Anionic composition of salts in soils of the Shira steppe (south of the middle Siberia)

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Abstract. With the use of data sets, the construction of salt profiles is a rather cumbersome way of expressing the results of the analysis of the water extract, in connection with which it is possible to discuss the narrow ratio of ions characterizing the salinization (desalinization) stages for the research area and their character. The steppe under research is characterized by the predominance of sulphate ions in the soil horizons; the variation of the values is typical for chloride ions and alkalinity from normal carbonates, which accordingly determines the overall types of salinity.

1. Actuality

Saline soils are common in almost all natural areas and countries [1-5], and within the steppe arid areas, they can occupy significant areas, which supports scientific and practical interest in these objects for many decades [6]. The assessment of salinity in the territory of the Russian Federation is usually carried out in an aqueous extract of 1:5, and, in spite of a number of disadvantages of the method, it has many advantages, among which is the possibility of determining the total content of readily soluble salts, including those contained in the solid phase and their ionic composition [7, 8]. The simplest expression of the results of this study is the construction of salt profiles, while they can demonstrate both the complete detectable ion set and the sample, according to the tasks being solved.

2. Objects and methods of research

The research objects were the soils of zonal conjugations of the Shira steppe (the Chulym-Yenisei basin of the Minusinsk intermountain trough (Figure 1), south of the middle Siberia). The results are based on a laboratory-analytical study of aqueous (1:5) and hydrochloric extracts of samples of genetic horizons of automorphic and hydromorphic soils of four catenas. Sulfate ions are determined by gravimetric method; chloride ions – argentometric, according to More; alkalinity from normal carbonates by titration with phenolphthalein [9].

3. Results discussion

The importance of considering salt profiles, especially Cl\(^-\)SO\(_4\)^{2-}, was also noted by B.B. Polynov, who on the basis of his own research laid the foundations for analyzing the data of water extract [10]. However, the visualization of the results is difficult in the presence of large arrays of values, so that the graphic representation of the quantitative ratio of ions can be represented in a slightly transformed form (Figure 2), which will allow us to look at the picture of the presence of water-soluble compounds in the soil cover in a more general format.
Figure 1. Schematic map showing the location of the studied some of island steppes of the Minusinsk intermountain trough (according to [11] with the authors’ additions). Shading shows the studied area.

Based on the data obtained, it can be concluded that sulfate ions prevail in the horizons of the soil profiles of the study area, excluding the most saline upper layers of typical solonchaks, which cause a considerable scatter of values for Cl$^-$ ions (Figure 2), clearly emphasizing the picture of progressive salinity soils of subordinate positions. The numerical expression for the average Cl$^-$/SO$_4^{2-}$ values for hydromorphic soils is 0.59, and for automorphic soils - 0.06 units; for the horizons of the maximum accumulation of salts: 1.39 and 0.04, respectively.

Figure 2. Cl$^-$ and SO$_4^{2-}$ of aqueous extract of hydromorphic and automorphic soils of the Shira steppe
The variation of $\text{SO}_4^{2-}$ anion in southern chernozems, reaching significant amounts, is due to the presence of sulfuric acid salts of calcium, which, despite their poor solubility, still affect the content of these ions in aqueous extract (Figure 3). Salt profiles, as a rule, have a classical appearance of some accumulation at depth. It should not be forgotten, however, that $\text{SO}_4^{2-}$ in such amounts will not be present in the soil solution, since in the case of a non-washable water regime and the presence of a drying horizon, they are usually part of the solid phase of the soils.

An interesting feature noted for plain soils is the connection between the horizons of the maximum accumulation of salts and the limiting values of sulfate ions, which emphasizes the predominant role of sulfates, the correlation dependence (R) between which is 0.95 units (standard error $S = 0.03$).

![Figure 3. Saline profiles of southern chernozems: Cl\(^{-}\) (water extract) and SO\(_4^{2-}\) (aqueous and hydrochloric extracts)](image)

An important role among the anions is played by alkalinity from normal carbonates, which largely determines the type of salinity. Both the hydromorphic soils and the chernozems of the territory under research are characterized by the presence of this ion, but for the first, it is inherent in maximum amounts for the salt crust of typical alkaline soils (up to 24 mmol/100 g of soil) and may be absent in other horizons (5 of 22), and for the latter it is possible to have it in the lower thickness of the profile (29 samples out of 58).

4. Conclusions
The soils of the territory under research are characterized by the predominance of sulfate ions in the aqueous extract, while in some cases the content of chloride ions for soils of subordinate positions can vary considerably, up to unconditional dominance in solonchaks crusts, indicating progressive salinity.
Wide limits of $SO_4^{2-}$ content in automorphic soils are associated with the presence of calcium sulphate salts within the profiles.

The salt composition of the water extract may contain $CO_3^{2-}$, the amount of which varies from 0 to 24 mmol/100 g of soil, which determines the type of salinization in specific cases as soda-chloride or chloride-soda. In automorphic soils, $CO_3^{2-}$ is, as a rule, contained in the lower part of the profile, not always, and in small amounts.

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