Rationing of the Nickel Content in Soils of the Rainfed Agricultural Landscapes of the Rostov Region

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Abstract. At present, the problem of conducting a reliable environmental and geochemical assessment of the territory is becoming most acute, which cannot be carried out without the use of reliable and scientifically sound soil pollution criteria. This article used the method of determining regional maximum permissible concentrations (RMPC), developed by V E Zakrutkin et al., which allows to develop reliable, logically corresponding to the local geochemical background, standards and taking into account the features of bioaccumulation of trace elements by various plant crops. As a result of the work, RMPC of nickel content in chernozems and chestnut soils, which are the most common types of soils in the Rostov region, were obtained.

1. Introduction

To date, there is an urgent need to develop methods for regulating the impact of heavy metals on environmental components. The solution to this problem is impossible without working out a new approach to determining the most common criterion – the maximum permissible concentration. According to research by many scientists, attempts to strictly regulate the content of heavy metals in the soil are meaningless, due to the fact that the concentrations of trace elements in the soil cover will change depending on the current soil-ecological situation. In addition to the properties of the contaminant metal itself, this is due to the dependence of their behavior on the formed properties of the soil, such as redox potential, pH, soil buffering, etc., and the dynamics of soil processes [1].

The maximum allowable concentration depends mainly on the following factors:

- landscape-geochemical, including local soil features (the amount of fine mineral particles and humus, the reaction of the medium, which determines the ability of the soil to inactivate pollutants, as well as background amounts of the latter);
- technogenic, reflecting the type and degree of anthropogenic load on the soil by specifying the functional features of the territory (urbanized zones, agricultural land, natural landscapes, etc.) [2].

All this indicates the need to develop the MPC of pollutants in soils, taking into account the existing soil-ecological situation.

Many researchers talk about the possibility of growing environmentally friendly products on polluted, according to existing standards, soils [3]. This means that the main criterion for soil contamination of agricultural land should be the quality of products obtained from these territories, which, in turn, is also determined relative to the existing maximum permissible concentrations.
Summing up the above, it is worth noting that the MPC of elements should be developed not only for each genetic type of soil, but also for a specific crop grown on these soils.

2. Theoretical part
In order to substantiate the theoretical aspects of calculating the regional MPC of trace elements in the soil based on existing biogeochemical criteria, it is necessary to analyze the regularities of the distribution of elements in the soil – plant system [2]. The intensity of accumulation of chemical elements by plant organisms can be described by the coefficient of biological absorption (CBA):

\[ \text{CBA} = \frac{C_P}{C_S} \]  

where \( C_P \) - element content in the plant ash, mg/kg, \( C_S \) – element content in soils (or the lithosphere as a whole), mg/kg [4].

P P Brooks [5] improved this expression by replacing the element content in the plant ash (\( C_P \)) with its content in the dry mass.

V E Zakrutkin et al. [2] developed a methodology for determining regional MPC. They revealed a certain relationship between the coefficient of biological absorption and \( C_S \), which is expressed in theoretical constructions of the hyperbolic-asymptotic curve and is universal for all elements and for all plant species. Adding another value equal to the MPC in a particular type of vegetation to the CBP formula, the normalized coefficient of biological absorption (\( \text{CBA}_n \)) is obtained, determined by the formula:

\[ \text{CBA}_n = \frac{(C_P - \text{MPC})}{C_S} \]  

3. Results and discussion
Nickel was chosen as the element under consideration, which is due to a significant spread of normalized values according to different authors (table 1).

|                | [6] | [7] | [8] | [9]  | [10] | [11] |
|----------------|-----|-----|-----|------|------|------|
| Nickel         | 100 | 100 | 100-150 | +25* | 50   | 80** |

* Excess over background concentration
**Approximate permissible concentration, mg/kg

As reference crops for determining the regional MPC of Nickel, the most common representatives among grain and industrial crops and forage grasses were selected – winter wheat, sunflower and alfalfa grown on various genetic types of soils in the Rostov region. After calculating the normalized coefficient of biological absorption of the element in these crops, graphs of the dependence of the Ni content in vegetation on the element content in soils were constructed (fig. 1-3), and the values of the regional MPC of the element for the soils of the region were determined.

Due to the fact that this dependence is often non-linear, and the correlation coefficient is far from unity (due to the heterogeneity of samples due to the influence of differences between the varieties of the studied crops and soil types, as well as other non-random and random factors), it is not possible to construct graphs unambiguously [2].

The graphs (Fig. 1-3) show that all the points of the obtained values of the normalized CBA fall on a certain field of values, and it becomes possible to draw a trend line and determine the desired value of the regional MPC of Nickel in soils as the abscissa of the intersection point of the constructed curve with the line \( \text{CBA}_n = 0 \), and how to solve the regression equation.
**Figure 1.** Dependence of CBA$_n$ Ni in wheat on the content in chernozems (a) and chestnut soils (b) of the Rostov region.

**Figure 2.** Dependence of CBA$_n$ Ni in sunflower on the content in chernozems (a) and chestnut soils (b) of the Rostov region.

**Figure 3.** Dependence of CBA$_n$ Ni in alfalfa on the content in chernozems (a) and chestnut soils (b) of the Rostov region.
When determining the regional MPC of nickel, an element content standard in cereals was used, equal to 0.5 mg/kg of crude substance, which corresponds to 0.465 mg/kg of dry substance; sunflower - 0.9 mg/kg of crude substance (0.978 mg/kg of dry substance); in alfalfa - 0.25 mg/kg of crude substance (1.0 mg/kg of dry substance) [12-15].

In accordance with these values, graphs were constructed for the dependence of the normalized CB A in wheat, sunflower and alfalfa on the Nickel content in the soil and regression lines described by the equations presented in table 2.

Table 2. Regression equations and RMPC.

| Crops  | Soil types | Regression equations | RMPC, mg/kg |
|--------|------------|----------------------|-------------|
| Wheat  | Chernozems | y = 0.0002x – 0.0126  | 63          |
|        | Chestnut soils | y = 0.0002x – 0.0143 | 72          |
| Sunflower | Chernozems | y = 0.0005x – 0.0404 | 81          |
|        | Chestnut soils | y = 0.0006x – 0.0430 | 72          |
| Alfalfa | Chernozems | y = 0.0004x – 0.0303 | 76          |
|        | Chestnut soils | y = 0.0004x – 0.0291 | 73          |

4. Conclusions

Thus, the calculated regional MPC of nickel was:

- for winter wheat: in chernozems ~ 63 mg / kg; in chestnut soils ~ 72 mg/kg;
- for sunflower: in chernozems ~ 81 mg / kg; in chestnut soils ~ 72 mg/kg;
- for alfalfa: in chernozems ~ 76 mg / kg; in chestnut soils ~ 73 mg/kg;

It should be noted that the author proposes stricter values of the regional MPC of nickel for chestnut soils compared to chernozem soils (with the exception of winter wheat, in the case of which the desired value is even more stringent).

5. References

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