Heavy Metals in Soil & Plant System Under Conditions of the South of Tyumen Region

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Abstract. The article considers the problems of pollution with heavy metals (zinc, copper, cadmium and lead) of topsoil and plant products. The article contains the results analysis for laboratory trials of the researched components of the natural environment in the territory of the reference plots of the south of the Tyumen region. The authors assessed soil pollution and the samples of natural as well as perennial grasses, rape, oats, wheat, barley with heavy metals. A correlation between the content of zinc, copper, cadmium, lead in the soil and plants growing in it was determined. The article identifies the regions where the agrotechnical procedures directed to the decrease of toxicants’ negative influence on the life form should be considered.

1. Introduction

Among the pollutants accumulated in the soils, the biggest alarm is caused by heavy metals as the most ecologically dangerous and stable [1-4]. The speed of their removal by the natural leaching, erosion and deflation, consumption by the plants is hundreds times smaller than the speed of atmospheric ingress [5-8].

Heterogeneity of soil-geochemical environment to high variability of element concentration in the topsoil. Research of balance of microelements in agriculture shows that in the whole series of Russian regions and in the world microelements act as a factor determining the potential of productivity of the growing cultures [9-11].

Heavy metals in the soils undergo chemical transformations in the course of which their toxicity changes within very wide limits. The biggest danger is posed by moving forms of heavy metals, i.e., the most available for the life forms [12,13].

Many pollutants have affinity with physiologically important compounds and, consequently, the ability to disturb their participation in the processes of exchange in life forms. As a result, output of production of this plant decreases, its quality impairs, they become the source of pollution of food chains leading to man and herbivorous animals. Under high pollution level there is a threat of death of plant organisms, lethal outcomes for man and animals [14-18].

All the main cycles of migration of heavy metals in the biosphere begin in the soil, because it is in it that the mobilization of metals and the formation of various migration forms take place. Soil (its finely dispersed particles and organic matter) is the most important factor regulating the flow of heavy metals into plants [12,19].

In this regard, there is a need to assess the consequences of their accumulation in the soil and vegetation cover, which will allow to predict the accumulation of toxicants in plant products,
determine migration rates and normalize their ingress into trophic chains, develop and introduce new technologies to reduce the content of pollutants in agricultural products in order to produce normatively clean and good quality food for the population [13,20-22].

2. Subjects and Methods
The researches of correspondence to the established requirements of heavy metals content in the soil and production of crop growing took place in testing laboratory. Determination was carried out on the atomic absorption spectrum “MGA-915” according to GOST 30178-96 (lead, arsenic, cadmium) «RA-915» according to Mass fraction measurement procedure 04-46-2007 (mercury).

3. Results
In connection with the absence of regional background, practical interest for ecological assessment is obtained by the most frequently used concentrations of heavy metals in the soils of region, conditionally accepted as the background: zinc -1.39 mg/kg; copper – 0.49 mg/kg; cadmium – 0.06 mg/kg; lead – 1.48 mg/kg.

The results of researches, presented in the Table 1 have shown that content of heavy metals in the soils of south of Tumen region was within the limits of established MCL in all researched regions. The largest concentration of lead in soil is typical for Tumen region (village Reshetnikovo) and it made up 1 mg/kg under MCL 6.0 mg/kg and background value 1.48 mg/kg. Insignificant excess of background values was observed in Tobolsk and Tumen regions by 1.5-2.0 times respectfully, in Tumen region – cadmium, by 1.2 times. The soils of researched regions are copper-depleted which is an important microelement responsible for the main physiological processes taking place in plants.

Table 1. Content of active forms of heavy metals in plough layer of reference parts of south of Tumen region, mg/kg.

| Region                                | Pd   | Cu | Zn | Cd   |
|---------------------------------------|------|----|----|------|
| Zavodoukovskiy (town of Zavodoukovsk) | 0,26 | 0,14 | 0,65 | <0,02 |
| Isetskii (village Isetskoe)           | 0,49 | 0,14 | 0,80 | 0,03 |
| N-Tavdinskiy (Malyi Velizhany village) | 0,49 | 0,16 | 1,10 | <0,02 |
| Omutinskiy (village Novaya Derevnya)   | 0,43 | 0,13 | 0,75 | <0,02 |
| Tobolskiy (village Vorogushino)       | 0,92 | 0,16 | 1,80 | 0,04 |
| Tobolskiy (village Abalak)            | 0,90 | 0,17 | 2,05 | 0,06 |
| Tyumen (village Reshetnikovo)         | 1,00 | 0,16 | 2,75 | 0,07 |
| Uporovskiy (village Uporovo)          | 0,53 | 0,14 | 0,80 | <0,02 |
| Yarkovskiy (village Usalka)           | 0,66 | 0,14 | 1,70 | 0,02 |
| MCL, mg/kg of soil                    | 6,0  | 3,0  | 23,0 | 0,5-1 |
| Background, mg/kg                     | 1,48 | 0,49 | 1,39 | 0,06 |

Analyzing the content of heavy metals in plant products presented in the table 2, we can note that accumulation of heavy metals in the main and secondary production is nonuniform. Exceed of MCL of lead is revealed in almost all examined regions: in Zavodoukovskiy (town Zavodoukovsk) on the crops of oats - by 2.3 times, in Isetskii (v. Isetskoe) on the crops of natural grasses (green mass) – by 3.56 times, Nijnetavdinskiy (v. Malye Velizhanti) – on the crops of wheat – by 2.5 times, Omutinskiy (v. Novaya Derevnya) on the crops of cheat (green mass) – by 2.14 times, Tobolskiy (v. Vorogushino) on the crops of clover+Lucerne – by 1.16 times, Tumenskiy (v. Reshetnokovo) on the crops of natural grasses (green mass) – by 2.46 times and maximum in Yarkovskiy region (v. Usalka) on the crops of barley by 3.8 times.
Maximum copper content 9.1 and 8.13 mg/kg in plants is observed in Tobolskiy region of v. Abalak and v. Vorogushino respectfully under MCL 10 mg/kg. Zinc content was above the norm in Isetskii region (v. Isetskoe) on the crops of natural grasses (green mass) – by 4 times; in Tobolskiy (v. Vorogushino) – on the crops clover+Lucerne by 3.2 times; in Tumenskiy (v. Reshetnikova) on the crops of barley the concentration of zinc was on the level 1 of MCL. Concentration of cadmium exceeded threshold values by 1.5 times in Isetskii region on the crops of natural grasses (green mass) and Tobolsk (v. Vorogushino) on the crops clover+Lucerne; by 2.2 times in UporOVo (v. Uporovo) on the crops of rape; by 2.3 times in Tobolskiy region (v. Abalak) on the crops of natural grasses (green mass).

### Table 2. Results of analysis of plant samples on the reference parts of south of Tumen region, mg/kg.

| Region                        | Culture     | Products | Pb   | Cu   | Zn   | Cd   |
|-------------------------------|-------------|----------|------|------|------|------|
| Zavodoukovsky (town of        | oats        | main     | 1.16 | 0.92 | 25.0 | 0.08 |
| Zavodoukovsk)                 |             | second.  | 1.00 | 1.49 | 36.3 | 0.14 |
| Isetskii (village Isetskoe)   | Nat. grass  | main     | 1.78 | 4.33 | 200.0| 0.15 |
|                               | Gr. mass    |          |      |      |      |      |
| N-Tavdinskii (Malvi Velizhany| wheat       | main     | 1.26 | 1.38 | 41.3 | 0.08 |
| village)                      |             | second.  | 0.88 | 2.61 | 13.4 | 0.14 |
| Omutinskiy (village Novaya    | cheat (gr.  | main     | 1.07 | 5.54 | 21.3 | 0.05 |
| Derevnya)                     | mass)       |          |      |      |      |      |
| Tobolskiy (village Vorogushino| clover+Luc.| main     | 0.58 | 8.13 | 162.0| 0.15 |
| Tobolskiy (village of Abalak) | Nat. grass  | main     | 0.35 | 9.10 | 36.3 | 0.23 |
| Tyumen (village Reshetnikovo) | Nat. grass  | main     | 1.23 | 3.48 | 95.0 | 0.08 |
|                               | (gr. mass)  |          |      |      |      |      |
| Uporovskiy (village Uporovo)  | rape (gr.   | main     | 0.15 | 2.31 | 15.0 | 0.22 |
|                               | mass)       |          |      |      |      |      |
| Yarkovskiy (village Usalka)   | barley      | main     | 1.90 | 4.52 | 50.0 | 0.07 |
|                               |             | second.  | 2.76 | 3.80 | 26.3 | 0.30 |
| MCL, mg/kg of soil            |             | main     | 0.50 | 30.0 | 50.0 | 0.10 |
|                               |             | second.  | 5.00 | 30.0 | 50.0 | 0.30 |

For better visual perception of the data, graphs were drawn that reflect the dependence of the content of elements in plant products on their content in the soil (Figure 1-4). The strength of this dependency is determined by the correlation coefficient (r), dimensionless quantity measured within -1 < r <+1. If r = 0 there is no correlation relationship, if r = ± 1 the correlation is transformed into a functional one.

![Figure 1](image.png)
If the value of $r$ is positive, the relationship is direct, if it's negative the relationship is inverse. The degree of correlation under $r < 0.2$ is very weak or absent; under $0.2 < r < 0.3$ - weak; under $0.3 < r < 0.5$ - moderate; under $0.5 < r < 0.7$ - noticeable; under $r > 0.7$ it is strong.

The correlation coefficient depending on the content of lead in plants to its content in the soils was $r = -0.18299$ - the inverse relationship is very weak.

The correlation coefficient depending on the content of copper in plants to its content in the soils was $r = 0.469991$ - the direct moderate relationship.

The correlation coefficient depending on the content of zinc in plants to its content in the soils was $r = 0.165183$ - the direct relationship is very weak or absent.

The correlation coefficient depending on the content of cadmium in plants to its content in the soils was $r = -0.5889x + 0.1819$ - the inverse relationship is very weak or absent.
The correlation coefficient depending on the cadmium content in plants to its content in the soils was $r = -0.14791$ - the inverse relationship is very weak or absent.

4. Discussion
Thus, the results of the studies showed the absence of heavy metals beyond the maximum allowable concentrations in the soil, while the exceeding of the established standards of lead to 3.8 MPC, zinc to 4.0 MAC and cadmium to 2.3 MPC is observed in crop production of the researched areas. The highest values of accumulation of the element is typical for sowing of perennial and natural grasses.

The dependence of the content of lead, zinc and cadmium in plants on the content of these elements in the soil is not traced, or can be traced very poorly, as evidenced by correlation coefficients $r = -0.18299; R = 0.165183; R = -0.14791$, respectively. The moderate strength of the relationship between the content in soil and plants is observed in copper, the correlation coefficient in this case is $r = 0.469991$. Drainage of soils in areas with a mobile biogenic form of copper leads to minimal indicators of this element in plants growing on it.

In our opinion, the increased content of heavy metals in plants is connected with the high acidity of the soil of separate plots and easy accessibility of these elements for cultivated plants. The main measure of reducing the content of heavy metals in products can be liming of soils, which will favorably affect the agrochemical parameters of the soil, will reduce the mobility of metals and their accumulation in plants.

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