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Metamorphization of Groundwater Chemistry Due to Soil Salinization

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Abstract: The article highlights the scientific basis of metamorphization of the chemical composition of natural waters on the basis of classical methods, as a result of which it is supposed to improve the ecological and geochemical state and as a consequence increase the fertility of saline soils.

Keywords: natural waters, metamorphization, salinization, salinization.

INTRODUCTION. The idea of unity of development of the system "soil - groundwater" has been repeatedly expressed by many scientists dealing with problems of salinity control on irrigated lands. V.A.Kovda noted that the main source of salts in soils (if mineralized irrigation water is not applied) is groundwater close to the surface.... [2]. From the above it is clear that the process of salinization of the upper part of the soil necessary for plants occurs under the action of physical evaporation mainly of mineralized groundwater. Therefore, to assess this process requires the analysis of metamorphization of salt composition and groundwater level regime. It should be noted that the problem of metamorphization of chemical composition of natural waters is far from new. However, in irrigated land hydrology the methodology of metamorphization analysis has not yet found wide application. Therefore, it is necessary to dwell on some aspects of this problem in more detail.

According to the nature of the ratios of sulfate and magnesium ions, G.Yu.Valukonis [1] proposed to name the branches of metamorphization as magnesium ($rMg>rSO_4$) and sulfate ($rSO_4>rMg$). In linear interpretation both branches of metamorphization look as follows:

$А \rightleftarrows Б \rightleftarrows В \rightleftarrows Д \rightleftarrows Е$

(sulphate)

$А \rightleftarrows Б \rightleftarrows Г \rightleftarrows Д \rightleftarrows Е$

(magnesium)

As shown by generalization of hydrochemical materials for different areas, the magnesium branch is most often realized within types A to G inclusive and characterizes typically continental conditions of fresh and brackish water formation.

Из общей схемы нелинейной метаморфизации следует, что магниевой ветви метаморфизации присущ химический тип Г следующего солевого состава: $NaCl$, $MgCl_2$, $MgSO_4$, $Mg(HCO_3)_2$ и $Ca(HCO_3)_2$. В водах, метаморфизующихся по сульфатной ветви, появляется химический тип В, имеющий такой солевой состав: $NaCl$, $Na_2SO_4MgSO_4$, $CaSO_4$ и $Ca(HCO_3)_2$. Таким образом, сульфатная ветвь характеризуется специфическим типом В с тремя сульфатными и одной солью магния, а магниевая ветвь, наоборот, типом Г с тремя солями магния и одной сульфатной.

It follows from the general scheme of nonlinear metamorphization that the magnesium branch of metamorphization is characterized by chemical type D with the following salt composition: NaCl, $MgCl_2$, $MgSO_4$, $Mg(HCO_3)_2$ and $Ca(HCO_3)_2$. In waters motoring along the sulfate branch, chemical type B appears, having the following salt composition: NaCl, Na_2SO_4 $MgSO_4$, $CaSO_4$ and $Ca(HCO_3)_2$. Thus, the sulfate branch is characterized by a specific type B with three sulfate and one magnesium salt, and the magnesium branch, on the contrary, by type D with three magnesium salts and one sulfate salt.

LITERATURE REVIEW. The above mentioned schemes of metamorphization (according to M.G.Valyashko, A.G.Bergman, M.V.Levchenko, G.Yu.Valukonis) constitute a single hydrochemical (normal) cycle of natural water metamorphization. Along with the normal cycle, an abnormal cycle was also revealed [1]. Its essence is as follows. If in the normal cycle the increase in the degree of solution mineralization is accompanied by metamorphization of water composition in the direct direction, in the anomalous cycle the increase in the degree of mineralization is associated with metamorphization in the opposite direction.

The salt diagram of O.K.Kashkarov is widely used to study the peculiarities of groundwater metamorphization. Combined salt triangles proposed by G.Y.Valukonis are more effective in some cases, as they allow distinguishing between sulfate and magnesium branches of metamorphization [3].

In order to elucidate the regularities of groundwater metamorphization of irrigated lands in the region, extensive hydrochemical material (about 1000 determinations) accumulated in the West-Uzbekistan Hydrogeological Expedition [4] was used.

From the consideration of these figures it is seen that in the part of cations carbonate type of waters is characterized by mottled composition with predominance of sodium ion. But in the anionic part sharply prevails NSO-3. Complex points of these analyses occupy the central part of the square, the so-called "soda" waters.

On the cation and anion triangles, chloride-type waters gravitate to the Na+ and Cl- vertices, i.e. it seems that they owe their existence largely to the dissolution and accumulation of sodium chloride in solutions (with subsequent exchange of sodium for calcium and magnesium of the absorbed rock complex).

According to the diagrams where the results of sulfate-type groundwater analyses are systematized, it is already evident by the number of points that these waters are predominant in the study area. This diagram also allows to conclude that the above described hydrocarbonate and chloride types in this case represent the product of far-reaching metamorphization of sulfate type waters in reverse or direct directions.

In the Kashkadarya basin, the cation composition of groundwater of sulfate type is very diverse. The content of Na^+ ion in them reaches 96, Ca^{2+} – 78, Ma^{2+} – 63 eq.%. The most typical area is characterized by the following ionic composition: Na+-50, Ca^{2+}-30, Mg^{2+}-20 eq.%, i.e. in terms of their mobility cations represent the following series (in descending order of mobility): Na+>Ca2+ >Mg2.

Among anions, chlorine predominates. Its content reaches 98 eq.%. The second place is occupied by sulfate ion. Its typical content does not exceed 10-70 eq. %, although there are samples with almost 100% sulfate ion content. The content of hydrocarbonate-ion does not exceed 5-10 eq.%. Geochemical mobility of anions can be characterized by the following sequence (in descending order of mobility): $SO^{2-}{}_4$>Cl>$HCO^-{}_3$.

RESULTS. In Surkhan-Sherabad basin the cation composition of groundwater of sulfate type is very diverse. The content of Na+ ion in them reaches 98, Ca2+-78, Mg2+-68 eq.%. The most typical area is characterized by the following ionic composition: Na+-50, Ca2+-30, Mg2+-20 eq.%, i.e. in terms of their mobility cations represent the following series (in descending order of mobility): Na+ >Ca2+ >Mg2+.

Here also among anions chlorine prevails. Its content reaches 98 eq.%. The second place is occupied by sulfate ion. Its typical content does not exceed 96 eq.%, although there are samples with almost 100% content of sulfate ion. The content of hydrogen carbonate ion reaches 60 eq.%, only in isolated cases rising to 90 eq.%. Geochemical mobility of anions can be characterized by the following sequence (in descending order of mobility): SO2-4 >Cl- >>>HCO-3.

From comparison of anion and cation triangles it follows that chemical appearance of groundwater of this type is determined by salts Na2SO4, NaCl and CaSO4.

Comparing Kashkarov's diagrams, we see that within the square fields the points of water analyses of all hydrochemical types largely overlap. This is another proof of genetic unity of groundwater of chloride, sulfate and hydrocarbonate types.

Additional information about the nature of metamorphization processes is obtained by analyzing the diagrams of G.Y.Valukonis. Figures show that metamorphization of water resources occurs along the sulfate branch (99% of all analyses). This is explained by the predominance of sulfate salts of sodium, calcium and magnesium - in subordinate amounts - both in the composition of groundwater and in the composition of the ion-salt complex of rocks. The groundwater analysis point fields of all PVCRs are completely overlapping, hence, their metamorphization trend is the same. However, the analysis points of waters of the upper and middle PVCR and sub-area are more shifted towards the Na_2SO_4 - $MgSO_4$ salt line. This indicates that under long-term irrigation, groundwater metamorphization occurs in the opposite direction. At the same time, the main mass of points is not taken out of the triangular field Na_2SO_4 - $MgSO_4$- $Mg(HCO_3)_2$, i.e. the hadrochemical type of groundwater as a whole does not change, although local sites are characterized by the appearance of centers with groundwater of soda type.

The points of surface water analysis in the Kashkadarya basin are shifted even more in the opposite direction. Almost all of them are concentrated within the triangular field: Na_2SO_4 − $MgSO_4$- $Mg(HCO_3)_2$.

CONCLUSION. So, it can be concluded that the theory of metamorphization is fully applicable to natural water-irrigated ecosystems in the south of Uzbekistan. The main hydrochemical types of groundwater have been established. The prevailing hydrochemical type is the type of sulfate water. Under metamorphization of such waters in the forward direction, chloride-type waters are formed, and under metamorphization in the reverse direction, hydrocarbonate-type waters are formed. Metamorphization proceeds along the sulfate branch.

Under land irrigation, the tendency to groundwater metamorphization in the reverse direction prevails, but at the same time the figurative points are mostly not taken out of the sulfate field. According to the degree of increasing metamorphization in the reverse direction, natural waters can be arranged in the following order: groundwater of the upper PVCR - groundwater of the middle and sub-area of the upper PVCR, lower PVCR.

It is established that local centers of soda salinization of soils in the south of Uzbekistan are not excluded in the future. And as in confirmation of our forecasts, V.A.Kovda ot notes: "Studies in recent decades have convinced us that the main factor of sodic salinization of soils is the presence of shallow slightly mineralized alkaline groundwater with salt concentration from 0.5-0.7 to 3-5 g/l. Evaporation of these waters through capillary fringe leads to sodic salinization of soils" [2].

As can be seen from the Valukonis diagram, chloride, insignificant amount of sulfate, and carbonate type of groundwater are already absent in the upper SWPPP of the Surkhan-Sherabad basin. According to the analysis of groundwater of Amir Temur farm of Shakhrisabz district

(2010-2016), which is a representative site of the Kashkadarya basin, magnesium hydrogen carbonate also appeared, i.e. metamorphization progresses in the opposite direction.

CONCLUSIONS. Summarizing, it can be concluded that the theory of metamorphization is fully applicable to natural waters of irrigated ecosystems in the region. The main hydrochemical types of groundwater have been clarified. The prevailing hydrochemical type is sulfate water. At metamorphization of such waters in the forward direction, chloride-type waters are formed, and at metamorphization in the reverse direction, hydrocarbonate-type waters are formed. Metamorphization proceeds along the sulfate branch. Under land irrigation, the tendency to groundwater metamorphization in the reverse direction prevails, but at the same time the figurative points are mostly not taken out of the sulfate field. According to the degree of increasing metamorphization in the reverse direction, natural waters can be arranged in the following order: surface and groundwater of the upper PVCR - groundwater of the middle and sub-area of the upper PVCR - groundwater of the lower PVCR.

The above-mentioned regularities constitute a theoretical basis for forecasts of secondary salinization (salinization) of soils and subsoils under irrigation. It can be assumed that at present chloride-sulfate type of secondary salinization should prevail. Under long-term operation of irrigation systems and washing of chloride and sulfate salts, groundwater mineralization decreases, and it metamorphizes in the opposite direction.

Thus, there is a general tendency of water composition approaching to hydrocarbonate-sodium type, as after complete disappearance of sodium sulfate it can be replaced by sodium hydrocarbonates, and the main antisoda agent - calcium sulfate - is almost absent in these waters.

Appearance of local centers of soda salinization of soils in the south of Uzbekistan in the future is not excluded. However, geological reserves of chloride and sulfate salts here are so significant that under existing scales of their removal by irrigation and drainage waters, it is possible that in the future the most toxic for plants centers of new salinization of soils may appear not earlier than in 3-5 years. This is one of the forms of modern desertification of irrigated ecosystems.

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