ENVIRONMENTAL ASSESSMENT OF THE TRACE ELEMENTS CONTENTIN THE AGROCOENOSIS OF CENTRAL CHERNOZEMREGIONS OF RUSSIA

Sergey V. Lukin¹, Sergey I. Smurov²

¹FGBU ASC “Belgorodsky"
²Belgorod State Agricultural University Named After V. Gorin

Corresponding Author: Sergey V. Lukin
E-mail: serg.lukin2010@yandex.ru

https://doi.org/10.26782/jmcms.spl.10/2020.06.00009

Abstract

The purpose of this study is to conduct an environmental assessment of zinc, copper and cobalt content in the agrocoenosis of forest-steppe zone of the Central Chernozemregions (CCRs) of Russia. During the investigations it was revealed that the average gross content of zinc is 37.1 mg/kg, copper - 13.8 mg/kg, and cobalt - 7.74 mg/kg in arable soils of the leached chernozem of forest-steppe zone of the CCRs. With increasing depth of the soil profile, the gross content of zinc and copper is significantly reduced, and cobalt gross content is not changed. According to the results of a continuous survey conducted in 2010-2014, it was found that 99.2% of the arable soils of Belgorod region are characterized by low provision of mobile forms of zinc, 96.8% of copper, and 94.3% of cobalt. According to the results of local monitoring, it was revealed that the content of mobile forms of cobalt and copper in the 81-100 cm layer is significantly lower than in the arable soil, and the zinc content does not change significantly. The exceeding MPC for mobile forms of trace elements was not observed. For the main products of winter wheat, pea, soybean, sunflower and corn, the biological absorption factors of zinc were in the range of 2.9-42.2, copper - 4.36-42.0, cobalt - 0.38-2.7, and for the by-products - 1.1-6.3, 1.8-4.63, and 0.16-1.54, respectively. The main source of trace elements entering the agrocoenosis of Belgorod region are organic fertilizers.

Keywords: Balance, percent abundance, trace elements, motile forms, cobalt, copper, zinc, chernozem.

I. Introduction

The trace elements include chemical elements, obligatory (binding) for plants and animals, the content of which is measured by values of the order of 0.01-0.00001%. Some authors attribute the elements contained in the dry mass of plants in
an amount of 0.01-0.001% to trace elements, and less than 0.0001% to ultra-trace elements [XIII, XIV]. In living organisms, the trace elements are part of enzymes, vitamins and other vital compounds [XVI, XXI, VI]. In domestic agrochemistry, the issue of trace elements has always been paid a lot of attention, which is quite justified. On the one hand, an inadequate provision of arable soils with mobile forms of trace elements can lead to a decrease in crop yields and deterioration in the quality of products. On the other hand, practically all trace elements with high content in the soil can become toxic to plants and accumulate in products in hazardous concentrations for animals and humans. Therefore, for basic trace elements, both low levels of soil in which it is necessary to use micro-fertilizers and maximum permissible concentrations (MPC) are established, beyond which it becomes necessary to carry out measures for soil detoxication [III, IV].

Given the high spatial variability in the trace elements distribution, the actual task is still to determine their content in the components of the biosphere in the context of specific regions, in particular the Central Chernozem regions of Russia, which include Belgorod, Voronezh, Kursk, Lipetsk, and Tambov regions. The program of state agroecological monitoring, which is carried out by the Agrochemical Service of Russia, provides for the study of the content of many trace elements, including zinc, copper and cobalt, in soils and agricultural plants, [V, VIII, XVII, XVIII, I, X]. The information obtained is the basis for the development of scientifically-based systems for the application of fertilizers in modern agricultural technologies.

The soils of many regions in Russia are not sufficiently provided with mobile forms of trace elements [X]. In Ulyanovsk region, 98.6% of arable soils have a low content of mobile forms of zinc [II]. The soils of the southern zone of Krasnoyarsk Territory are characterized by a low content of mobile forms of zinc (99.4%) and copper (58.2%) [XVI]. In the soils of Vologda region, zinc and cobalt are found in the first minimum among trace elements [XIX].

The purpose of this study is to conduct an environmental assessment of zinc, copper and cobalt content in the agrocoenosis of forest-steppe zone of the Central Chernozem regions (CCRs) of Russia.

II. Study Methods

The studies were carried out on the territory of Belgorod region, which includes a forest-steppe (about 75% of the area) and steppe soil zones. The area of arable soils is 1651 thous. ha.

The paper draws upon the solid agrochemical survey of arable soils. During the survey, a single soil sample, consisting of 20-40-point samples, was taken from the arable (0-25 cm) soil layer from an area of 20 ha. In addition, the data of local agroecological monitoring, which was conducted at twenty reference points of the forest-steppe zone, were used. They are a field or a plot of 4-40 ha. The soil cover of reference plots is represented by leached chernozem (Luvic Chernozems). The content of organic matter and pH values over the layers of soil profile are given in Table 1.
Table 1: The change in the content of organic matter and pH value over the layers of soil profile in the leached chernozem of reference objects

| Indicator       | Soil layers, cm | 0-20 | 21-40 | 41-60 | 61-80 | 81-100 |
|-----------------|-----------------|------|-------|-------|-------|--------|
| Organic matter, %|                 | 5.3  | 4.9   | 4.1   | 3.3   | 3.0    |
| pH_{KCl}        |                 | 5.3  | 5.5   | 6.0   | 6.4   | 6.7    |
| pH_{water}      |                 | 6.4  | 6.6   | 7.0   | 7.4   | 7.6    |

The content of trace elements in soils, plants and fertilizers was determined by the method of atomic emission spectrometry in accordance with M-MVI-80-2008. Determination of the content of zinc mobile forms was carried out according to GOST R 50686-94. Copper and cobalt mobile forms - according to GOST R 50683-94. To extract these elements from the soil, an acetate-ammonium buffer solution (AAB) with pH of 4.8 is used.

To characterize the selective absorption of chemical elements by agricultural crops, the biological absorption factor (BAF) is used, which is calculated as the ratio of element content in the plant ash to its content in the arable soil layer. The ash content in absolutely dry matter of sunflower seeds is 2.5%, stems and sunflower basket - 5.1, corn kernels - 1.5, cornstraw - 7.3, grains of winter wheat - 2.2, wheat straw - 6.9, soy beans - 5.2, soybean straw - 5.6, pea beans - 3.1, pea straw - 8.0, and steppe grasses (reserve "Belogorye" section "Yamskaya steppe") - 6.4%.

In statistical data processing, the confidence interval calculations for the average value ($\bar{x} \pm t_{0.05} s_{\bar{x}}$) and variation coefficient (V, %) are used.

III. Results and Discussion

According to A.P. Vinogradov (1957), percent abundances for the gross content of zinc, copper and cobalt in soils are equal to 50, 20, and 8.0 mg/kg, respectively [XX]. According to the modern estimates, in soils of the world the percent abundance of zinc is 70.0, copper - 38.9, and cobalt - 11.3 mg/kg [VI].

The approximate permissible concentrations (APCs) for heavy loam soils of pH_{KCl}< 5.5 are: for zinc – 110, copper - 66 mg/kg. The Russian normative documents do not regulate the gross content of cobalt in soils.

In the section "Yamskaya Steppe" of the reserve "Belogorye", the background gross content zinc is 45.7, copper - 14.3, and cobalt - 8.3 mg/kg in the layer of 10-20 cm leached chernozem. A decrease in the gross content of zinc and copper was found out by the depth of soil profile. The cobalt concentration did not change significantly (Table 2).
According to the results of local monitoring, it was revealed that gross average zinc content in the arable soil layers of leached chernozem is about 37.1 mg/kg, copper - 13.8 mg/kg, and cobalt - 7.74 mg/kg. With increasing depth of the soil profile, the total content of those metals was decreased significantly. Thus, zinc and copper are characterized by a biophil accumulation in the humus horizon. The gross content of zinc and copper in the 0-20 cm soil layer was higher than in the 81-100 cm layer by 1.2 times. No statistically significant changes in cobalt distribution over the depth of soil profile have been found (Table 3).

The content of all the elements studied in the leached chernozem was below the percent abundance and their concentrations in the reserve chernozem, and also substantially below the APC values.

According to the gross content of trace elements in the soils of arable land, it is difficult to determine their availability to plants. To assess the provision of crops with trace elements in the soil, the concentration of their mobile forms is determined. The background content of mobile forms of zinc, copper and cobalt in the 10-20 cm layer of virgin leached chernozem in the reserved section "Yamskaya Steppe" is 0.75, 0.19 and 0.14 mg/kg, respectively, which according to the modern scale for arable soils corresponds to low level.

### Table 2: The content of trace elements in the strong fat leached chernozem of section "Yamskaya Steppe" of the reserve "Belogorye", mg/kg

| Depth of horizon, cm | Sampling depth, cm | Gross content | The content of mobile forms |
|---------------------|-------------------|--------------|---------------------------|
|                     |                   | Zn  | Cu  | Co  | Zn  | Cu  | Co  |
| 7-45                | 10-20             | 45.7| 14.3| 8.6 | 0.75| 0.19| 0.14|
| 46-68               | 50-60             | 46.3| 13.0| 8.9 | 0.63| 0.15| 0.12|
| 69-90               | 70-80             | 46.6| 12.6| 8.7 | 0.47| 0.12| 0.09|
| 91-120              | 100-110           | 45.1| 12.0| 8.6 | 0.51| 0.19| 0.14|
| 121-165             | 140-150           | 44.1| 12.9| 8.5 | 0.63| 0.26| 0.13|
Table 3: Variable-based and statistical indicators of the trace elements content in leached chernozem, mg/kg

| Element | Indicator | Soil layer, cm |
|---------|-----------|----------------|
|         |           | 0-20 | 21-40 | 41-60 | 61-80 | 81-100 |
| Zn      | Gross content |       |       |       |       |       |
|         | $\bar{x} \pm t_0.05$ | 37.1±2.44 | 35.8±2.41 | 33.9±2.40 | 31.8±2.26 | 30.7±1.82 |
|         | lim | 26.7-51.2 | 24.0-40.5 | 20.6-43.3 | 19.7-38.3 | 20.5-36.1 |
|         | V, % | 14.1 | 14.4 | 15.1 | 15.2 | 12.7 |
| Zn      | The content of mobile forms |       |       |       |       |       |
|         | $\bar{x} \pm t_0.05$ | 0.74±0.06 | 0.73±0.06 | 0.68±0.07 | 0.63±0.07 | 0.63±0.08 |
|         | lim | 0.52-0.93 | 0.50-0.94 | 0.44-0.90 | 0.40-0.93 | 0.40-0.93 |
|         | V, % | 17.2 | 18.9 | 20.3 | 25.1 | 26.8 |
| Cu      | Gross content |       |       |       |       |       |
|         | $\bar{x} \pm t_0.05$ | 13.8±0.34 | 13.4±0.36 | 12.6±0.37 | 11.8±0.39 | 11.5±0.40 |
|         | lim | 12.7-14.8 | 12.0-14.7 | 10.8-13.9 | 10.4-13.0 | 10.3-13.1 |
|         | V, % | 5.3 | 5.8 | 6.2 | 7.1 | 7.5 |
| Cu      | The content of mobile forms |       |       |       |       |       |
|         | $\bar{x} \pm t_0.05$ | 7.74±0.22 | 7.68±0.21 | 7.49±0.33 | 7.30±0.38 | 7.24±0.44 |
|         | lim | 6.81-8.63 | 7.15-8.72 | 6.26-8.56 | 6.07-8.83 | 5.80-9.27 |
|         | V, % | 6.2 | 5.9 | 9.4 | 11.2 | 13.0 |
| Co      | Gross content |       |       |       |       |       |
|         | $\bar{x} \pm t_0.05$ | 7.1 | 9.1 | 7.8 | 12.5 | 12.4 |
|         | lim | 0.10-0.12 | 0.09-0.12 | 0.09-0.12 | 0.06-0.11 | 0.07-0.10 |
|         | V, % | 7.6 | 8.8 | 9.6 | 15.3 | 12.7 |

Copyright reserved © J. Mech. Cont. & Math. Sci. 
Sergey V. Lukin et al
According to the data of continuous agroecological survey, the content of mobile zinc in the soils of Belgorod region has declined in recent years. In 1990-1994, the weighted average value of indicator was 1.44, in 1995-1999 - 0.66, in 2000-2004 - 0.51, and in 2005-2009 - 0.5 mg/kg. Only in 2010-2014, there was a slight tendency to increase this indicator up to 0.52 mg/kg. Between the weighted average content of zinc mobile forms and the value of pH\textsubscript{KCl} by areas of the region, an inverse correlation dependence of the mean force (r=-0.64) was found. At increasing acidity, the content of zinc mobile forms is usually increased in soils.

In arable soils of the region, the weighted average content of copper mobile forms is 0.12, with fluctuations at areas in the range of 0.07-0.15 mg/kg. The weighted average content of cobalt mobile forms is 0.095 mg/kg, and the fluctuation by areas of the region - 0.068-0.131 mg/kg.

According to the results of a continuous survey conducted in 2010-2014, 99.2% of arable soils in the region are classified as low-content with zinc mobile forms (less than 2 mg/kg), 96.8% - with the content of copper mobile forms (less than 0.2 mg/kg), and 94.3% - with the content of cobalt mobile forms (less than 0.15 mg/kg).

Among the reasons for the low content of arable chernozems with copper and zinc mobile forms, at least two can be distinguished. First, the low background content of mobile forms of those elements in virgin soils. Second, their negative balance in agrocoenosis caused by the low level of use of organic fertilizers, which was observed in Belgorod region during 1995-2008[IX, XII]. For example, in 2000-2007 the intensity of zinc balance was 56.7%, copper - 36.0% [XII].

At reference objects, the content of zinc mobile forms from the gross amount of element in the arable soil layer was 2.0, copper - 0.8, and cobalt - 13.6%. With increasing depth of the soil profile of leached chernozem, a tendency was observed to decrease in the content of zinc mobile forms. The content of copper and cobalt mobile forms in the 81-100 cm layer was significantly lower than in the arable layer. One of the most significant parameters that determine the patterns of element mobile forms distribution along the soil profile is pH\textsubscript{KCl} value of the soil solution. In the leached chernozems, there is a regular change in the medium reaction with the depth. At a depth of 40-60 cm (at the boundary of horizons A and B), pH\textsubscript{KCl} value (5.5 to 6.0) changes drastically, which leads to a decrease in the mobility of most trace elements.

For agroecological normalization of the content of zinc mobile forms in soils, the maximum permissible concentration (MPC) level is set equal to 23, copper - 3.0, and cobalt - 5.0 mg/kg. Arable soils with exceeding of those MPCs have never been identified within the region.

The trace element composition of plants in a particular region is an important indicator of the environment quality. In the vegetation cover of the reserve "Belogorye", section "Yamskaya Steppe", represented by the steppe grass variety (up to 45 species per m2 with the predominance of feather grass, fescue, and prairie June
Among the surveyed cultivated plants, the greatest amounts of zinc are accumulated in sunflower seeds (39.1 mg/kg) and a grain of soybean (34.4 mg/kg), and in the kernel of corn its content was only 16.9 mg/kg. Zinc is mainly accumulated in the commodity part of the harvest of surveyed crops. The main products of winter wheat contained this metal 3.6 times, pea - 7.9, corn - 1.4, soybean - 5.6, sunflower - 3.3 times higher than the by-products.

Copper was most strongly accumulated in sunflower seeds (14.5 mg/kg) and grains of soybean (11.7 mg/kg), and the minimum amount of this element was found in kernels of corn (2.56 mg/kg). The main products of winter wheat contained copper 2.3 times, pea - 1.5, sunflower - 4.7, soybean - 3.3 times higher than the by-products. The content of copper in the straw of corn was 1.7 times higher than in the kernel.

The greatest amounts of cobalt were contained in the grain of winter wheat (0.46 mg/kg), and the smallest - in kernel of corn (0.044 mg/kg). The content of this trace element in the by-products of winter wheat, corn, soybean and sunflower was respectively 1.8, 3.4, 1.4, 1.1 times higher than in the main one. The content of cobalt in pea beans was 1.8 times higher than in its straw. The corn grain was characterized by the lowest content of all micro trace elements studied in comparison with the main products of other studied crops (Table 4).

Table 4: Variable-based and statistical indicators of the trace elements content in plants, mg/kg of absolutely dry matter

| Crop       |          | ±t0.05 | lim   | V, % |
|------------|----------|--------|-------|------|
| Winter wheat | Zn       |        |       |      |
| grain      | 28.1±2.0 | 22.8-37.0 | 15.4 |
| straw      | 7.75±1.74| 4.18-16.40| 48.0 |
| Pea        |          |        |       |      |
| beans      | 26.5±1.5 | 17.3-30.9 | 12.6 |
| straw      | 3.34±0.57| 1.30-5.51 | 38.5 |
| Corn       |          |        |       |      |
| grain      | 16.9±1.5 | 9.70-19.8 | 21.5 |
| straw      | 11.8±1.7 | 2.73-14.2 | 34.8 |
| Soybean    |          |        |       |      |
| beans      | 34.4±0.5 | 31.9-37.0 | 3.5  |
| straw      | 6.12±0.34| 5.39-9.10 | 12.8 |
| Plant          | Component | Value | Range          | PhA (%) |
|---------------|-----------|-------|----------------|---------|
| **Sunflower** | seeds     | 39.1±2.6 | 25.3-45.7     | 16.4    |
|                | stalks    | 11.9±1.2 | 5.33-14.30    | 24.7    |
| **Steppe grasses** |       | 27.7±0.36 | 26.5-28.7    | 2.8     |
| **Winter wheat** | grain    | 3.86±0.24 | 3.29-5.29     | 13.1    |
|                | straw     | 1.70±0.36 | 0.68-2.98     | 44.6    |
| **Pea**       | beans     | 3.85±0.33 | 1.88-4.79     | 19.6    |
|                | straw     | 2.55±0.31 | 1.09-4.00     | 27.5    |
| **Corn**      | grain     | 2.56±0.39 | 1.63-3.94     | 27.5    |
|                | straw     | 4.40±0.85 | 2.31-6.76     | 34.9    |
| **Soybean**   | beans     | 11.7±0.4  | 8.30-12.9     | 7.7     |
|                | straw     | 3.58±0.10 | 3.00-4.12     | 6.7     |
| **Sunflower** | seeds     | 14.5±1.6  | 6.02-17.1     | 27.4    |
|                | stalks    | 3.10±0.15 | 2.18-3.57     | 11.7    |
| **Steppe grasses** |       | 5.20±0.05 | 5.07-5.38    | 2.2     |
| **Winter wheat** | grain    | 0.46±0.08 | 0.20-0.79     | 33.2    |
|                | straw     | 0.82±0.15 | 0.56-1.13     | 33.3    |
| **Pea**       | beans     | 0.180±0.010 | 0.150-0.210 | 10.0    |
|                | straw     | 0.100±0.010 | 0.600-0.120 | 16.0    |
| **Corn**      | grain     | 0.044±0.002 | 0.032-0.057 | 13.4    |
|                | straw     | 0.148±0.013 | 0.090-0.200 | 22.1    |
| **Soybean**   | beans     | 0.140±0.010 | 0.100-0.190 | 17.2    |
|                | straw     | 0.190±0.025 | 0.080-0.250 | 30.5    |
The biological factor of zinc absorption by steppe grasses was 9.5, copper - 5.7, and cobalt - 0.2. The values of zinc BAF for the main products of studied agricultural crops were in the range of 17.8-42.2, copper - 9.0-42.0, and for the by-products - 1.1-6.3 and 1.8-4.63, respectively. These trace elements can be attributed to the group of elements accumulated in the plants, since the BAF value was above 1. The cobalt BAF values for peas, soybeans, corn, and sunflower were in the range of 0.16-0.75, which allows us to classify this metal as a group of weakly accumulated elements. The winter wheat is characterized by a relatively high BAF of cobalt: 2.7 – for grain, and 1.5 for straw (Table 5).

Table 5: Biological factors of trace elements absorption by various crops, (mg/kg of ash) / (mg/kg of soil)

| Crop         | Zn   | Cu   | Co   |
|--------------|------|------|------|
| Winter wheat |      |      |      |
| grain        | 34.4 | 12.7 | 2.70 |
| straw        | 3.0  | 1.8  | 1.54 |
| Pea          |      |      |      |
| bean         | 23.0 | 9.0  | 0.75 |
| straw        | 1.1  | 2.30 | 0.16 |
| Corn         |      |      |      |
| grain        | 30.4 | 12.4 | 0.38 |
| straw        | 4.4  | 4.36 | 0.26 |
| Soybean      |      |      |      |
| bean         | 17.8 | 16.3 | 0.35 |
| straw        | 2.9  | 4.63 | 0.44 |
| Sunflower    |      |      |      |
| seeds        | 42.2 | 42.0 | 0.72 |
| stalks       | 6.3  | 4.41 | 0.40 |
| Steppe grasses |     |      |      |
|              | 9.5  | 5.70 | 0.20 |

In accordance with the current Technical Regulations of the Customs Union "On the safety of grain" (TR CU 015/2011), the content of trace elements in grains and sunflower seeds used for food and feed purposes is not regulated. The content of...
trace elements in the by-products of crops on the average did not exceed the maximum permissible concentrations (MPCs) established for the coarse fodder.

One of the main sources of trace elements supply to agrocoenosisis traditionally the organic fertilizers [XI, VII]. A certain amount of trace elements is supplied at liming acidic soils with ameliorant defecate, which is very widely used in the CCRs.

The organic fertilizers used in Belgorod region differ greatly in content and ratio of major and trace elements. To make organic fertilizer with a nitrogen dose of 100 kg/ha, it is required approximately 3.3 t of straw and litter compost, 13.2 t of cattle manure or 47.6 t of manureliquid. Together with this amount of organic fertilizers, the following will be supplied into the soil, respectively: zinc - 888, 440 and 2632 g/ha, copper - 498, 132, 392 g/ha, and cobalt - 5.8, 9.2, 6.9 g/ha (Table 6).

The most common mineral fertilizers contain a few trace elements. The content of zinc, copper and cobalt in ammonium nitrate is 5.93, 0.36, and 0.26 mg/kg, respectively, and in the nitrogen-phosphorus-potassium fertilizer - 4.29, 1.71, and 0.18 mg/kg.

Table 6: Variable-based and statistical indicators of the trace elements content in organic fertilizers and defecate, mg/kg

| Indicator | Zn     | Cu     | Co       |
|-----------|--------|--------|----------|
| Manure liquid (2.22% of dry matter) | 55.3±10.4 | 8.24±1.54 | 0.145±0.02 |
| lim       | 16.7-93.7 | 3.96-15.26 | 0.090-0.260 |
| V, %      | 40.1   | 40.0   | 29.7     |
| Straw and litter compost (56% of dry matter) | 269±46.6 | 151±23.6 | 1.76±0.26 |
| lim       | 143-485 | 50.2-210 | 0.850-2.85 |
| V, %      | 37.1   | 33.5   | 31.3     |
| Cattle manure (44% of dry matter) | 33.3±7.5 | 10.0±1.8 | 0.697±0.152 |
| lim       | 15.2-62.3 | 4.40-19.6 | 0.149-1.190 |
| V, %      | 48.2   | 37.7   | 46.8     |
Defecate (87% of dry matter)

|          | Defecate (87% of dry matter) |
|----------|-----------------------------|
| $\bar{x} \pm t_{0.05} \bar{x}$ | 30.9±7.3 | 8.40±2.4 | 3.00±0.7 |
| lim      | 20.7-51.4                   | 2.10-12.5 | 0.760-5.48 |
| V, %     | 31.4                        | 40.1      | 49.7     |

On average for the years 2010-2013, the application rate of organic fertilizers in Belgorod region was 3.95 t/ha, and 90.3% of the total amount of zinc, 92.1% of copper, 72.8% of cobalt was supplied to agrocoenosis with it. The balance intensity value (the ratio of incoming balance sheet to expenditure one, expressed as a percentage) of zinc was 98.0, copper - 111.4, and cobalt - 23.7% [VII].

IV. Conclusion

Thus, it was revealed that the average gross content of zinc is 37.1, copper - 13.8, cobalt - 7.74 mg/kg in arable soils of the leached chernozem of forest-steppe zone of the CCRs. With increasing depth of the soil profile, the gross content of zinc and copper is significantly reduced, and cobalt gross content is not changed. According to the results of a continuous survey conducted in 2010-2014, it was found that 99.2% of the arable soils of Belgorod region are characterized by low provision of mobile forms of zinc, 96.8% of copper, and 94.3% of cobalt. According to the results of local monitoring, it was revealed that the content of mobile forms of cobalt and copper in the 81-100 cm layer is significantly lower than in the arable soil, and the zinc content does not change significantly. The exceeding MPC for mobile forms of trace elements was not observed. For the main products of winter wheat, pea, soybean, sunflower and corn, the biological absorption factors of zinc were in the range of 2.9-42.2, copper - 4.36-42.0, cobalt - 0.38-2.7, and for the by-products - 1.1-6.3, 1.8-4.63, and 0.16-1.54, respectively. The main source of trace elements entering the agrocoenosis of Belgorod region are organic fertilizers.

References

I. Chekmarev P.A., Sidorov A.V., and Moiseev A.A. (2017) Fertility dynamics of arable soils in the Republic of Mordovia // Achievements of the AIC science and technology, Vol. 31, No. 1, pp. 4-9.

II. Cherkasov E.A., Kulikova A.Kh., and Lobachev D.A. (2017) Fertility dynamics of soils in Ulyanovsk region for years 1965-2015. // Achievements of the AIC science and technology, No. 4, pp. 10-17.
III. Chernykh N.N., and Sidorenko S.N. (2003) Environmental monitoring of toxicants in the biosphere. M.: Publishing House of the Peoples' Friendship University, 430 p.

IV. Chetverikova N.S. (2013) Environmental assessment of the impact of intensive agricultural activities in the state of agro-ecosystems in the forest-steppe zone of the Central Chernozem region: thesis for a doctor's degree in Biological Sciences. M.: Russian State Agrarian University - Moscow Timiryazev Agricultural Academy, 22 p.

V. Goryanikov Yu.V., Kalakhanova V.Yu., and Tamova E.V. (2017) Agro-chemical and ecological-toxicological condition of soils, the effectiveness of chemicals using in the Karachay-Cherkess Republic // Achievements of the AIC science and technology, Vol. 31, No. 8, pp. 23-27.

VI. Kabata-Pendias A. Trace Elements in Soils and Plants. – 2011, 41 p.

VII. Khizhnyak R.M. (2016) Environmental assessment of the content of trace elements (Zn, Cu, Co, Mo, Cr, Ni) in Agroecosystems of forest-steppe zone, southwestern part of the CCRs: thesis for a doctor's degree in Biological Sciences. M.: Russian State Agrarian University - Moscow Timiryazev Agricultural Academy, 24 p.

VIII. Konarbaeva G.A., and Yakimenko V.N. (2017) Changes in the content of heavy metals in agrocenosis at different intensities of mineral fertilizers use // Achievements of the AIC science and technology, Vol. 31, No. 10, pp. 44-48.

IX. Korneiko N.I. (2008) Agroecological assessment of the change in the main indicators of the fertility of arable soils of the Central Chernozem Region at the long-term agricultural use: thesis for a doctor's degree in Agricultural Sciences. Kursk: Kursk State Agricultural Academy named after Professor I.I. Ivanov, 22 p.

X. Lukin S.V. Dynamics of the Agrochemical Fertility Parameters of Arable Soils in the Southwestern Region of Central Chernozem Zone of Russia // Eurasian Soil Science, 2017, Vol. 50, No. 11, pp. 1323–1331. DOI: 10.1134/S1064229317110096.

XI. Lukin S.V., and Selyukova S.V. (2016) Agroecological assessment of the effect of organic fertilizers on the trace element based composition of soils // Achievements of the AIC science and technology, No. 12, pp. 61-65.

XII. Melentsova S.V. (2007) Agroecological assessment of the content of chemical elements (S, Zn, Mn, Cu, Cd, Pb) in soils of the forest-steppe and steppe zones (the case of Belgorod region): thesis for a doctor's degree in Biol. Sciences. M.: Russian State Agrarian University - Moscow Timiryazev Agricultural Academy, 22 p.

Copyright reserved © J. Mech. Cont. & Math. Sci.

Sergey V. Lukin et al
XIII. PeiveYa.V. (1960) Trace elements and enzymes. Riga: Publishing House of the Latvian SSR Academy of Sciences, 136 p.

XIV. RinkisG.Ya., and Nollendorf V.F. (1989) Balanced nutrition of plants with major and trace elements. Riga: Znanie, 196 p.

XV. Sergeev A.P., LipatnikovaT.Ya., and Goreeva E.V. (2017) The fertility condition of arable soils in the southern zone of the Krasnoyarsk Territory // Achievements of the AIC science and technology, No. 4, pp. 17-21.

XVI. SheudzhenA.Kh., Onishchenko L.M., and Prokopenko V.V. (2005) Fertilizers, ground soils and plant growth regulators. Maikop: State Unitary Enterprise of the Republic Adygea Republican Publishing and Printing Company "ADYGEA", 404 p.

XVII. Soil cover and agrochemical characteristics of soils in Arkhangelsk region / G.E. Antropova, E.M. Romanov, E.A. Rokhina, E.N. Nakvasina // Achievements of the AIC science and technology. 2017, Vol. 31, No. 2. pp. 5-10.

XVIII. Unkanzhinov G.D., Boldyreva L.A., and Tertyshnaya A.G. (2017) Agrochemical characteristics of arable soils and the use of fertilizers in the Republic of Kalmykia // Achievements of the AIC science and technology, Vol. 31, No. 1, pp. 10-15.

XIX. Vedeneeva N.V., Rogov V.A., Nakleischikova L.V., and Naliukhin A.N. (2016) Soil cover and agrochemical characteristics of arable soils in Vologda region. Dynamics of soil fertility by cycles of agrochemical survey // Achievements of the AIC science and technology, No. 8, pp. 22-27.

XX. Vinogradov A.P. (1957) Geochemistry of rare and trace chemical elements in soils. M.: Publishing House of the USSR Academy of Sciences, 238 p.

XXI. Yagodin B.A., and Udelnova T.M. (1993) Zinc in the life of plants, animals and humans // Advances in modern Biology, Vol. 113, No. 2, pp. 176-189.