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SUITABILITY OF GROUNDWATER FOR WATER SUPPLY AND IRRIGATION (in the example Shirvan steppe)

Chingiz J. Gulmammadov

Amelioration Scientific Research Institute LLC

I. Dadashov st. 324, Baku, AZ 1130, Azerbaijan

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Abstract

The article provides information on the usability of groundwater with different degrees of mineralization for irrigation in water supply. Research shows that groundwater with a mineralization rate of up to 1.5 g/l can be used freely without any additional measures in water supply. Most of the quality indicators of waters with a mineralization rate of 1.5 g/l to 3.0 g/l are within the norm, but some quality indicators are outside the acceptable limits. Therefore, it is necessary to take additional measures to improve their quality when using such water. However, in crisis situations, groundwater with a mineralization rate of up to 3 g/l can be fully used for water supply. The quality of water used for irrigation must meet 2 main requirements: 1. Irrigation water should not harm the biological development of plants, productivity, and product quality; 2. During irrigation, the process of repeated salinization and solnetzicity should not occur in the soil and should not damage the fertility and productivity of the soil. The quality and suitability of irrigation water are classified according to their degree of mineralization: If the degree of mineralization of water is $\leq$ 0,5 g/l, water is fully suitable for irrigation, 0.5-2.0 g/l - suitable, 2-5 g/l - less suitable, >5 g/l - irrigation is dangerous. It is recommended that the temperature of the irrigation water be 14-20^0. Water is considered completely suitable for irrigation when pH = 6-8.5, conditionally suitable when pH > 8.5, and unsuitable when it is pH<6 and pH>9.

Keywords: underground water, groundwater, irrigation, chemical composition, water supply, mineralization

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Corresponding author.

E-mail address: ***gcin56@mail.ru*** (C.Gulmamadov)

1. Introduction

In different countries, water with a high degree of mineralization has been used for irrigation and other purposes for more than a thousand years. The degree of mineralization of the water of the Artek River in Turkmenistan reaches 9 g/l and agricultural crops have been irrigated with this water for thousands of years. The degree of mineralization of the Shirabad and Tajan rivers rises to 4 g/l during the vegetation period and this water is used for irrigation. In Uzbekistan, cotton plants develop normally during irrigation with saline water [2].

In India, barley, wheat, and other plants are irrigated with water with a mineralization level of 2-7 g/l. But the fields are left to rest for one year [3]. In Italy and England, groundwater with a mineralization rate of up to 10 g/l has been used for a long time to meet the water needs of plants [3]. Irrigation experiments of groundwater with a mineralization rate of 1.5-9.0 g/l were carried out on well-drained soils on the coast of the Adriatic Sea in Italy. Based on experiments, it has been determined that the productivity of eggplant, tomato, sweet pepper, and cabbage increases during irrigation with water with a mineralization level of up to 3.3 g/l, during irrigation with water with a mineralization level of 7-8 g/l, the productivity of those plants decreases. In Algeria, Tunisia, and Morocco, groundwater with a mineralization rate of 2-4 g/l is used to irrigate trees and plants. In 1962, with the assistance of UNESCO, a scientific center was established in Tunis to study the use of saltwater in agriculture in the valley of the Macarek River. The aim was to investigate the effects of saline water on plants and soil under various soil, climatic, and hydrogeological conditions. In Tunisia, irrigation with water having a mineralization rate of 2-6 g/l was conducted for 7 years, resulting in grain yields of 20-25 sen/ha. Simultaneously, irrigation was performed on saline soils, revealing that in well-drained soils, water with a mineralization level of up to 6 g/l can be fully utilized. In Spain, an experimental station was established in 1959 to examine the feasibility of irrigation with seawater having a mineralization rate of 31-37 g/l [2-4]. Experiments conducted on sandy soils in coastal areas revealed that all agricultural crops tested exhibited high yields, with no occurrence of soil salinization.

In Arabia and North Africa, high yields have been achieved through irrigation with groundwater having a mineralization rate of 5-7 g/l in areas with high drainage capacity, without soil salinization occurring. However, in regions with poor natural groundwater flow in arid zones, severe salinization of the soil has been observed even after irrigation with fresh water. Such occurrences have been documented in Central Asia, Iraq, Pakistan, Syria, and North India within a short timeframe. In the United States, over half of agricultural produce is cultivated on soils irrigated with water containing mineralization levels of 5-6 g/l or higher. Forage crops in grasslands in the sandy semi-deserts of southern New Mexico State are irrigated with groundwater containing a mineralization rate of up to 16 g/l [194, 40 p.]. Experiments conducted at the Center for Citrus Plants of the University of California determined that the productivity of Portuguese trees does not decrease when irrigated with water containing a mineralization rate of 1.2 g/l; it decreases slightly at 1.2-1.7 g/l and sharply when exceeding 2 g/l. In Ukraine, tomatoes, potatoes, cabbage, and other agricultural crops have long been irrigated with water from the Donbas mine, with a mineralization rate of 2.4-6.3 g/l. Over 40 years of irrigation, soil salinization did not occur. However, irrigation with water containing a mineralization rate of over 3 g/l led to slight soil salinization and decreased productivity [3]. Interestingly, soil erosion was recorded during irrigation with clean canal water.

In Azerbaijan, the potential use of underground, collector-drainage, sea, and sewage water with a mineralization rate ranging from 1.0 g/l to 18.5 g/l for the irrigation of agricultural crops and the leaching of salinized soils has been studied for over 50 years by the Azerbaijan Scientific Production Association of Hydraulic Engineering and Amelioration. The experiments involved the irrigation of grains, cotton, clover, rice, decorative shrubs, trees, vines, and other agricultural plants, employing various irrigation techniques and technologies.

Through many years of experience, it has been determined that irrigation can be conducted using waters with a mineralization level of up to 10 g/l []. In such cases, certain conditions must be met: the area should possess a high degree of drainage, either natural or artificial; consideration must be given to the salt resistance of plants; the cropping period should adhere to a rotation system; irrigation methods and techniques should be tailored to the biological characteristics of each plant; the water-physical properties of the soil must be satisfactory; the filtration coefficient should range from 0.06 to 0.30 m/day; the type of soil salinization, content and degree of toxic salts, and the ratio of absorbed bases must be taken into account; the chemical properties of water should be evaluated; a balance between the irrigation rate and atmospheric precipitation should be anticipated; and relevant agro technical rules should be adhered to during the cultivation of agricultural plants [2].

2. Object, problems, and methods of the research.

The water supply of the Shirvan steppe in the Kura-Araz plain of the Republic of Azerbaijan and the areas where underground water suitable for irrigation were chosen as the research object. To assess the suitability of groundwater for water supply and irrigation, their chemical, physical, biological, and available stock properties, as well as literature and published information on bacteriological properties, were collected and analyzed and additionally, the results of scientific research conducted by the author at different times were included in the analysis.

3. Analysis and discussion

After the water samples taken from the wells underwent physical, chemical, and biological analysis, the potential use of underground water in the water supply was assessed according to established norms and allowable limits. Soil and pressurized waters with a mineralization rate ranging from 0.5 g/l to 3.0 g/l were included in the analysis. The results of the groundwater analysis are presented in Table 1.

Table 1. Suitability of underground water for water supply

Row №	Ingredients	unit of measu-rement	Price of indicators					
1	Degree of mineralization	mg/l	500	1000	1414	2050	2509	2767
2	Hydrocarbon, HCO_3^-	mg/l	329	232	275	262	275	366
3	Chlorine, Cl^-	mg/l	27	76	275	262	657	763
4	Sulfate, SO_4^{--}	mg/l	86	442	680	936	823	739
5	Calcium, Ca^{2+}	mg/l	46	51	100	175	60	190
6	Magnesium, Mq^{2+}	mg/l	6	33	84	47	174	174
7	Natrium, $Na^{+}+K^{+}$	mg/l	119	244	297	426	521	435
8	The roughness	mg-eg	3	5	12	13	17	24

9	Nitrite, NO_2	mg/l	0,00 2	0,03	0,05	0,002	0,04	0,06
10	Nitrate,NO_3	mg/l	0,37	0,78	1,00	8,4	15,3	22,8
11	Ammonium, NH_4	mg/l	0,04	0,30	0,06	0,05	0,20	0,25
12	Iron, Fe^{3+}	mg/l	0,40	0,50	0,70	12,0	18,0	25,0
13	Copper, Cu^{2+}	mg/l	yox	yox	yox	0,02	0,08	0,10
14	Zinc, Zn^{2+}	mg/l	0,5	2,0	4	6	8	8
15	Aluminum, Al^{3+}	mg/l	18	18	21	28	32	45
16	Biological demand for oxygen, BDO_5	mg/l	2,2	2,5	3,0	1,6	1,6	17
17	Dissolved oxygen	mg/l	3,5	3,8	4,0	5,0	3,2	3,2
18	Oil and oil products	mg/l	n\a	n\a	n\a	n\a	n\a	n\a
19	Suspended particles	mg/l	n\a	n\a	n\a	n\a	n\a	n\a
20	Smell	score	n\a	n\a	n\a	n\a	n\a	n\a

The analysis of the data from Table 1 indicates that the quality indicators of underground water, with a degree of mineralization up to 1.5 g/l, fully meet all regulatory requirements, making them suitable for drinking, domestic, and economic-cultural purposes such as bathing and sports activities. Nitrogen compounds - nitrite, nitrate, ammonium, toxic ingredients, heavy metals, surfactants, oil, and oil products are almost absent in water with a mineralization level of up to 1 g/l, failing to exceed regulatory limits. Additionally, the hardness of these water is significantly lower than the norm, thereby enabling their unrestricted use in the food industry [5, 10].

The mineralization rate ranges from 1.5 to 2.0 g/l, and most quality indicators in the water supply from these sources permit their use. The composition is quite favorable chemically, physically, biologically, and bacteriologically. However, the levels of sulfate ions and iron in these waters exceed the allowable limits. Nevertheless, they meet sanitary-hygienic norms, do not contain oil and oil products, surface synthetic active substances, suspended particles, coli-index, or other harmful substances, moreover, nitrogen and nitrogen compounds are below the normal threshold. Additionally, the smell, color, transparency, and taste of these waters meet the established standards.

Oil and oil products in groundwater with a mineralization rate between 2-3 g/l as well as synthetic active ingredients on the surface and suspended particles are absent. Nitrite, nitrate, and ammonium levels are within the norm, and the total roughness count does not exceed the permissible limit, additionally, its color, smell, transparency, and taste fully comply with the standards. However, the content of iron, aluminum, and zinc in this water exceeds the norm and allowable limits, furthermore, the degree of water mineralization and the amount of chlorine and sulfate ions exceed the norm, making them less suitable for drinking purposes but useful for economic purposes. They can be fully utilized in some industries. During water shortages and crises, water with a mineralization rate of 2-3 g/l can be used for drinking-domestic and agricultural-cultural purposes. During such times, it is necessary to neutralize substances that compromise water quality and improve its quality using specialized technologies [1, 6, 11].

Thus, research indicates that groundwater with a mineralization rate of up to 1.5 g/l can be freely used in water supply without the need for additional measures. While most of the quality indicators of waters with a mineralization level ranging from 1.5 g/l to 3.0 g/l fall within acceptable norms, some quality indicators exceed the acceptable limits. Therefore, it becomes necessary to implement additional measures to enhance their quality when utilizing such waters. However, during crisis situations, groundwater with a mineralization rate of up to 3 g/l can be fully utilized in water supply [2, 8-12].

Regarding requirements for the quality of water used for irrigation purposes, there exist several methods and criteria for assessing the quality of water intended for irrigating agricultural crops. However, these methods are often scattered and fragmentary. Additionally, the results obtained from these assessment methods sometimes contradict each other and may not consistently align with the desired outcomes.

The requirements for the quality of water used for irrigation purposes are crucial. There are various methods and criteria available for assessing the quality of water intended for the irrigation of agricultural crops, however, these methods are often scattered and fragmentary. Moreover, the results obtained from the developed assessment methods may even contradict each other at times and may not consistently align with the expected outcomes.

The quality of water used for irrigation must meet two main requirements:

1. Irrigation water should not adversely affect the biological development of plants, their productivity, or the quality of the products.

2. The irrigation process should not lead to repeated soil salinization and solonetzicity, as this can damage soil fertility and productivity.

A.N. Kostyakov categorized the quality and suitability of irrigation water based on its degree of mineralization: water with a mineralization level of $\leq$ 0,5g/l is fully suitable for irrigation, 0.5-2.0 g/l is considered suitable, 2-5 g/l is less suitable, and a mineralization level exceeding >5 g/l is deemed dangerous for irrigation.

It is recommended that the temperature of irrigation water be between 14°C and 20°C. When the water pH is 7, it indicates a neutral solution, which is completely suitable for irrigation? in the pH range of 6-8.5, the water is both slightly acidic and slightly alkaline, yet it remains completely suitable for irrigation, if the pH exceeds 8.5, the water is considered alkaline and conditionally suitable for irrigation, however, water with a pH below 6 or above 9 is deemed unsuitable for irrigation (Fig. 1).

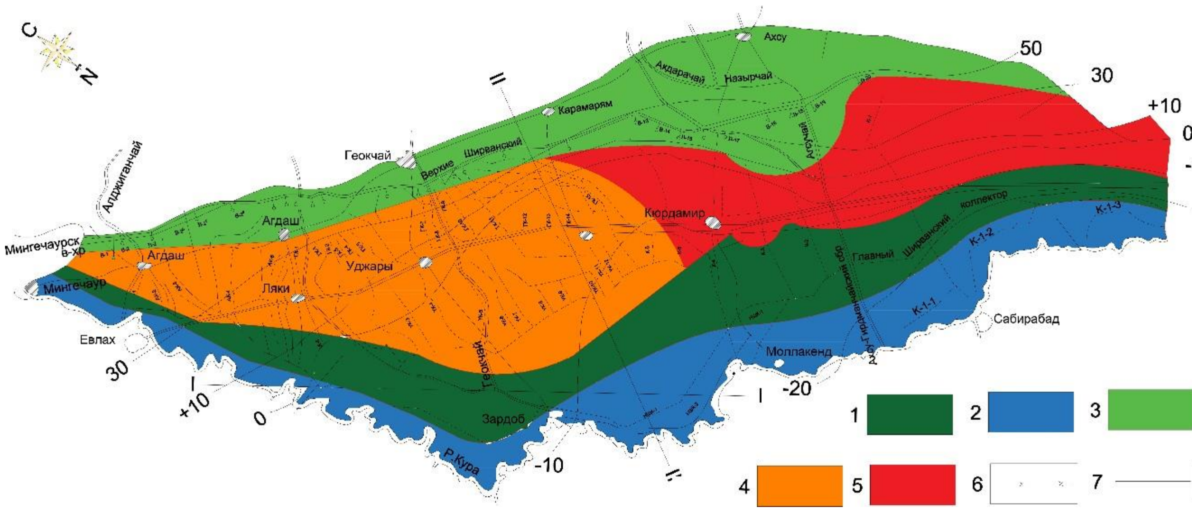

Fig. 1. Schematic map of Shirvan steppe zoning by types of groundwater regime for 1980–2022 (compiled by Ch.D. Gulmamedov). Regime types: 1 – irrigation-climatic; 2 – hydrological; 3 – irrigation; 4 irrigation-irrigation- drainage; 5 – irrigation-irrigation; 6 – line type modes; 7 – hidroisohypses

The suitability of the soil and pressurized water in the Shirvan steppe area was assessed using the aforementioned criteria. The degree of mineralization and chemical composition of these water are provided in table 2.

Table 2. Mineralization and measurement of groundwater in the area, mg-eg.

Mineralization, g/l	Anions			Cations		
	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^++K^+
0,5	5,40	0,76	1,79	2,29	0,49	5,17
1,0	3,80	2,14	9,21	2,54	2,79	10,62
1,5	4,51	7,75	12,17	5,00	7,00	12,93
2,0	4,30	7,39	19,51	8,73	3,95	18,52
2,5	4,51	18,51	17,15	3,00	14,50	22,65
3,0	6,00	21,49	15,40	9,50	14,50	18,91
4,0	3,80	3,50	48,92	20,10	19,15	16,91
5,0	9,40	42,30	33,88	23,21	6,41	46,46
6,0	7,60	0,70	77,85	4,56	2,87	79,32
7,4	2,51	195,49	93,31	2,80	32,00	55,39
8,4	34,00	113,30	7,17	2,00	26,00	126,48
10,0	1,70	88,0	70,79	12,00	28,00	120,52

4. Result

In the Shirvan steppe, when assessing the suitability of groundwater for irrigation, the lower limit of their mineralization level was set at 0.5 g/l, while the upper limit was 10 g/l. The establishment of these limits is associated with the prevalence of mineralization within the studied area, and irrigation in arid zones with water having a mineralization level greater than 10 g/l is generally deemed inappropriate. In such zones, including the plains and irrigated areas of Azerbaijan, precipitation levels are 3-4 times lower than evaporation rates. Under these conditions, the likelihood of soil salinization in irrigated lands is higher.

According to globally accepted evaluation criteria, the chemical composition of groundwater in the studied area primarily consists of neutral salts, making it suitable for irrigation. Groundwater with a mineralization level of up to 7 g/l meets all evaluation criteria (table 1 and 2) for irrigation suitability. The utilization of this water poses no risk of soil salinization or solonetzicity.

The concentration of hydrocarbons in groundwater with a mineralization rate of 0.5 g/l is 2-10 times higher than other ions, except for sodium ions. Consequently, based on both evaluation criteria and the chemical composition of the water, prolonged use of such water may pose a risk of soil salinization.

It is recommended that the temperature of irrigation water remain within the range of 14-20°C. When the pH = 7 in the water, the water is a neutral solution and completely suitable for irrigation, when the pH = 6-8.5, it is both acidic and alkaline, but completely suitable for irrigation, when the pH > 8.5, the water is alkaline and conditionally suitable, pH<6 and pH >9, it is considered unusable.

Groundwater with a mineralization rate of up to 7 g/l in the studied area is highly favorable for irrigation due to its alkalinity index, sodium sorption rate, magnesium percentage, and irrigation coefficient. Utilizing such water for irrigation does not compromise soil structure, and the risk of soda formation is entirely eliminated.

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