RESEARCH ON THE ACTION OF MINERALIZED WATER ON THE CHARACTERISTICS OF ORDINARY CHERNOZEM

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Abstract

The agro-industrial complex of the Republic of Moldova operates in risky conditions. Due to its geographical location, the territory of the republic falls within the area with insufficient and unstable humidity. The annual amount of atmospheric precipitation varies between 380 and 550 mm. Long-term research has established that the main limiting natural factor in obtaining high and stable harvests is the low level of accessibility of plants to accessible water. In the conditions of the republic one of the most effective measures to optimize the soil moisture regime is irrigation. Obviously, it does not exclude the application of agrotechnical processes for storing water in the soil. Soil irrigation as a method of improving water regime has been known since ancient times, but so far there are a number of complicated problems related to the reaction of some soil types to changes in water regime and water quality used for irrigation. Thus, the irrigation of chernozems with mineralized water (> 3000 mg/l) does not cause essential changes in the soil adsorbent complex and does not lead to its secondary salinization. The works carried out aimed at testing and assessing the effectiveness of methods to prevent and combat soil degradation during irrigation. The results of the researches highlight the following: the use of good quality water in the irrigation of chernozems has as a consequence the weak decalcification of the plowed layer, the reduction of the hydrostability of the structure and its compaction; irrigation of chernozemic soils with surface and deep (alkaline) water leads to secondary alkalization and solonization, degradation of the structure, peptization of fine clay, secondary compaction and reduction of water permeability; the degrading effect of chernozems irrigation with water of poor quality can be mitigated by applying organo-calcium amendments or treating the water used with soluble calcium compounds. The experimental polygon from Cozești commune, Singerei district, is located on a straight slope with a south-eastern exposure, with a slope of 2%. The soil is presented by ordinary chernozem strongly deep humic clay-loam. It is irrigated for 9 years. The water used is deep water with an unfavorable chemical composition and a strongly alkaline reaction. The evolution of secondary pedological processes and changes in physical and chemical properties in irrigated soils were established by the method of "pair profiles" (irrigated soil and non-irrigated soil). This method is widely used in pedo-ameliorative study and is considered feasible in the quantitative determination of soil characteristics.

Key words: ordinary chernozem, chemical composition, irrigation water, quality indicators

In the Northern part of the Republic the volume of precipitations is attested as below the middle, in the central pedoclimatic zone this indicator appreciated as low, and in the southern one - as very low.

A peculiarity of the republic's climate is the phenomenon of drought. According to the analysis of observational data over the last hundred years, severe and prolonged droughts occur every three years in the northern and central areas and over two years in the southern area (Гаврилица А. 1993). The result of this climatic phenomenon is the reduction or compromise of agricultural production. Long-term research has established that the main limiting natural factor in obtaining high and stable crops is the low level of availability of plants to accessible water (Andrieş S. 2007). In the conditions of the republic one of the most effective measures to optimize the soil moisture regime is irrigation. Obviously, it does not exclude the application of agrotechnical methods for storing water in the soil. Soil irrigation as a method of improving water regime has been known since ancient times, but so far there are a number of complicated problems related to the reaction of some soil types to changes in water regime and water quality used for irrigation. Thus, the irrigation of chernozems with mineralized water (> 3000 mg/l) does not cause essential changes in the soil adsorbent complex and does not lead to its secondary salinization (Ковда В. 1981).

At the same time, the same author points out that the use of water with a degree of mineralization higher than 1000 mg/l on

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chernozemic soils, has as a consequence the secondary salinization and solonization, but also their hydromorphic evolution. As a result of multiannual research, V. A. Covda (Ковда В. 1981) concludes that the development of unified irrigation water quality indicators is practically impossible due to the extremely high diversity of pedological, geomorphological and geochemical conditions of irrigated territories.

In the Republic of Moldova, chernozems make up over 74% of the surface of soils suitable for irrigation (Filipciuc V., 2007). They can be included in the irrigation regime only if the use of water with low soluble salts (up to 1000 mg/l) and favorable chemical composition. Research on different chernozem subtypes shows that changing the natural water regime by irrigation, even when using good quality water, leads to degradation of the structure, compaction of the upper horizon and decalcification (Крупеников И. *et al,* 1978; Подымов Б. 1976). The use of water with a high degree of mineralization or with an inadequate chemical composition for the irrigation of chernozems has as a consequence their salinization and / or secondary solonization (Позняк С. *et al*, 1997; Filipciuc V. *et al*, 1990; Филипчук В. 2014). In this context it is useful to mention that the solonization process severely affects not only the physical and physico-chemical properties of the soil. It also produces degrading effects on the mineralogical composition by increasing the content of swelling material in the smectite and illit-smectite group (Алексеев В. *et at*, 1985). Some secondary pedological processes induced by chernozem irrigation with water of unsatisfactory quality, such as clay, fine clay peptization and ilitization, are irreversible and cannot be restored or restored by amelioration methods. Contrary to these findings, some authors argue that chernozem soils can be irrigated with water in which the soluble salt content is 1500-3000 mg/l (Рабочев И. 1981; Безднина С. 1990; Зимовец Б. *et al,* 1993). V. A. Kovda, by analyzing the global experience of the consequence of irrigation, points out that the unification of water quality indicators for irrigation and the setting of limit values presents great difficulties or is impossible due to the diversity of climatic, geomorphological conditions. For the pedoclimatic conditions of the Republic of Moldova, water quality indicators used for irrigation were established, which regulate the degree of mineralization, reaction, sodium adsorption ratio, magnesium indicator, chlorine and residual sodium carbonate content (Filipciuc V. 2007).

MATERIAL AND METHOD

In order to establish and evaluate the impact of irrigation of chernozem soils with water of different quality, field, laboratory and office methods were used. The following works were carried out in the field: opening the soil profiles, morphological and morphometric description; collecting soil samples from genetic horizons to determine chemical, physical, water and physico-mechanical properties; collection of water samples for irrigation in order to determine the chemical composition and quality indicators; determination of apparent density and penetration resistance (on genetic horizons); determination of water permeability and water capacity in the field.

In the laboratory it was determined: the hygroscopic water content; density of the solid phase of the soil; granulometric and microaggregatic composition; structural-aggregate composition and hydrostability of the structure; hygroscopicity and wilting coefficients; humus content and composition; calcium and magnesium carbonate content; nutrient content nitric nitrogen, mobile phosphorus and exchangeable potassium; soluble salt content, reaction and ionic composition of the aqueous extract; the content of adsorbed cations; chemical composition and water quality indicators for irrigation. At the office phase, the calculations of the field and laboratory determinations were performed, the results obtained were systematized and analyzed and the report for the current year's stage was elaborated. The works provided by the thematic plan were carried out on selected experimental polygons within the irrigation systems and in their immediate vicinity (non-irrigated soils). The experimental polygon from Cozești commune, Sîngerei district, is located on a straight slope with a south-eastern exposure, with a slope of 2%. The soil is presented by ordinary chernozem strongly deep humic clay-loam. It is irrigated for 9 years. The water used is deep water with an unfavorable chemical composition and a strongly alkaline reaction.

RESULTS AND DISCUSSIONS

Hydrochemical characterization of the water source used for irrigation. The chemical composition and water quality indicators of lakes, reservoirs and ponds are determined by multiple factors, including lithological, geomorphological, hydrogeological and climatic. Hydrochemical research of local water sources shows that their quality depends largely on the power supply. They are very varied, and their mineralization varies in a wide range from 0.5 to 7.0 g/l. On the territory of the Republic there is a zoning of surface waters, including accumulation basins. In the Northern area, non-mineralized lakes with a soluble salt content below 1000 mg/l predominate. In the Central and Southern area, the degree of water mineralization varies between 1000 and 3000 mg/l. There are hydrochemical districts in which the salt content is 3000 - 5000 mg/l. Such water accumulation basins are concentrated within the Ciuluc - solonetz height. One of the specific characteristics for the water of lakes and ponds in the Republic is the high concentration of magnesium. Previous research has shown that the ratio of bivalent cations (Ca:Mg) is favorable in only 12% of the total number of ponds.

The soil of the Singerei experimental polygon is irrigated for 9 years with water from the pond. Determinations of chemical composition and quality indicators show that the content of soluble salts is very high and varies from 2750 mg/l to 3756 mg/l. This indicates a high danger of soil salinization. The water reaction is estimated to be moderate to strongly alkaline with pH values between 8.70 - 8.90 units. The anionic composition is predominated by SO_4^{2-}, the content of which is 23.60 - 33.82 me/l. Chlorine exceeds the maximum allowable limit for irrigation water, with values of 3.73 - 4.41 me/l. CO_3^{2-} is permanently present in the anionic composition in quantities of 2.40-4.80 me/l. Na^+ predominates among the cations, the content of which ranges between 27.83 and 39.13 me/l. It is followed by Mg^{2+} with a concentration of 11.66 - 12.60 me/l. In the composition of Ca^{2+} cations it has a subordinate role with a content of only 4.60 - 7.34 me/l. Based on the chemical composition of the water, the SAR, PMg and CSR indicators were calculated. The sodium adsorption ratio is high (9.9 - 11.2) and shows an increased risk of secondary soil solonization. The evolution of this process also indicates the extremely high values of residual sodium carbonate (11.57 - 21.03 me/l). The magnesium index makes up 70 - 72%, so long-term irrigation will lead to the accumulation of magnesium cation in the adsorbent complex of the soil. It is important to emphasize that in the composition of soluble salts of the pond water, sodium sulfate predominates, the content of which varies from 23.60 to 33.92 me/l. Summary Toxic sodium and magnesium compounds have a share of 86-90% of the total soluble salt content.

Irrigation changes of the chemical properties of ordinary chernozem. Due to the humus content, the soil of the Sîngerei experimental polygon falls into the category of moderately humiferous ones (3.15%). On the profile the content of organic matter decreases slowly and obtains values of 0.56 - 0.7% in the solidification rock. Calcium and magnesium carbonates appear in the B1 horizon at a depth of 45 cm in the form of pseudomyceles. Their content increases in depth from 1 to 11%. Irrigation with mineralized water does not produce significant changes in the content of $CaCO_3$ and humus, but has a negative effect on its composition. In the irrigated soil, there was a tendency to decrease the carbon content in the fraction of humic acids. At the same time, a slight increase of this element in the fraction of fulvic acids is observed. The mentioned changes led to the reduction of the CAH: CAF ratio from 3:1 in non-irrigated soil to 2.4:1 in irrigated soil. Other unfavorable changes in the composition of humus relate to the decrease in the content of calcium-bound humic acids and the increase in the content of free humic acids bound to iron and aluminum sesquoxides. In a very short period of time, these changes seem insignificant, but they should not be neglected, because long-term irrigation can substantially increase the mobility of organic matter in the soil. Highly mineralized water has degrading effects on the saline indices of ordinary chernozem and, first of all, on the ionic composition of the aqueous extract. Unirrigated soil is characterized by very low content of soluble salts. The humus-cumulative layer contains only 0.025% salts. In the transition horizons and in the rock the value of the dry residue increases slightly to 0.039 - 0.045%. The current reaction of the first two horizons is neutral with pH values between 7.02 and 7.20. In depth, with the appearance of carbonates, the soil reaction becomes poorly alkalized with variations in pH from 8.05 to 8.30 units.

In the anionic composition of the aqueous extract, the bicarbonate ion predominates, which makes up 0.15 - 0.59 me, and in the cationic one, calcium prevails with a participation of 0.28 - 0.54 me/100 g of soil. The ratio between bivalent and monovalent cations is high and ranges from 6 to 9:1. The use of highly mineralized water for irrigation has the consequence of increasing the content of soluble salts on the entire soil profile. The largest increase was recorded in the humus-cumulative horizon on the thickness of 0-43 cm. Here the value of the dry residue practically doubled from 0.025 - 0.027 to 0.048 - 0.057%. It should be noted, however, that due to the content of soluble salts, the ordinary irrigated chernozem remains in the category of non-saline ones. The reaction of the irrigated soil, through the application of mineralized and alkaline water, registers a significant increase, especially in the upper horizons. On the soil thickness 0 - 43 cm the pH value increased by 1.18 - 1.23 units, reaching sizes of 8.20 - 8.43 units. In the ionic composition of the aqueous extract of the irrigated soil, a significant increase of the HCO_3 content and, in particular, of the Na^+ content is observed. On the profile of non-irrigated soil, the concentration of sodium in the soil solution is 0.05-0.11 me, and in the variant with irrigation regime this element reaches values of 0.44 - 0.52 me/100 g of soil, thus registering an increase of 5-9 times. These changes significantly reduced the Ca + Mg: Na ratio from 6 ... 9:1 to 1 ... 2:1. Thus, favorable conditions are created for the evolution of the secondary solonization process.

The use of water of unsatisfactory quality in the irrigation of ordinary chernozem has severe implications on the composition of soluble salts. Calculations show that in the unirrigated chernozem, harmless compounds predominate - calcium bicarbonate and calcium sulfate, which briefly make up 70 - 74% of the total salt content. In irrigated soil toxic compounds of sodium and magnesium [$Mg(HCO_3)_2$; $MgCl_2$; $NaHCO_3$; Na_2SO_4; NaCl] are the dominant salts with a weight of 61 - 66%. It is important to note that in the composition of soluble salts of the soil in irrigation appears sodium bicarbonate, a compound that is missing in the solution of unirrigated soil. The impact of alkaline and mineralized irrigation on soil adsorbent complex is sufficiently studied for different soil and climatic conditions. It is unanimously accepted that the use of these waters leads to the emergence and evolution of the process of secondary soil solonization. The effect of using mineralized water was studied on the Sîngerei experimental polygon. The comparative study performed on ordinary chernozem shows that the adsorbent complex of non-irrigated soil is saturated in calcium at 80-87% and in magnesium at 12-18%. The adsorbed sodium is contained in insignificant amounts of 1-2% of the sum of exchangeable cations. From the presented data it can be seen that the Ca^{2+} content decreases in profile from 28.93 me in the humus-cumulative horizon to 20.12 me in the parent rock. Magnesium cation increases from the surface horizon (3.88 me/100 g soil) to the depth (4.58 me). The adsorbed sodium is evenly distributed on the profile, having a content of 0.29-0.37 me/100 g soil.

Irrigation of ordinary chernozem with mineralized water results in a change in the content of exchange bases. For the soil under irrigation, conditions have been created for the appearance and evolution of the decalcification process, diagnosed by the appreciable decrease of the adsorbed calcium content. According to the obtained results, from the humus-cumulative horizon of the irrigated soil Ca^{2+} was substituted in the amount of 2.93 me/100 g soil. It is useful to note that the desorption of this cation is not located only in the surface layer. It is recorded at a depth of 90 cm. Among the effects induced by mineralized water on the soil adsorbent complex is the increase in the magnesium content and, in particular, the adsorbed sodium content. In the colloidal complex of irrigated chernozem Na^+ makes up 6% of the sum of exchange bases. Through this indicator the soil is included in the category of moderately alkalized ones. In depth the degree of alkalization is appreciated as weak. Therefore, the use of mineralized water for irrigation generates secondary solonization of the entire soil profile.

The impact of mineralized water on the physical, hydric and physical-mechanical properties of the soil. It has previously been noted that soil texture is a virtually unchangeable property. However, in the literature it is reported that irrigation conditions the claying process and the textural differentiation of the soil profile. Obviously, such changes in particle size composition can occur over a fairly long period of time. The size particle determined on the genetic horizons of the two soil variants require their classification in the class of fine clay-loamy texture. The summary content of coarse and medium sand is very low at 0.1 - 0.2%, and that of fine sand is relatively higher with values between 4.8 and 7.8%. In the dust fraction, coarse dust predominates (27.9 - 33.5%), followed by dust with a participation of 13.0 - 17.5%. The middle dust occupies an intermediate position, this being 7.4 - 10.3%. The amount of fine clay is high (36.6 - 41.9%), slightly lower in irrigated soil. The physical clay content varies between 62.0 and 64.8%. In its composition fine clay has a weight of 61 - 64%. Thus, it can be concluded that during the nine years of irrigation with mineralized water, the texture of ordinary chernozem does not register appreciable changes.

The microaggregate composition represents the totality of aggregates with a diameter of less than 0.25 mm, stable to energetic agitation in water. They highlight a very high content of hydrostable microaggregates with a diameter of 0.05 - 0.01 mm. In both unirrigated and irrigated soil, the content of the fraction equivalent to coarse dust varies in a range of 41.5 - 47.7%. When interpreting the results of soil microaggregate analysis, special attention is paid to the content of fine hydropeptized clay. Multiple publications in the soil physics literature specify the role of the fraction <0.001 mm in the process of potential structuring. Thus, it is considered that at a high content of uncoagulated fine clay, the soil has a very low self-structuring capacity. The peptization process of fine clay depends to a large extent on the composition and content of adsorbed cations. For calcium-saturated soils, a high degree of clay coagulation is characteristic. The presence of monovalent cations in the adsorbent complex favors the peptization process. A very high peptizing capacity possesses the sodium cation. As a result of the secondary alkalization process, the adsorbed calcium is replaced by sodium in the irrigation water. The accumulation of Na^+ in the adsorbent complex increases the degree of peptization of fine clay. This process is observed in irrigated soil. The content of fractions with a diameter below 0.001 mm increased compared to non-irrigated soil, and the dispersion factor, especially in the humus-cumulative horizon, increased from 9 to 16%. The evolution of the degradation processes of the physico-chemical properties under the influence of the mineralized water induces some modifications of the physical, hydric and physico-mechanical properties of the ordinary chernozem. To a lesser extent these changes refer to intrinsic properties, which are difficult to modify, such as the density of the solid phase of the soil. The determinations show that this indicator varies in a range of 2.59 - 2.72 g/cm^3, increasing from the humus-cumulative horizon to the parent rock. As the soil profile is texturally and mineralogically homogeneous, the increase in solid phase density is due to the decrease in deep organic matter content.

The apparent density can be modified under the action of the anthropogenic factor, including by the application of irrigation. In the plowed horizon of the unirrigated soil, this indicator makes up 1.24 g/cm^3, falling into the large class of values. The surface horizon of irrigated soil is characterized by a high apparent density of 1.38 g/cm^3. In depth, it registers an increase up to 1.41 - 1.44 g/cm^3, remaining in the same class of values. The total porosity of the unirrigated soil has average values of 52% only in the plowed horizon. In depth this indicator decreases to 47 - 50% and is included in the small class of values. For irrigated soil, the total porosity values vary between 45 and 48%, being appreciated as small. Thus, difficult irrigation conditions are established in the irrigated soil. For the soils in the irrigation arrangements, the aeration porosity is of special importance. On the researched soil profiles, this indicator registers significant changes. In the humus-cumulative horizon of non-irrigated soil, the aeration porosity is medium (18%) and decreases to very low in the transition horizon B1 (10%). Starting with the B2 horizon, this indicator is increasing, reaching a high value of 23% in the parent rock. The aeration porosity in the irrigated soil is very low right from the surface (9%) and up to the B1 horizon. Towards the solidification rock, an increase is observed from 15% in the B2 horizon to 22% in the C horizon, here being appreciated as medium. The settlement status of the common chernozem was assessed by determining the degree of settlement. In non-irrigated soil, the degree of compaction is determined as small (0) in the surface horizon (plowing). On the profile, in the B1 horizon, it is attested as high (+ 12%), and the soil as moderately compacted. In depth, the degree of compaction decreases to +8 ... + 10%, the soil being poorly compacted. The soil in irrigation regime is estimated as poorly compacted from the surface, the values of the degree of compaction oscillating between +8 ... + 10%. The mentioned state of settlement is maintained on the entire soil profile except for the transition horizon B1, in which this indicator makes up + 13%, and the soil is considered moderately compacted.

One of the main mechanical characteristics of the soil is the resistance to penetration. It also presents a simple and quick method of assessing the condition of the soil. From the data presented in table 18 it is observed that the penetration resistance has very low values only in the plowed layer of the non-irrigated chernozem. In depth it increases gradually, indicating values of 12.6 - 23.6 Kgf/cm^2, these being appreciated as small. On the chernozem in irrigation, the indicators of penetration resistance are higher. Thus, in the plow layer its value is 16.2 Kgf/cm^2 or about 2 times higher compared to non-irrigated soil. On the profile, the penetration resistance registers an increase from 18.3 to 24.5 Kgf/cm^2, still remaining in the small class of values. It has previously been reported that irrigation does not essentially influence the hydrophysical indices of the soil. This finding also applies to the use of mineralized water. The hygroscopicity coefficient on both soil variants is high with values between 10.43 and 11.22%. The withering coefficient falls in the large to very high class of values and ranges from 15.6 to 16.8%. The high values of this index are due to the fine texture and high clay content. The water capacity in the field has different sizes on the soil profile. It is estimated as high in the humus-cumulative horizon which includes the plowed and the submerged layer (26.3 - 27.9%). In the transition horizons the field capacity is medium, comprising values of 20.8 - 25.6%, and in the parent rock this index is reduced to 17.8 - 18.5 and is attested as small. The useful water capacity is the range of soil moisture between the wilting coefficient and the water capacity in the field. It is the reserve of water that the soil can give to plants. The calculations show the following: the useful water capacity is medium (11.7 - 11.8%) in the plowed layer; has low values in the transition horizons B1 and B2 (7.0 - 9.5%); in the BC horizon and in the solidification rock C this index is very small with values between 1.7 and 4.9%. The evolution of the process of secondary solonization of the soil as a result of the use of alkaline and mineralized water has negative effects on the structural-aggregate composition of the ordinary chernozem. Degradation of soil structure during irrigation takes place under the influence of two main causes: decalcification of the upper horizons and accumulation of sodium in the adsorbent complex.

CONCLUSIONS

The use of Dniester river water to irrigate the carbonate chernozem does not influence the saline indices. The effect of irrigation on physical properties refers to the increase of the hydropeptized fine clay content and the dispersion factor.

Irrigation of ordinary chernozem with mineralized water from local sources results in: - change in the composition of humus and soluble salts; - intensification of the process of decalcification and secondary alkalizing; - increasing the degree of peptization of the fine clay and the dispersion factor; - secondary destructuring and compaction of the soil; - reduction of water permeability.

The application to irrigation of groundwater with inadequate quality indices leads to: - modification of the composition of soluble salts in the soil; - the evolution of the secondary alkalizing process; - increasing the content of peptized clay and the dispersion factor; - secondary soil compaction, increased compaction and penetration resistance; - the appearance of the massive structure with reduced hydrostability; - decrease in the stabilized infiltration rate.

REFERENCES

Гаврилица А.О., 1993 - *Современные проблемы дождевания*. Кишинев: Тип. ГАУМ, 338 с.

Andrieş S., 2007 - *Optimizarea regimurilor nutritive a solurilor şi productivitatea plantelor de cultură*. Chişinău: Pontos, 374 p.

Ковда В.А., 1981 - *Почвенный покров, его улучшение, использование и охрана*. М.: Наука, 173 с.

Filipciuc V., 2007 - *Pretabilitatea solurilor și apelor la irigație*. În: Seceta și metode de minimalizare a consecințelor nefaste. Chișinău, pp. 10-11.

Крупеников И.А., Подымов Б.П - 1978. *Диагностика и принципы классификации орошаемых почв*. В сб: Почвенно-мелиоративные проблемы орошаемого земледелия. Кишинев: Штиинца, с. 8-13.

Подымов Б.П., 1976 - *Почвы и воды Молдавии в связи с развитием орошения*. В: Сельское хозяйство Молдавии. Кишинев: №5, с. 26-27.

Позняк С.П., Тортик Н.И., 1997 - *Орошаемые черноземы юго-запада Украины*. – Львов, ВНТЛ, 239 с.

Filipciuc V., și col. 1990 - *Buletin de monitroring ecopedologic (pedoameliorativ)*. Ediţia I. Chişinău: Agroinformreclama, 50 p.

Филипчук В.Ф., 2014 - *Деградация черноземов при орошении и методы восстановления плодородия*. В: Природные и антропогенные факторы воздействия на качество почв и водных ресурсов Республики Молдова. Кишинэу, с. 108-136.

Алексеев В.Е., Филипчук В.Ф., Арапу К.Г., 1985 - *Преобразование глинистых минералов и свойств тепличных почв под воздействием поливных вод и химических мелиорантов*. В сб.: Состав, свойства и агроэкологическая оценка почв Молдавии. Кишинев: сс. 80-93.

Незнаненко С.Н., 1978 - *Влияния орошения на солевой режим почв.* Тр. Волгоградского с.-х. ин-та, вып. 68, с. 57-63.

Баскаченко И.Н., 1975 - *Использование природных минерализованных вод в сельском хозяйстве*. Л.: Колос, 179 с.

Калашников К.Г., 1963 - *Применение минерализованных вод для орошения сельскохозяйственных культур*. Кишинев: Штиинца, 131 с.

Рабочев И.С., 1981 - *Классификация минерализованных вод по пригодности для орошения*. Тезисы докладов VI делегатскогосъезда всесоюзного общества почвоведов. Тбилиси, т. 5, с. 64-65.

Безднина С.Я., 1990 - *Регламентирование и улучшение качества оросительной воды*. В: Повышение качества оросительной воды. Москва: Агропромиздат, с. 4-11.

Зимовец Б.А. и др., 1993 - *Методы оценки и изучения пригодности воды для орошения*. Москва: Изд-во ГОСНИТИ, 64 с.