

Conference Paper

Trace Element Content in the Soils of the Forest-Steppe of Western Siberia

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Abstract

This research is based on local monitoring in 1994–2018 on reference plots of agricultural lands and materials of a large-scale agrochemical survey. The research examined the soils of the forest-steppe zone of the Omsk Region: ordinary chernozem low-power low-humus heavy loamy soil; meadow-chernozem medium-thick medium-humus heavy loamy soil; and solonetz meadow chernozemic deep low humus clay soil. It was found that almost the entire surveyed area of arable land in the forest-steppe zone of the Omsk Irtysh Land (98.1 %) had low mobile zinc availability with an average level of 0.85 mg/kg. 41.1% of arable land had low mobile manganese availability, 41.3% had medium and 17.6% had high availability; the weighted average was 13.0 mg/kg. Most of the arable land was characterized by a low degree of mobile copper content security (81.2%), while 18.3% of the land had soil with an average content, and only 0.5% of the land had high mobile copper content. The average concentration was 20.0 mg/kg. The soil levels of mobile molybdenum availability were as follows: 71.6% of land had medium availability, 26.5% had high, and only 1.9% had low; the weighted average concentration was 0.20 mg/kg. All soils had a high degree of mobile forms of boron, while the weighted average was 2.69 mg/kg of soil. 67.8% of the area had low mobile cobalt availability, 31.6% had average availability, and 0.5 % had high availability, with an average concentration of 0.16 mg/kg in the zone. The reference plots did not differ in terms of their content of mobile zinc, copper, and cobalt, ordinary chernozems, meadow chernozem soils, and deep solonetz. Movable connections of molybdenum, manganese, and boron in ordinary chernozem were lower than in meadow chernozem soil, and the maximum ones were observed in solonetz meadow chernozemic deep.

Keywords: trace elements, content, soil, survey, dynamics, Omsk region

1. Introduction

In the Omsk region, as in all constituent entities of the Russian Federation, the agrochemical service conducts large-scale agrochemical monitoring of soil capabilities, including a survey for the content of trace elements [1–3].

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The agrochemical survey of arable land in the forest-steppe zone of the Omsk Irtysh Land makes it possible to analyze and assess the reserves of available forms of such trace elements like Zn, Mn, Cu, Mo, B, Co [4,5,6].

Trace elements are important for plant life, acting as a mandatory factor for increasing effective soil fertility and improving the size and quality of crop yields of agricultural crops [7,8,9]. Trace elements in combination with macronutrients are necessary to create an optimal ratio of chemical elements of plant nutrition in the soil, which causes their normal growth and development, and also improves stability to external impact factors. At the same time, the availability of agricultural crops with nutrients, including trace elements, is determined mainly by their reserves in soils [10–12].

The subject of studying the trace element composition of soils in the forest-steppe zone of the Omsk region was:

- 3.1. ordinary chernozem;
- 3.2. meadow-chernozem soil
- 3.3. meadow chernozemic solonetz

The research purpose is to identify patterns of changes in the content of mobile trace elements in arable soils of the forest-steppe of the Omsk region.

2. Methods and Equipment

The research is based on the results of local monitoring in 1994-2018 on reference plots of agricultural lands. The objects of research were the soils of the forest-steppe zone of the Omsk Region: ordinary chernozem low-power low-humus heavy loamy soil (JV Druzhba, Gorky district); meadow-chernozem medium-thick medium-humus heavy loamy soil (APC Pushkinsky in the Omsk region); solonetz meadow chernozemic deep low humus clay soil (Yuryevskoye LLC, Kormilovsky district). We also used materials of a large-scale agrochemical survey conducted by the Omsk Agrochemical Service Center and the Tarskaya Agrochemical Service Station. Moving forms of trace elements in the soil were determined by the atomic absorption method (extract: acetate-ammonium buffer pH 4.8).

3. Results

The agrochemical survey of arable land in the forest-steppe zone of the Omsk Irtysh Land makes it possible to analyze and assess the reserves of available forms of such trace elements like Zn, Mn, Cu, Mo, B, Co [table 01, 02].

TABLE 1: Area distribution of arable land in the forest-steppe zone of the Omsk Irtysh Land by the availability of trace elements (as of 31.12.2018)

| Element | Surveyed area, thousand ha | Level of security | | | | | |
|------------------------|----------------------------|-------------------|------|-------------|------|-------------|-------|
| | | low | | average | | high | |
| | | thousand ha | % | thousand ha | % | thousand ha | % |
| Zinc | 934.5 | 899.1 | 96.2 | 35.3 | 3.8 | 0.1 | 0.0 |
| Manganese | 934.5 | 267.4 | 28.6 | 481.5 | 51.5 | 185.5 | 19.9 |
| Copper | 934.5 | 749.8 | 80.2 | 175.8 | 18.8 | 9.0 | 1.0 |
| Molybdenum | 451.9 | 8.8 | 1.9 | 282.4 | 62.5 | 160.7 | 35.6 |
| Boron | 451.9 | 0.0 | 0.0 | 0.0 | 0.0 | 451.9 | 100.0 |
| Cobalt | 934.5 | 617.2 | 66.0 | 309.0 | 33.1 | 8.3 | 0.9 |
| Southern forest-steppe | | | | | | | |
| Zinc | 1093.4 | 1090.7 | 99.8 | 2.5 | 0.2 | 0.2 | 0.0 |
| Manganese | 1093.4 | 566.5 | 51.8 | 356.0 | 32.6 | 170.9 | 15.6 |
| Copper | 1093.4 | 897.8 | 82.1 | 194.6 | 17.8 | 1.0 | 0.1 |
| Molybdenum | 1093.4 | 21.3 | 1.9 | 823.7 | 75.3 | 248.4 | 22.7 |
| Boron | 1093.4 | 0.0 | 0.0 | 0.0 | 0.0 | 1093.4 | 100.0 |
| Cobalt | 1093.4 | 758.6 | 69.4 | 332.2 | 30.4 | 2.6 | 0.2 |
| forest-steppe | | | | | | | |
| Zinc | 2027.9 | 1989.8 | 98.1 | 37.8 | 1.9 | 0.3 | 0.0 |
| Manganese | 2027.9 | 833.9 | 41.1 | 837.5 | 41.3 | 356.5 | 17.6 |
| Copper | 2027.9 | 1647.6 | 81.2 | 370.3 | 18.3 | 10.0 | 0.5 |
| Molybdenum | 1545.3 | 30.1 | 1.9 | 1106.1 | 71.6 | 409.1 | 26.5 |
| Boron | 1545.3 | 0.0 | 0.0 | 0.0 | 0.0 | 1545.3 | 100.0 |
| Cobalt | 2027.9 | 1375.8 | 67.8 | 641.2 | 31.6 | 10.9 | 0.5 |

TABLE 2: Content of mobile forms of trace elements in the soils of the forest-steppe zone of the Omsk Irtysh Land, mg/kg of soil (as of 31.12.2018)

| No. | Content | Zn | Mn | Cu | Mo | B | Co |
|-----|---------|-----------|-----------|-----------|-----------|-----------|-----------|
| 1 | Min | 0.04-0.10 | 1.70-2.00 | 0.06-0.07 | 0.04-0.07 | 0.88-1.01 | 0.04-0.05 |
| 2 | Max | 7.10-7.64 | 110-113 | 0.72-0.80 | 1.00-1.60 | 20.0-20.3 | 1.70-1.90 |
| 3 | Average | 0.85 | 13.00 | 0.20 | 0.20 | 2.69 | 0.16 |

It is established that almost the entire surveyed area of arable land (1989.8 thousand ha, 98.1 %) has a low degree of mobile zinc availability, the average content is 37.8 thousand ha (1.9 %), and the high content is only 0.3 thousand ha. At the same time, the

concentration of mobile zinc in the soil varies from 0.04-0.1 mg/kg to 7.1-7.64 mg/kg of soil, with an average level of 0.85 mg/kg in the zone.

The availability of mobile manganese in soils varies from low to high: 833.9 thousand ha of arable land (41.1 %) is low, 837.5 thousand ha (41.3 %) is medium, and 356.5 thousand ha (17.6 %) is high. This indicator ranges from 1.7-2.0 mg/kg to 110.0-112.9 mg/kg of soil, and the weighted average is 13.0 mg/kg.

According to the mobile copper content, most of the arable land area of the forest-steppe zone of the Omsk Irtysh Land is characterized by a low degree of security (1647.6 thousand ha, 81.2 % of the surveyed arable land area). Soils with an average content of this element occupy 18.3% of the surveyed arable land (370.3 thousand ha), and with a high content – only 0.5 % of arable land (10 thousand ha), the average concentration is 20.0 mg/kg.

The soils of the forest-steppe zone are characterized mainly by an average and high level of mobile molybdenum availability. The surveyed arable land area 1545.3 thousand ha, 1106.1 thousand ha or 71.6 % is medium, 409.1 thousand ha (26.5 %) is high, and only 30.1 thousand ha (1.9 %) is low. The weighted average concentration is 0.20 mg/kg of soil.

According to the content of boron mobile forms, all soils are characterized by a high degree of security. It ranges from 0.88-1.01 mg/kg to 20.00-20.30 mg/kg of soil, with a weighted average of 2.69 mg/kg of soil.

The low level of mobile cobalt availability is 1375.8 thousand ha or 67.8% of the surveyed area, the average – 641.2 thousand ha (31.6 %), and the high – 10.9 thousand ha (0.5 %). Its concentration in the arable land soils in the forest-steppe zone varies from 0.04 to 1.7-1.9 mg/kg and the average for the zone is 0.16 mg/kg.

The study of the results of changes revealed the dependence of trace element reserves on soil types and their zonal location. The soil cover of the forest-steppe zone of the Omsk Irtysh Land is particularly diverse, which in combination with climatic conditions determines the nature and direction of biochemical transformations of trace elements in the soil, their mobility degree, and availability to plants. Therefore, to regulate the optimal nutrition of agricultural crops with trace elements, it is necessary to have quantitative characteristics of the reserves of available substances in the soil. According to long-term agrochemical monitoring of reference plots reveal the dynamics of the changes of trace element content in the main types of agricultural soil forest-steppe zone of Omsk Irtysh Land (table. 03).

The share of mobile zinc compounds in the arable soil horizon was at a low level of security, but analysis of the results of the multi-year cycle of observations shows

a gradual increase in concentration in the soil. In general, the content of mobile zinc has increased: in ordinary chernozem it increased from 0.43 (1994-1998) to 0.48 mg/kg of soil (2014-2018); in meadow-chernozem soil - from 0.44 to 0.59 mg/kg of soil; in deep solonetz - from 0.36 to 0.41 mg/kg of soil. This may result from the decrease in mobile phosphorous content in these soils due to the lack of fertiliser application. And according to some scientists, the increase in the content of mobile phosphorus has a negative impact on the concentration of mobile zinc in the soil and, conversely, because of the formation of insoluble zinc compounds in the presence of phosphates [13–15].

TABLE 3: Content of mobile forms of trace elements in the arable soil horizon of reference areas of the forest-steppe zone of the Omsk Irtysh Land, mg/kg of soil (1994-2018)

| Years of research | Zn | Mn | Cu | Mo | B | Co |
|---|------|-------|------|------|------|------|
| Ordinary low-power low-humus chernozem | | | | | | |
| 1994-1998 | 0.43 | 7.06 | 0.13 | 0.17 | 2.12 | 0.13 |
| 1999-2003 | 0.39 | 7.20 | 0.15 | 0.19 | 2.14 | 0.13 |
| 2004-2008 | 0.37 | 7.13 | 0.12 | 0.18 | 2.16 | 0.11 |
| 2009-2013 | 0.49 | 7.02 | 0.13 | 0.18 | 2.12 | 0.11 |
| 2014-2018 | 0.48 | 7.01 | 0.13 | 0.17 | 2.11 | 0.12 |
| Average | 0.43 | 7.08 | 0.13 | 0.18 | 2.13 | 0.11 |
| Meadow-chernozem medium-power medium humus soil | | | | | | |
| 1994-1998 | 0.44 | 8.13 | 0.13 | 0.23 | 2.41 | 0.12 |
| 1999-2003 | 0.42 | 8.10 | 0.13 | 0.23 | 2.40 | 0.10 |
| 2004-2008 | 0.39 | 8.15 | 0.14 | 0.25 | 2.42 | 0.10 |
| 2009-2013 | 0.50 | 8.11 | 0.12 | 0.26 | 2.38 | 0.11 |
| 2014-2018 | 0.59 | 8.17 | 0.11 | 0.24 | 2.38 | 0.10 |
| Average | 0.47 | 8.13 | 0.13 | 0.24 | 2.40 | 0.10 |
| Meadow chernozemic deep low humus solonetz | | | | | | |
| 1994-1998 | 0.36 | 10.71 | 0.13 | 0.29 | 3.97 | 0.09 |
| 1999-2003 | 0.32 | 10.68 | 0.14 | 0.30 | 3.98 | 0.10 |
| 2004-2008 | 0.32 | 10.65 | 0.12 | 0.29 | 3.96 | 0.12 |
| 2009-2013 | 0.40 | 10.56 | 0.11 | 0.29 | 4.03 | 0.11 |
| 2014-2018 | 0.41 | 10.54 | 0.14 | 0.27 | 4.02 | 0.13 |
| Average | 0.36 | 10.63 | 0.13 | 0.29 | 3.99 | 0.11 |

The level of mobile manganese is low in all types of soils. And the highest concentrations were detected in meadow-chernozem solonetz (10.54-10.71 mg/kg). In the ordinary chernozem and meadow-chernozem soils, its concentration was slightly lower and made 7.01-7.20 mg/kg and 8.10-8.17 mg/kg of soil respectively.

In terms of the copper content, ordinary chernozems, meadow chernozem soils, and deep solonetz did not differ in reference plots. Over 25 years of research their concentration almost did not change and was in the range of 0.11-0.14 mg/kg of soil.

One feature of molybdenum geochemistry in soils is its higher mobility in an alkaline environment. Movable compounds of molybdenum in ordinary chernozem varied at the level of 0.17-0.19 mg/kg of soil that corresponds to their average concentration in soil. Meadow-chernozem soils (0.23-0.26 mg/kg of soil) and meadow-chernozem deep solonetz (0.27-0.30) had a higher element content.

Monitoring observations show that all soils in the forest-steppe zone of Omsk Irtysk Land have a high level of pine forest content, which we noted earlier, and this is largely due to soil-forming rocks (Azarenko Yu.A. (2019). Over 25 years of research it remained almost unchanged, in reference plots the average level of boron was 2.11-2.16 mg/kg of soil in ordinary chernozems during the monitoring period. The level of accumulating mobile boron in meadow-chernozem soils is significantly higher, which is explained by the degree of salinization, and was 2.38-2.42 mg/kg of soil.

Distribution of boron in salts is due to the specifics of their geochemical conditions and the prevalence of accumulation processes in conditions of weak washing of the profile, intense physical evaporation of moisture from the soil surface and the inflow of soluble salts and compounds of trace element with the flow from the surrounding areas. The intensity of developing the solonetz process influences the content and distribution of boron in solonetz. As a rule, the greatest accumulation of boron is observed in the arable horizon of solonetz soils. In deep solonetz the boron concentration was 3.96-4.03 mg/kg of soil.

The concentration of cobalt did not depend on the type of soil, as in all studied soils the content of cobalt was at a low level and amounted to 0.09-0.13 mg/kg of soil.

4. Discussion

Some trace elements, such as copper and zinc, have a strong impact on plant development and product quality, and their excess may have toxic effects on human and animal bodies. Therefore, these elements also belong to heavy metals [11]. In the studied soils the concentration of mobile forms of copper and zinc is low and does not exceed MAC (which is 3 and 23 mg/kg, respectively). Therefore, it does not cause deterioration of the quality of the natural environment and the received agricultural products.

5. Conclusion

Thus, the content of mobile forms of trace elements in soils of the forest-steppe zone of the Omsk Irtysk Land depends on their properties and different soil and geochemical

conditions. The studied soils have the necessary level for optimal development of agricultural crops only by the reserves of mobile molybdenum and boron. Other micronutrients have a deficiency that needs to be replenished by using micronutrient fertilisers to produce a stable crop and high-quality agricultural products. In terms of the content of mobile zinc, copper, and cobalt, ordinary chernozems, meadow chernozem soils, and deep solonetz did not differ in reference plots. Movable connections of molybdenum, manganese, and boron in ordinary chernozem are lower than in meadow chernozem soil, and the maximum ones were observed in solonetz meadow chernozemic deep.

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Conflict of Interest

The authors have no conflict of interest to declare.

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