect on plants [7]. Since the maximum Selenium concentration in explored soils equals to 0.413 mg/kg the Selenium content in soils does not exceed the acceptable limits of safety regarding plants.

In Russia there is a limitation on Selenium content in grain and vegetables: acceptable residual quantity equals to 0.5 mg/kg in conditions of natural humidity. Comparison of Selenium concentration in agricultural plants of the south of the Tyumen region to this index provides a basis to state no exceeding of hygienic norms.

Therefore, on the basis of the conducted research it is possible to make the following conclusions:

1. The Selenium is concentrated in humus and illuvial horizons.
2. The Selenium concentration in surface soil layer (0-20cm) is determined by the content of humus.
3. The Selenium content in plants primarily depends on the content of humus in soils but in a smaller degree it depends on a type of soil.
4. It is possible to range the soils of the south of the Tyumen region regarding Se content in a descending order: chernozems – alluvions – gray forest.
5. The Selenium content of soils and agricultural plants of the south of the Tyumen Region is within health standards.

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