International Journal of Design & Nature and Ecodynamics
Vol. 19, No. 4, August, 2024, pp. 1327-1340
Journal homepage: http://iieta.org/journals/ijdne

Hydrochemical Characteristics of Groundwater in Northwestern Kazakhstan Aquifers: Implications for Livestock Water Supply

Marat Ongayev, Sarsenbek Montayev*, Serik Denizbayev, Shynar Sakhipova

Zhangir Khan Agrarian Technical University, Uralsk 090009, Kazakhstan

Corresponding Author Email: sarsenbek_montayev@mail.ru

https://doi.org/10.18280/ijdne.190425

Received: 20 June 2024
Revised: 19 July 2024
Accepted: 29 July 2024
Available online: 28 August 2024

Keywords:
West Kazakhstan region, pasture cattle rearing, pasture, pasture water supply, underground water sources, water mineralization

ABSTRACT

The uneven distribution of open water sources, low flow rates, and a high degree of mineralization of underground sources are constraining factors for the development of animal husbandry in West Kazakhstan. The purpose of the study was to evaluate the hydrochemical characteristics of groundwater in the aquifers in northwestern Kazakhstan to determine their possibility for pasture water supply. During the study, 85 groundwater samples were analyzed for the concentration of anions and cations, and total mineralization and Piper diagrams were used to assess the quality of groundwater for livestock watering. The hydrochemical analysis of water was carried out using chemical and physicochemical methods. The analysis of water samples from boreholes and shaft wells located within the Common Szyrt and the Pre-Szyrt ledge of the studied region revealing groundwater from Upper Pliocene under-Szyrt sands and the locally aquiferous lower and upper quaternary horizon of the upper part of the Szyrt stratum showed that in 17.2% of the sources, the water was highly brackish and in 10.3%, it was saltwater. In boreholes located within the Caspian lowland of the studied region, exposing groundwater of the Upper Pliocene Absheron deposits, water in 25.7% of the sources was highly brackish, and in 17.1%, it was saltwater. In a separate area, boreholes with heavily salted water were found that needed deep desalination. Despite the great diversity of the composition and mineralization of groundwater, the authors established patterns in changing hydrochemical parameters. They differed in different areas and aquifer complexes and depended on the water body feeding conditions, the intensity of water exchange, and the nature and composition of water-bearing rocks and water-soluble salts. The findings suggest that the intensive use of pasture lands in a region with poor freshwater availability is possible using technologies for the desalination of brackish and salt groundwater. Enhanced water quality will lead to better livestock health and productivity, contributing to higher agricultural output. This, in turn, will promote sustainable agricultural practices, reduce the pressure on scarce freshwater resources, and improve food security.

1. INTRODUCTION

Agriculture is the largest water consumption industry in the world: more than a third of agricultural water is used to produce animal products [1, 2]. Animal husbandry successfully develops with sufficient water supply for livestock and when farm animals can drink directly on pastures [3]. Sheep farming is prevalent in arid and semi-arid areas, with Asia and Africa hosting 42.6% and 31.7% of the global sheep population, respectively, out of a total of 1.2 billion. These regions primarily struggle with water scarcity [4, 5]. In arid and semi-arid pastures, water for animals is obtained from wells [6, 7]. Livestock breeders have to constantly change pastures due to lack of water [6]. In drought-prone areas like the semi-arid regions of the United States, South America, and Australia, groundwater serves as a crucial water source for grazing livestock. In Queensland's Great Artesian Basin, grazing is the primary land use, with groundwater extraction for livestock drinking water and domestic use accounting for an estimated 50% of total water production. It is anticipated that the pressure on global freshwater resources will intensify due to increased meat consumption [8-10].

Providing livestock with high-quality water has the same benefits as providing high-quality feed [11, 12]. Therefore, providing livestock with good-quality water should be an important component of pasture management [13]. Water quality is crucial for maintaining the quality of livestock products [14]. The presence of chemical compounds in concentrations exceeding permissible levels in water consumed by animals can reduce meat production and endanger animal health [15]. To establish water quality criteria for livestock in Argentina, Australia, New Zealand, the Canadian Council of Ministers of the Environment (CCME), and the Food and Agriculture Organization (FAO) have set maximum permissible values based on the presence of these compounds in groundwater [16, 17].

Understanding the hydrochemical properties of water in a semi-arid climate is essential for sustainable development and effective management of water resources [18]. Consequently, hydrochemical characterization of different water sources on a regional scale is crucial [19]. Hydrogeochemical studies elucidate the relationship between the chemical composition of water and the lithology of the aquifer [20-22].

Groundwater serves as a crucial alternative to meet freshwater demands, as it is more evenly distributed than surface water [23]. Groundwater resources are vital for food security, energy supply, and other essential needs [24]. The chemical composition of deep groundwater is influenced by its origin and the type of rock it interacts with. The primary solutes are rock-forming elements, with groundwater containing NaCl concentrations (equivalent) below 5,000 ppm being the most prevalent type [25].

The study area, northwestern Kazakhstan, was specifically chosen due to its significant agricultural potential and the critical role of groundwater in supporting livestock in this region [26, 27]. The area faces unique hydrogeological challenges, including uneven distribution of groundwater, varying degrees of mineralization, and limited flow rates from wells and boreholes. The topography, climatic factors, and geological structure further complicate water availability and quality [28].

The resource properties of groundwater garner significant attention due to the high demand for freshwater in human society. However, its overexploitation has led to numerous environmental issues [29]. In many regions, groundwater extraction has surpassed the replenishment rate from surface water and precipitation [30]. Acute water scarcity in aquifers is common in areas with concentrated irrigation, where groundwater serves as the primary irrigation source. The increasing demand for freshwater has resulted in a continuous decline in groundwater levels, as precipitation alone has been insufficient to replenish the deficit. Consequently, surface waters have begun to recharge groundwater reserves, reducing river runoff and potentially causing environmental impacts [31].

2. LITERATURE REVIEW

In studies on pasture water supply in the West Kazakhstan region, we performed an analysis of the state and problems of pasture water supply in the natural and climatic zones of the region [32-34]. The papers analyze the results of underground source monitoring for pasture water supply. They contain the results of laboratory hydrochemical analyses of water samples from underground water supply sources for pasture cattle-rearing sites.

The presence of groundwater with various degrees of mineralization is confirmed by the data from the survey of the territory [32-34]. Pasture water supply is one of the main conditions for the use of pasture lands for grazing farm animals [35].

Distant pastures in Kazakhstan are located mainly in desert and desert-steppe zones and are unproductive in their natural form, as they are poorly provided with water. Currently, only 32.6% of pastures in Kazakhstan are considered watered pastures, and significant areas of pasture lands are not used. The main source of water supply in pasture areas is groundwater. Its distribution is uneven, and the flow rates of boreholes, tube, and shaft wells are insignificant (0.1-1.5l/s) and have low water quality in terms of physicochemical composition. Of the total number of underground sources used for water provision and water supply, about 30% have slightly mineralized (up to 5g/l) or mineralized water (5-10g/l), and even though their flow rates are high, they are practically not used [36].

West Kazakhstan has great potential for a natural food supply, and, with its rational use, significant success can be achieved in the production of livestock products. The presence of significant pastureland with high productivity distinguishes the West Kazakhstan region among other regions in western Kazakhstan as a region with great prospects for the development of the livestock industry. The total area of the region's pastures is 10,144.1 thousand ha, which is 73.3% of the total territory of the region. The Kaztal district is one of the largest districts of the region in terms of pasture area (Figure 1).

The presence of significant pasture land makes it possible to keep cattle, using pasture cattle rearing in most areas of the region. Since the Kaztal district has the largest number of agricultural animal livestock in the region, this area was chosen as the focus of the study (Figure 2).

The formation of groundwater, its distribution, depth of occurrence, qualitative composition, and amount of resources are influenced by surface topography, climatic factors, surface runoff, geological structure, and hydrogeological features of the territory.

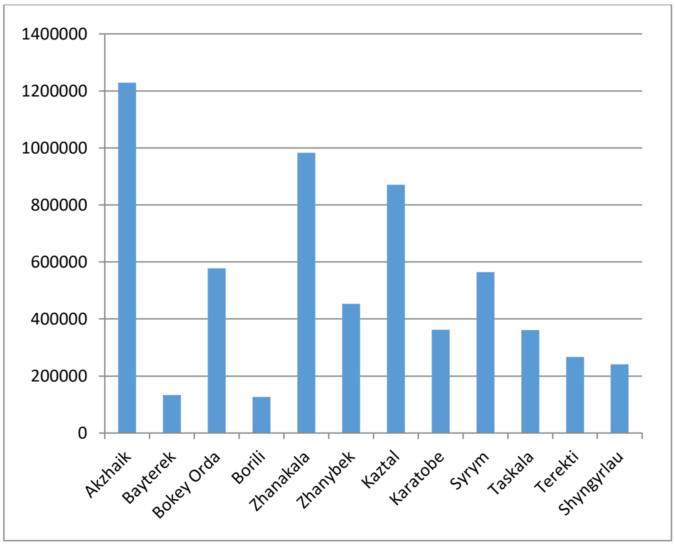


Figure 1. Pasture areas of the West Kazakhstan region, ha

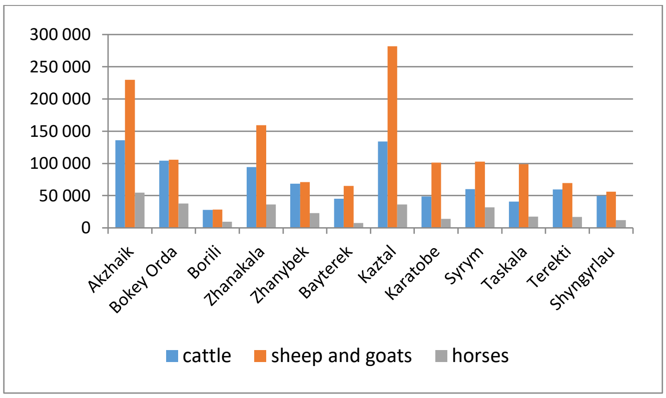


Figure 2. Farm animal livestock in the districts of the West Kazakhstan region

The most promising and used aquifers for pasture water supply in the Kaztal district are the upper quaternary marine Khvalynsky aquifer, the locally aquiferous lower-upper quaternary horizon of the upper part of the Szyrt stratum, the Upper Pliocene subsurface aquifer, the Upper Pliocene Absheron aquifer, and the Upper Pliocene Akchagyl aquiferous horizon.

Aquifers of marine sediments of the Caspian transgressions are distributed mainly within the Caspian lowland of the studied region. The groundwater here is confined to interlayers and lenses of mixed-grained sands with a non-uniform area. The waters lie at depths from 3-5m in depressions (estuaries, potholes, sandy plains, etc.) to 15-20m in elevated areas. In the near-Szyrt plains, the waters open at a depth of 7-25m. The strong salinity and poor washing of the Caspian sediments, and the presence of numerous salt marshes, salt lakes, and salt domes cause high mineralization of groundwater (from 10 to 300g/l or more). Fresh and slightly saline waters (1-3g/l) formed by infiltration of atmospheric precipitation lie mainly along the outer margin of the Caspian lowland at depths of 2-10 m on an area of about 40-50 thousand km^2.

The aquifer complex of undifferentiated quaternary and combined upper-lower quaternary and Pliocene sediments occupies Common Szyrt and a strip of the pre-Szyrt ledge of the studied area. The total thickness of Szyrt deposits varies from 10-20m on the slopes of valleys to 55m on watersheds. At the base of the Szyrt stratum, one or two aquifers are deposited in fine-grained, rarely multi-grained quartz sands, with a total thickness of 1-2 to 6-10m. In addition to these ("sub-Szyrt") sands, layers of aquifer sands and sandy loams at depths from 10-15 to 20-35m are found in the sediments of the pre-Szyrt ledge.

In the northeastern part of the Common Szyrt, the pre-Szyrt sands do not have a continuous distribution and are often replaced by interlayers of sandy clays with interlayers of gravel, light gravel, and sand nests. Groundwater has a sporadic distribution here. In the rest of the territory, where the aquifer of the Szyrt stratum is hydraulically connected to the waters of the Pliocene, it is well maintained along the course and in some places has a pressure up to 5-12m. The thickness of the aquifer is insignificant and rarely reaches 10m.

Pliocene deposits occupy the western and central parts of the Caspian Basin (the Caspian lowland, Szyrt, and Pre-Szyrt regions), where they are mainly represented by terrigenous, and along the sides of the depression by continental deposits of Akchagylian and Absheron layers. Groundwater is mainly pressurized and is captured in the studied area by tube wells (boreholes). Within the limits of the Common and Trans-Ural Szyrt, the pressure height varies from 8 to 100m, and in the Caspian lowland up to 150-200m or more. The water levels in the boreholes are set at depths from 5 to 40m. One of the most important zoohygienic factors contributing to the preservation of health and increased productivity of animals is uninterrupted watering with sufficient quantities of good-quality drinking water.

However, groundwater resources of adequate quality in the locations of pasture livestock rearing in the northwestern part of Kazakhstan are very limited. Administratively, the shortage of water resources is most acute in the pasture lands of the Kaztal district of the West Kazakhstan region.

Thus, to determine the possibility of using groundwater to water pastures in the northwestern part of Kazakhstan, we set a goal to study the hydrochemical characteristics of groundwater aquifers in the pastures of this region.

3. MATERIALS AND METHODS

These studies were conducted in 2023. The objects under study were underground water sources for water supply to the pasture cattle rearing sites in the Kaztal district of the West Kazakhstan region. In most of the region, groundwater is used to water pastures.

In the surveyed area, the sources of livestock watering are shaft wells and tube wells (boreholes). Water samples were taken from 85 boreholes and shaft wells in the study area to study the quality of groundwater (Table 1).

Table 1. Composition of the study samples

District/Area	Number of Samples	Source Type
Karaoba rural area	4	Wells
	2	Boreholes
Kushankul rural area	7	Boreholes
	8	Wells
Kayindy rural area	1	Boreholes
	4	Wells
Taldykuduk rural area	1	Boreholes
Bolashak rural area	2	Wells
Akpater rural area	1	Boreholes
Kaztal rural area	2	Boreholes
	1	Wells
Terenkul rural area	9	Boreholes
	4	Wells
Brik rural area	10	Boreholes
	7	Wells
Bostandyk rural area	8	Boreholes
	4	Wells
Zhanazhol rural area	1	Boreholes
	1	Wells
Kukterekrural area	2	Wells
Karasu rural area	1	Boreholes
Taldyapan rural area	1	Boreholes
	2	Wells
Karauzen rural area	2	Wells

Table 2. Indicators of surveyed boreholes and wells of the Kaztal district of the West Kazakhstan region

Water Sources	Quantity, Pieces	Depth, m	Diameter, m (mm)	Debit, dm^3/s	Mineralization, g/dm^3
Shaft wells	39	4.0-21.58	1.0-2.0m	0.06-2.0	0.34-86.92
Boreholes	46	20-93	114-202mm	0.4-3	0.4-41.3

Samples were taken directly from wells and shaft wells that were used for watering livestock. The location of each water sample was recorded using a GPS device (Garmin eTrex 10). Water sampling was carried out according to the regulatory document "Nature Protection. The hydrosphere. Devices and tools for sampling, primary processing, and storage of natural water samples" regulated in the Republic of Kazakhstan for sampling water from springs. Water samples were collected in new plastic bottles that had been washed three times on site with the same sampling water, after a significant pumping time (more than 30 minutes) to avoid stagnation and contamination of groundwater in wells, then filled and immediately closed to avoid exposure to air. Each bottle was labeled to identify it. If the delivery of samples to the laboratory was delayed for more than 24 hours, the water samples were preserved.

When examining water sources, the following source parameters were determined: the flow rate of the source, the depth of the well, and the diameter of the borehole casing (Table 2).

To assess underground water sources crucial for supplying water to pasture cattle rearing sites, we analyzed laboratory hydrochemical data from water samples. Water samples from these underground sources were collected to measure parameters such as total mineralization, and the concentrations of carbonate, bicarbonate, chloride, sulfate, calcium, magnesium, sodium, and potassium ions. These specific ions were chosen due to their significant impact on water quality and livestock health. High levels of certain ions, such as chlorides and sulfates, can reduce water palatability and have laxative effects on animals [37]. Similarly, elevated concentrations of calcium and magnesium can affect animal growth and productivity.

The hydrochemical analysis was performed using chemical and physicochemical methods. The method for determining the chloride content was based on the precipitation of chlorine ions in a neutral or slightly alkaline medium with silver nitrate in the presence of potassium chromate as an indicator.

Total mineralization levels were analyzed to understand the overall salinity of the groundwater, as high mineralization can render water unsuitable for livestock consumption without desalination. The selected ions and mineralization levels are standard indicators of water quality used in hydrochemical studies and align with guidelines set by international organizations such as the Canadian Council of Ministers of the Environment (CCME) and the Food and Agriculture Organization (FAO) [38].

The approximate content of chlorine ions was determined by sediment or turbidity. The chlorine ion content (mg/l) was determined by calculation. The method for determining the sulfate content was based on the precipitation of sulfate ions in a hydrochloric acid medium with barium chloride in the form of barium sulfate. The content of sulfates (mg/l) was determined by calculation. Carbonates and bicarbonates were determined by the titrimetric method. Carbonates and bicarbonates in terms of the mass of carbonate and bicarbonate ions were determined by sequential titration visually with such indicators as phenolphthalein and methyl orange. The mass concentrations of carbonates and bicarbonates in mg/dm^3 were determined by calculation. Calcium determining method: Calcium was titrated in an alkaline medium (pH=12) with a solution of trilon B with murexide as an indicator. The mass concentration of calcium in mg/dm^3 was determined by calculation. In the complexometric method for the determination of magnesium in the presence of calcium, the sum of calcium and magnesium was titrated with a solution of trilon B in the presence of an ammonium-ammonia buffer solution (pH=9-10) with black chromogen as an indicator. When processing the results, the volume of the trilon B solution consumed for the determination of calcium by the calcium determination method was considered. The mass concentration of magnesium in mg/dm^3 was determined by calculation. The determination of Na+ and K+ was carried out by calculation in mg/l.

According to the Sanitary Rules and Regulations (SanPiN) No. 209 "Sanitary and epidemiological requirements for water sources, places of water intake for household and drinking purposes, household and drinking water supply and places of cultural and domestic water use and safety of water bodies", approved by Order No. 209 of the Ministry of National Economy of the Republic of Kazakhstan dated March 16, 2015, permissible concentration in water samples should not exceed 350mg/l for chloride, 600mg/l for sulfate, 150mg/l for calcium, and 100mg/l for magnesium.

4. DATA ANALYSIS

Analytical, statistical, and laboratory hydrochemical (spectrophotometric) research methods were used to assess the qualitative characteristics of groundwater. When working on the paper, we performed a comparative analysis of the obtained information. Statistical data analysis was carried out using the Excel 2010 Analysis Package.

The classification of hydrochemical facies of the selected water samples from the study area was analyzed and presented graphically on the Piper diagram to display the main chemical components of the waters. The Piper diagram is a widely used graphical representation in hydrochemical studies to display the chemical characteristics of water samples. It consists of two triangular fields, each representing the composition of cations and anions, and a diamond-shaped field representing the combined composition. This method allows for a clear visualization of the water types and comparison of hydrochemical data across different samples. The Piper diagram helps in identifying hydrochemical facies, understanding the geochemical evolution of groundwater, and comparing the water quality of different sources within the study area [39].

The trilinear Piper diagram is used to graphically represent the chemical composition of water samples. This diagram considers the percentage values of six ionic groups: calcium, magnesium, and sodium plus potassium cations, along with sulfate, chloride, and carbonate plus bicarbonate anions. To compare waters with different mineralization levels and obtain proportional values, the number of milligram equivalents is converted into percentage equivalents. The water composition is listed in ascending order, from low-content ions to predominant ions, starting with anions and then cations. The results of the hydrochemical analysis of underground water sources are displayed in Piper diagrams using the graphical method in Excel. These diagrams illustrate the degree of mineralization and the salt composition of the underground water sources.

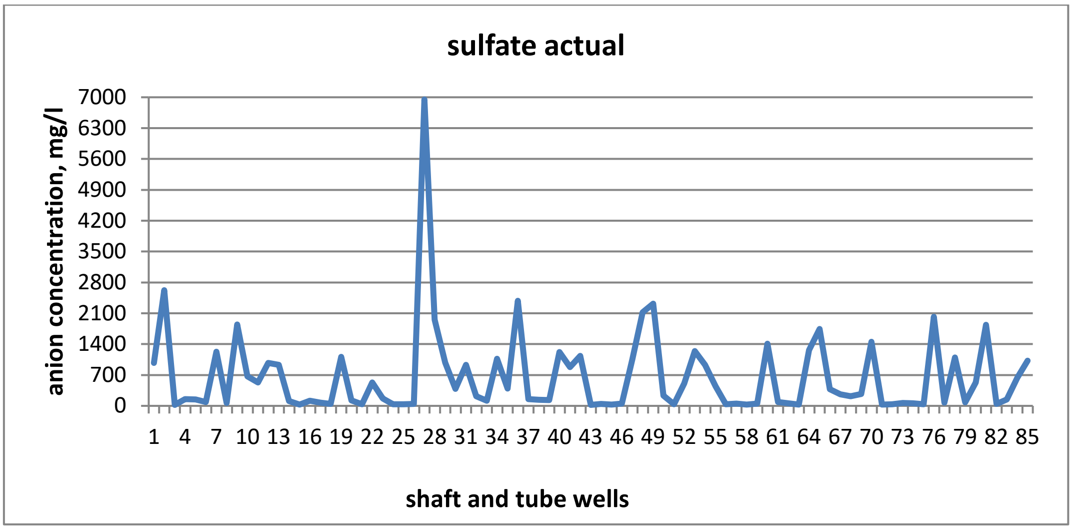
5. RESULTS

The concentrations of cations and anions, as well as the mineralization of water source samples, are shown in Figures 3-5.

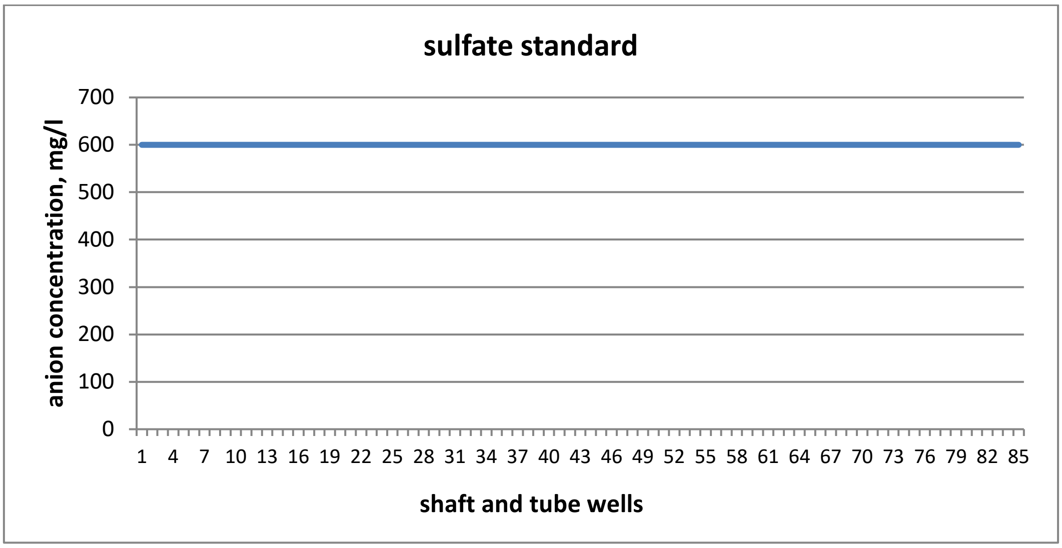
As the results shows in the Figures 3-5, Boreholes and wells: 1-4: boreholes; 5, 6: wells (Karaoba rural area); 7-13: boreholes and 14-21: wells (Kushankul rural area); 22: borehole and 23-26: wells (Kayyndin rural area); 27, 28: wells (Bolashak rural area); 29: borehole (Taldykuduk rural area); 30: borehole (Akpater rural area); 31, 32: boreholes and 33: well (Kaztal rural area); 34-42: boreholes and 43-46: wells (Terenkul rural area); 47-56: boreholes and 57-63: wells (Brik rural area); 64-71 boreholes and 72-75: wells (Bostandyk rural area); 76: borehole and 77: well (Zhanazhol rural area); 78, 79: wells (Kukterek rural area); 80: borehole (Karasu rural area); 81: borehole and 82, 83: wells (Taldyapan rural area); 84, 85: wells (Karauzen rural area).

Boreholes and wells: 1-4: boreholes; 5, 6: wells (Karaoba rural area); 7-13: boreholes and 14-21: wells (Kushankul rural area); 22: borehole and 23-26: wells (Kayyndin rural area); 27, 28: wells (Bolashak rural area); 29: borehole (Taldykuduk rural area); 30: borehole (Akpater rural area); 31, 32: boreholes and 33: well (Kaztal rural area); 34-42: boreholes and 43-46: wells (Terenkul rural area); 47-56: boreholes and 57-63: wells (Brik rural area); 64-71 boreholes and 72-75: wells (Bostandyk rural area); 76: borehole and 77: well (Zhanazhol rural area); 78, 79: wells (Kukterek rural area); 80: borehole (Karasu rural area); 81: borehole and 82, 83: wells (Taldyapan rural area); 84, 85: wells (Karauzen rural area).

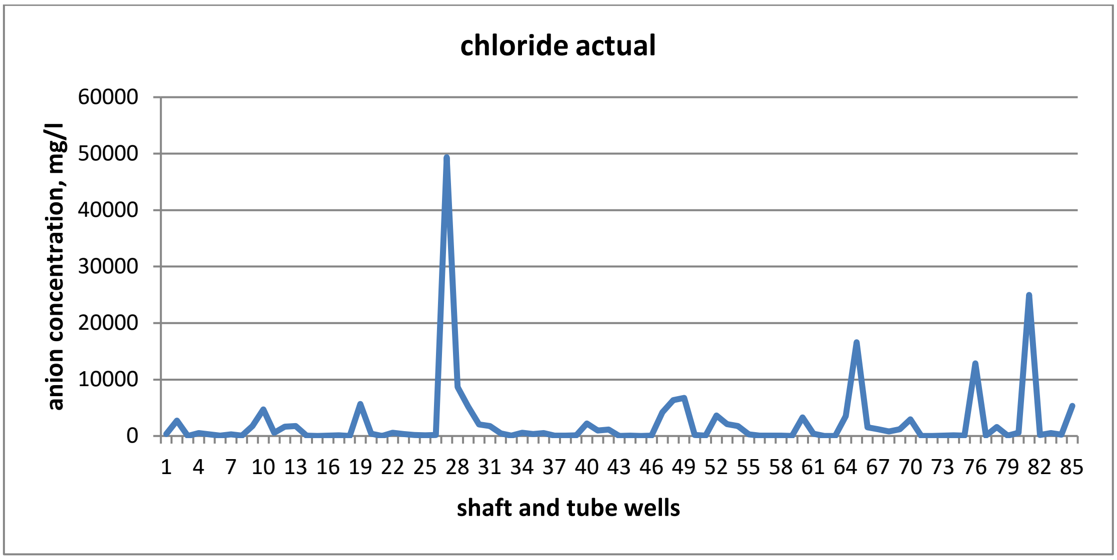
Boreholes and wells: 1-4: boreholes and 5, 6: wells (Karaoba rural district); 7-13: boreholes and 14-21: wells (Kushankul rural area); 22: borehole and 23-26: wells (Kayyndin rural area); 27, 28: wells (Bolashak rural area); 29: borehole (Taldykuduk rural area); 30: borehole (Akpater rural area); 31, 32: boreholes and 33: well (Kaztal rural area); 34-42: boreholes and 43-46: wells (Terenkul rural area); 47-56: boreholes and 57-63: wells (Brik rural area); 64-71 boreholes and 72-75: wells (Bostandyk rural area); 76: borehole and 77: well (Zhanazhol rural area); 78, 79: wells (Kukterek rural area); 80: borehole (Karasu rural area); 81: borehole and 82, 83: wells (Taldyapan rural area); 84, 85: wells (Karauzen rural area).



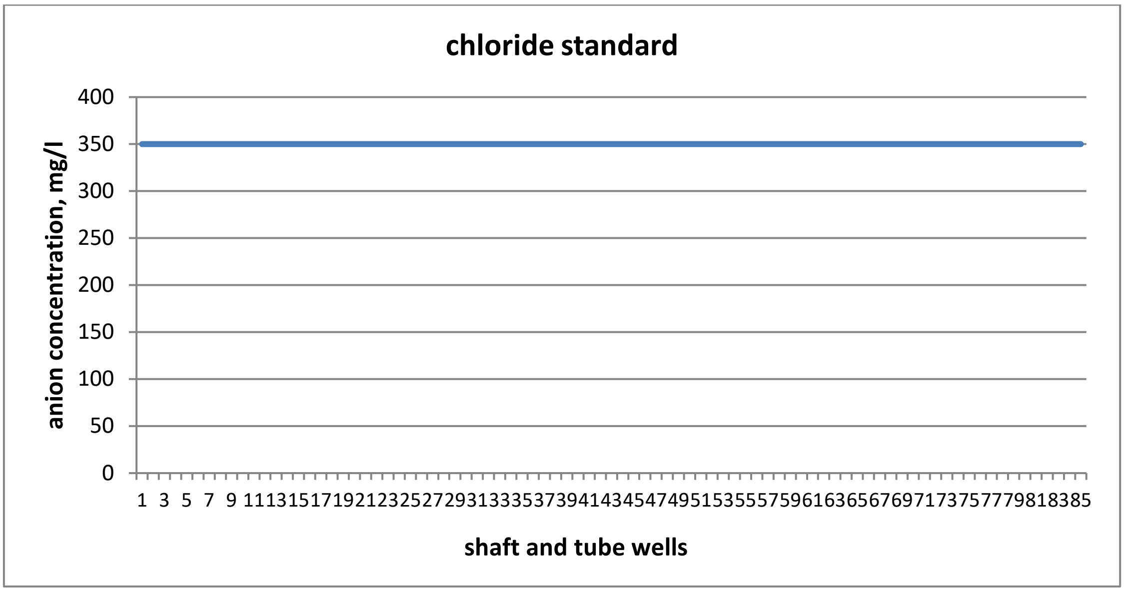
A



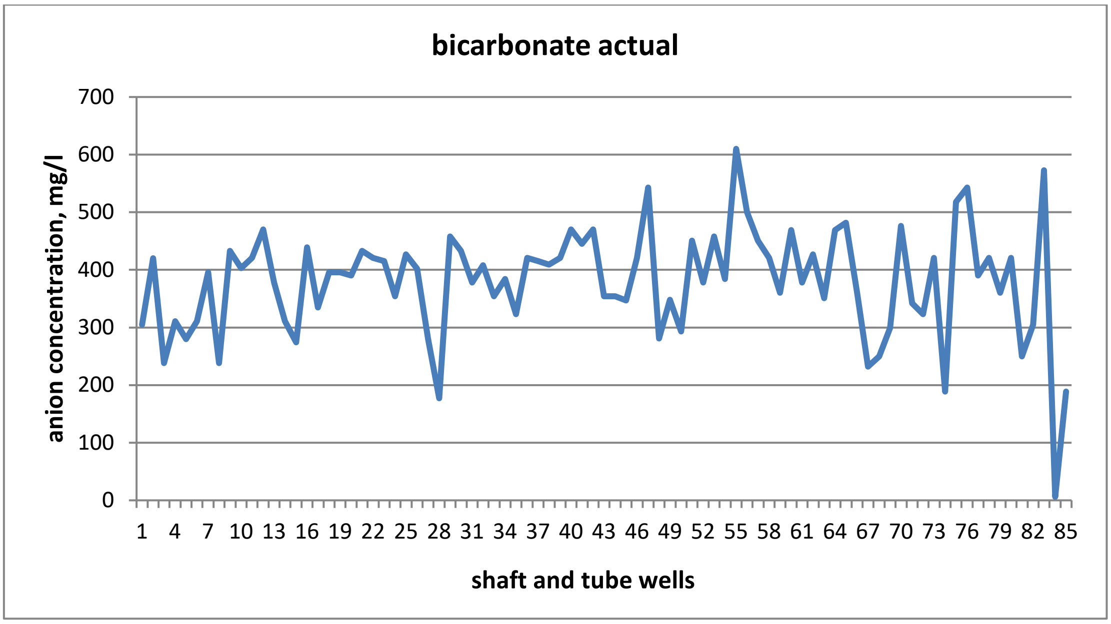
B



C

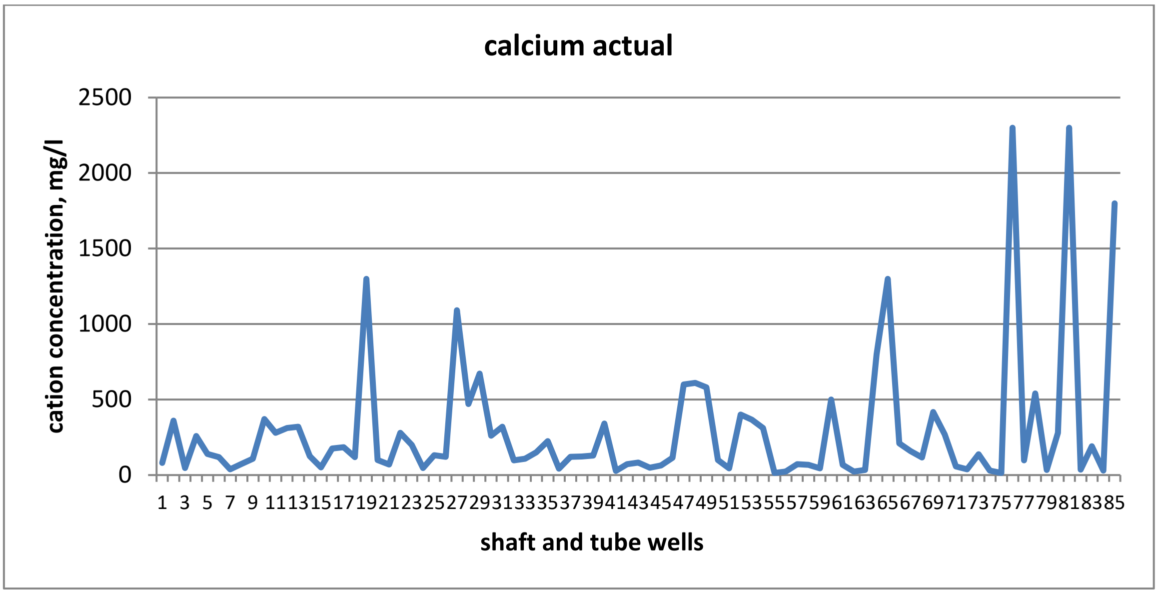


D

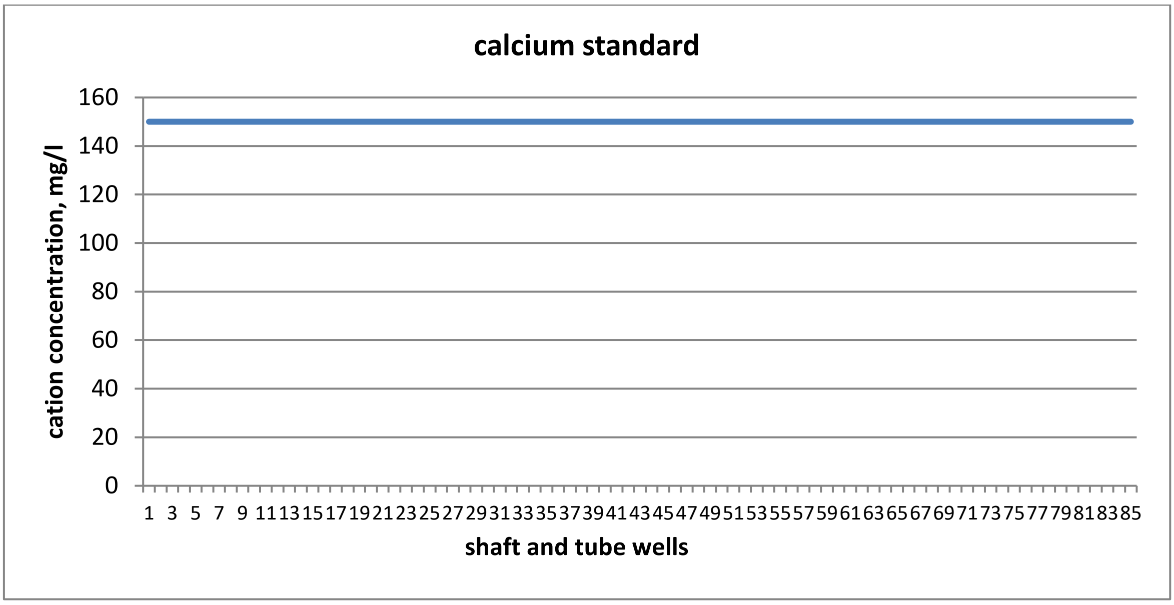


E

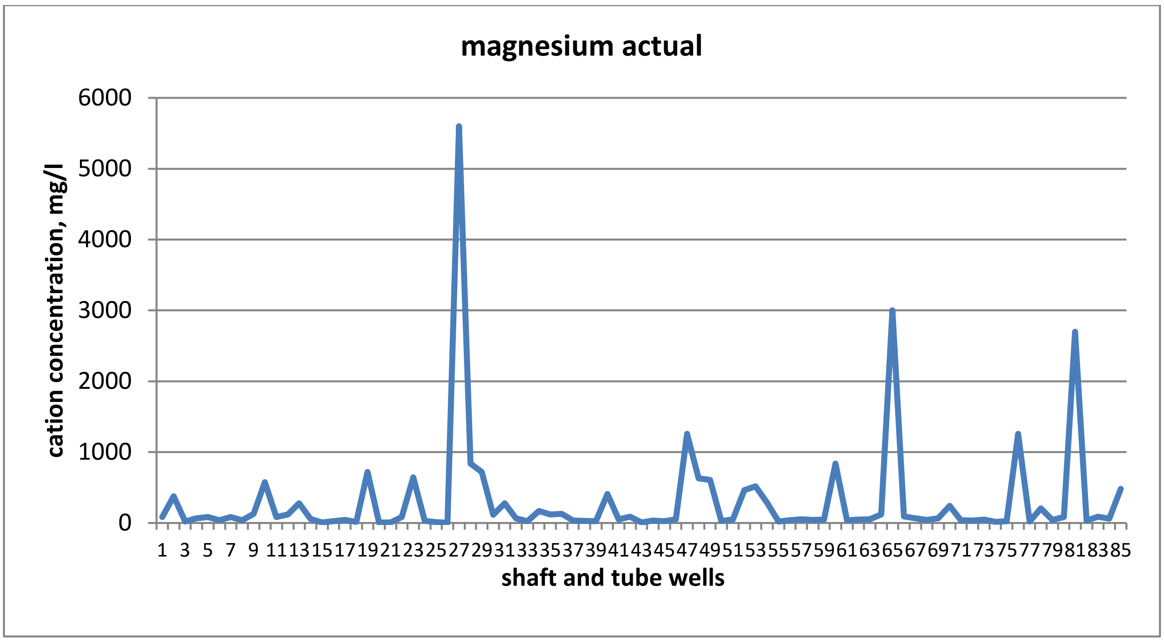
Figure 3. (A, B, C, D, E)-Concentrations of different anions in water samples (mg/l)


calcium actual
cation concentration, mg/l
2500
2000
1500
1000
500
0
1 3 5 7 9 1113151719212325272931333537394143454749515355575961636567697173757779818385
shaft and tube wells

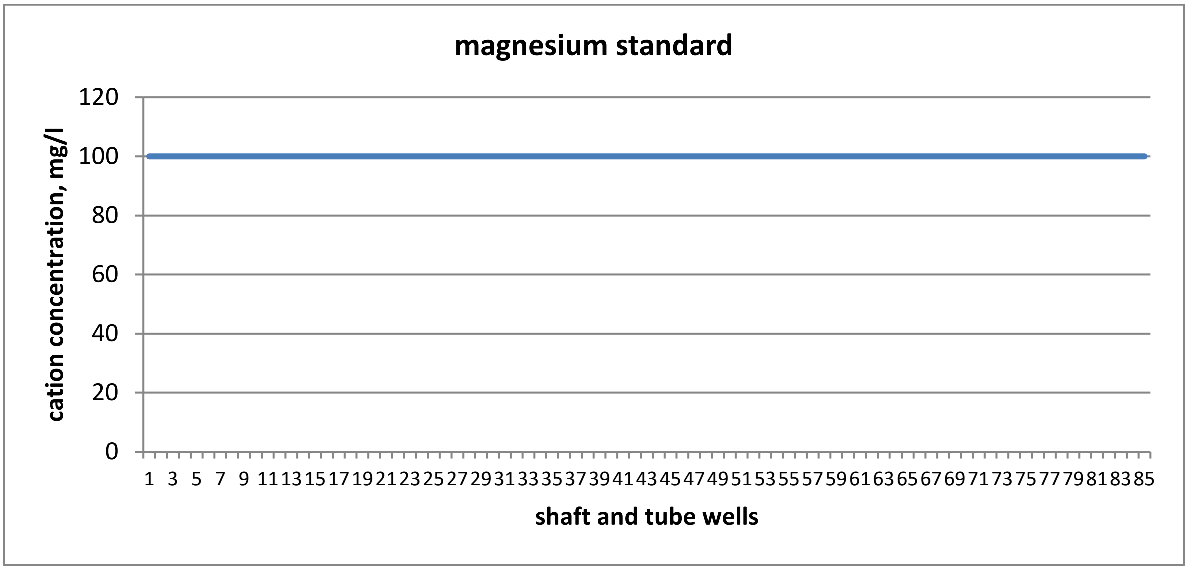
A


calcium standard
cation concentration, mg/l
160
140
120
100
80
60
40
20
0
1 3 5 7 9 1113151719212325272931333537394143454749515355575961636567697173757779818385
shaft and tube wells

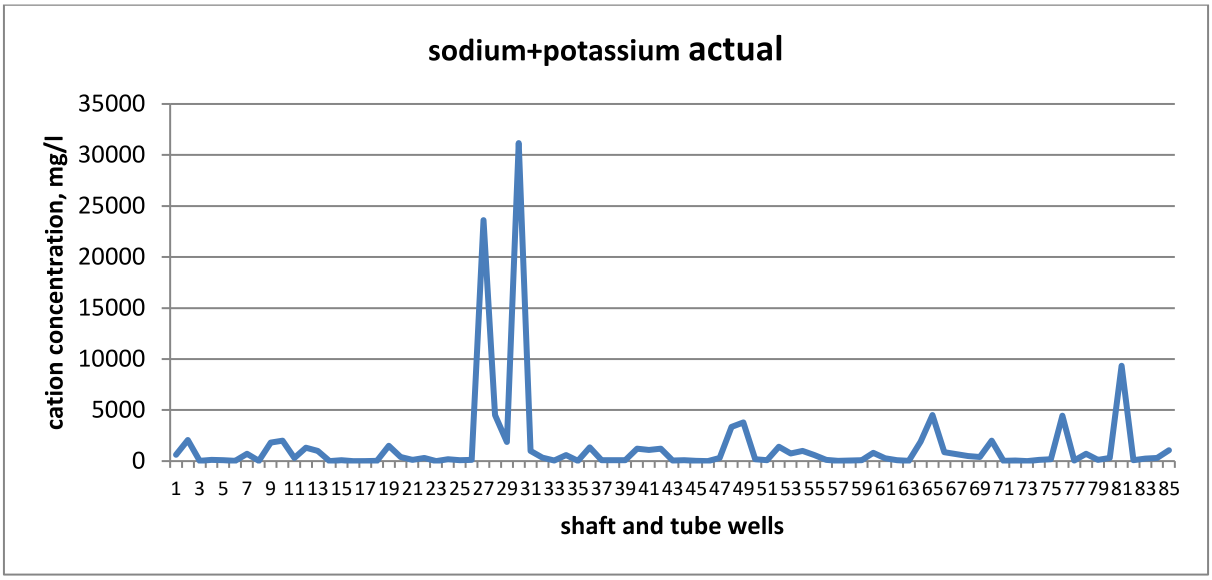
B


magnesium actual
cation concentration, mg/l
6000
5000
4000
3000
2000
1000
0
1 3 5 7 9 1113151719212325272931333537394143454749515355575961636567697173757779818385
shaft and tube wells

C

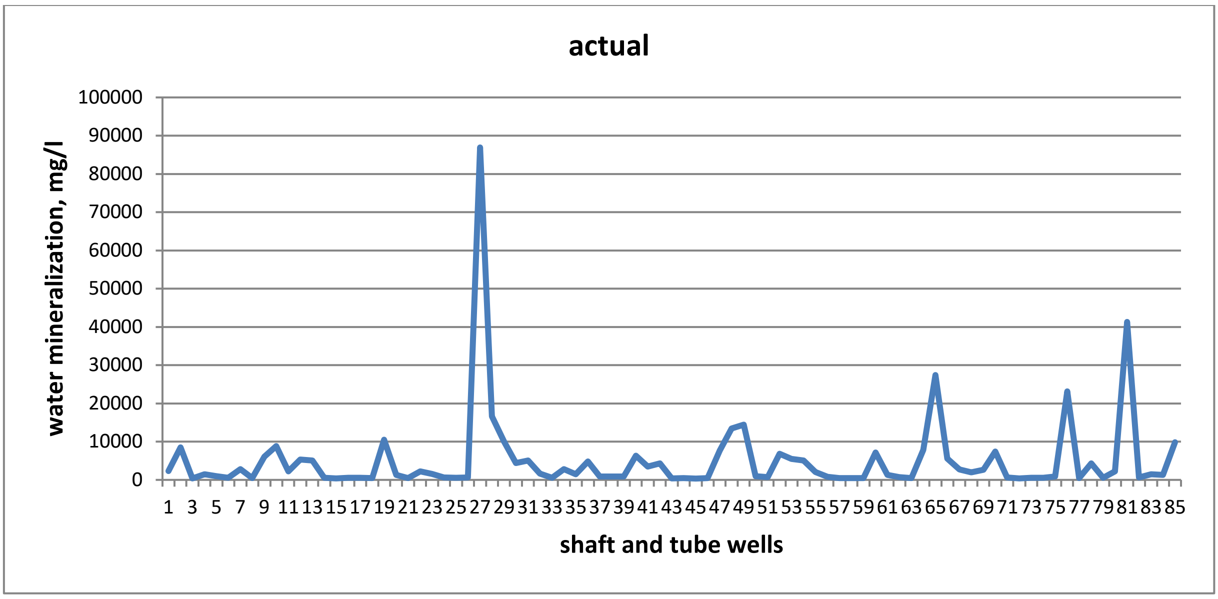


D

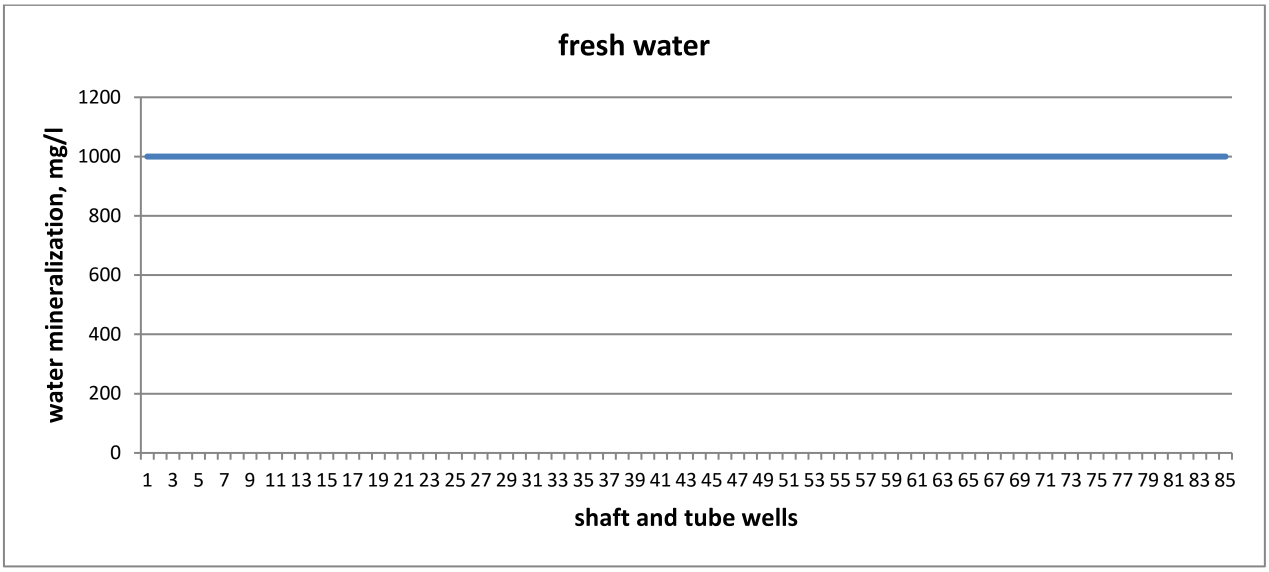


E

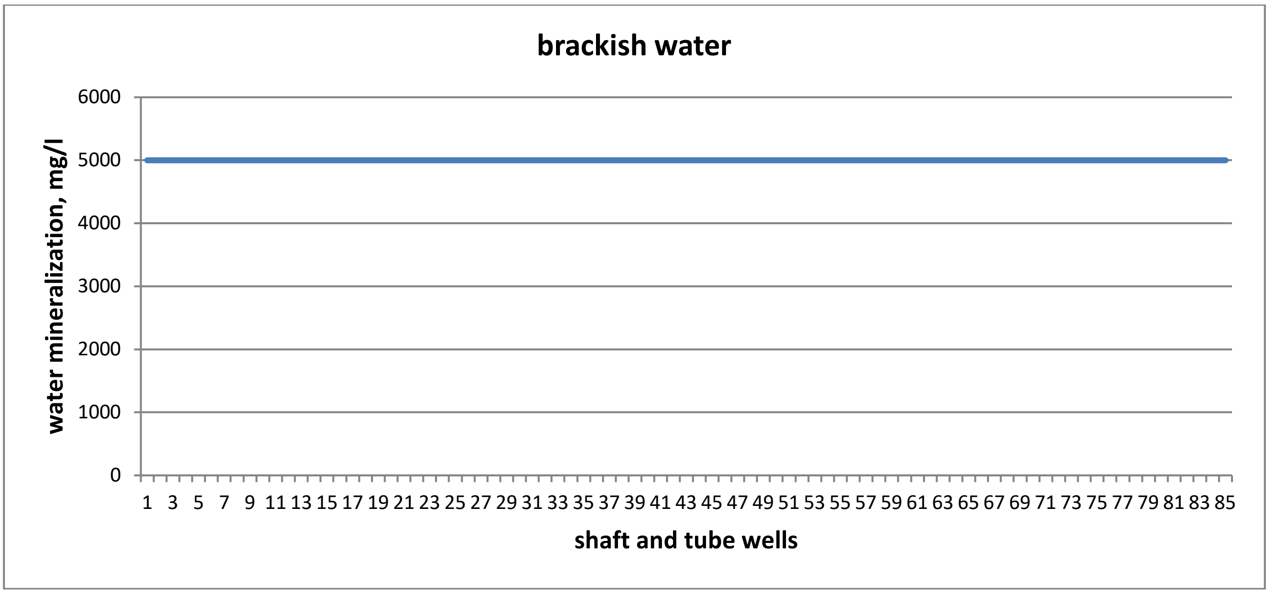
Figure 4. (A, B, C, D, E)-Concentrations of different cations in water samples (mg/l)



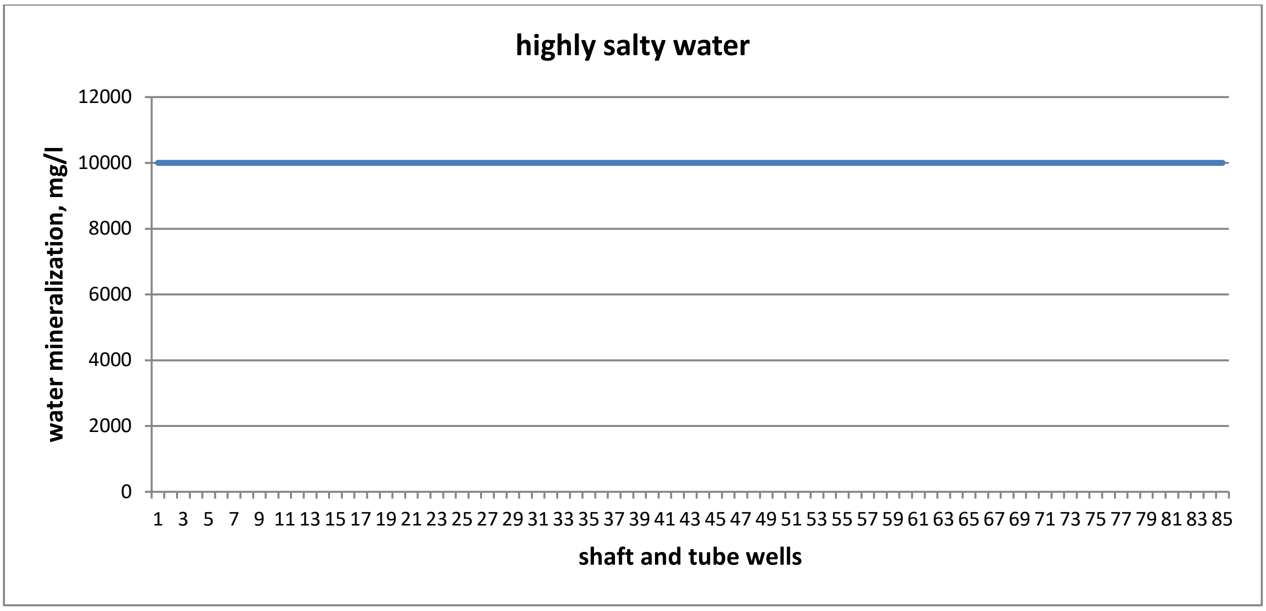
A



B



C



D

Figure 5. (A, B, C, D)-Mineralization of water samples (mg/l)

However, the results of laboratory chemical analyses of the concentrations of anions and cations in water samples taken in the study area show that the concentration of bicarbonate in water samples varies from 6.1mg/l to 610mg/l, from 23.7mg/l to 49,368mg/l for chloride, from 21.8mg/l to 6,949mg/l for sulfate, from 14mg/l to 2,300mg/l for calcium, from 4.2mg/l to 5,600mg/l for magnesium, and sodium and potassium concentrations in total in all water samples varies from 0mg/l to 31,164mg/l. Thus, a significant number of underground sources are characterized by exceeding the normative indicators for these elements.

Of the surveyed boreholes and shaft wells located within the Common Szyrt and the Pre-Szyrt ledge of the studied region, where groundwater from the Upper Pliocene subsurface sands and the locally aquiferous lower-upper quaternary horizon of the upper part of the Szyrt column is used, the water in 44.8% of the sources is fresh in terms of mineralization, 27.5% it is brackish, in 17.2% highly brackish, and in 10.3% it is saltwater.

From the surveyed shaft wells located within the Caspian lowland of the studied region, where the groundwater of the upper Quaternary marine Khvalynsky deposits is used, the water of the sources is mainly fresh in terms of mineralization.

Of the surveyed boreholes located within the Caspian lowland of the studied region, where groundwater from the Upper Pliocene Absheron deposits is used, the water in 22.8% of the sources is fresh in terms of mineralization, in 34.2% it is brackish, in 25.7% highly brackish, and in 17.1% it is saltwater.

The classification of hydrochemical facies of selected water samples from the study area analyzed in the Piper diagram is shown in Figure 6.

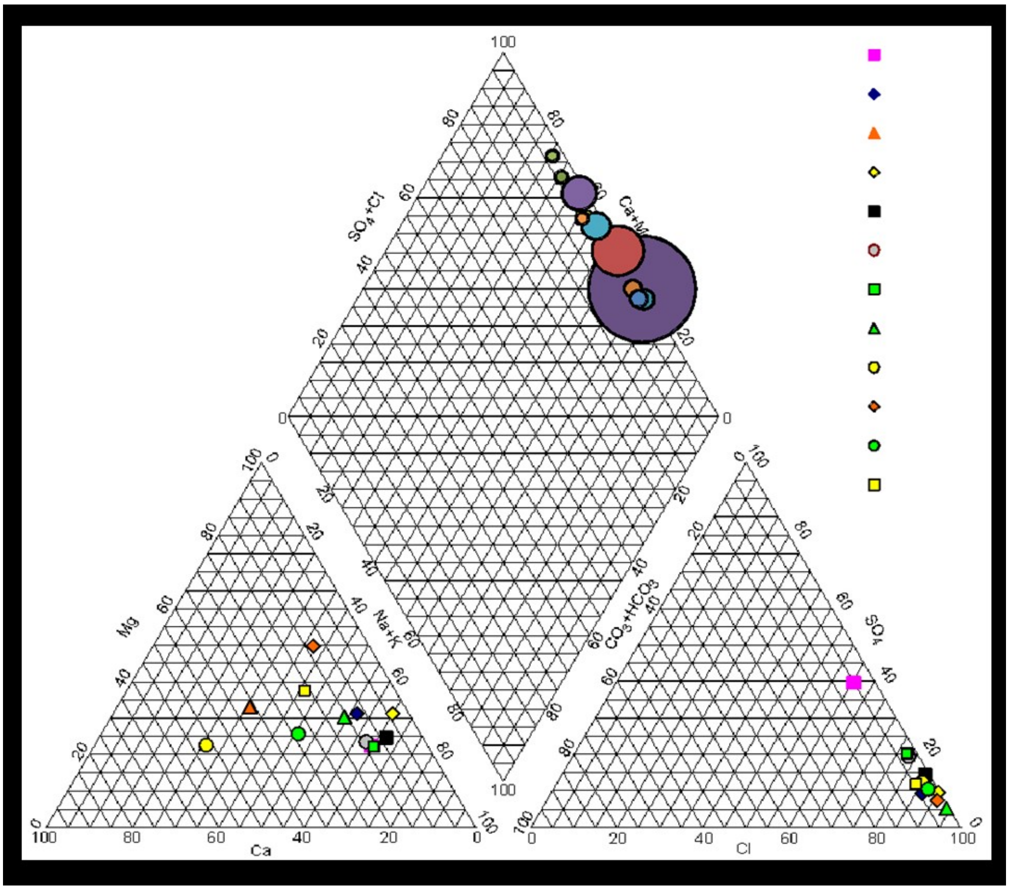


Figure 6. Chemical characterization of the most heavily mineralized waters of boreholes and wells in the Kaztal district

In Figure 6, Boreholes and wells: F1: borehole (Karaoba rural district); F2, F3: a borehole and a well (Kushankul rural area); F4, F5: wells (Bolashak rural area); F6, F7: boreholes (Brik rural area); F8: borehole (Taldyapan rural area); F9: well (Karauzen rural area); F10: borehole (Bostandyk rural area); F11: borehole (Zhanazhol rural area); F12: borehole (Taldykuduk rural area).

The collected samples of the most highly mineralized waters from the studied area were plotted on the Piper diagram, which shows that the main cation in the water samples is sodium and potassium in total. In all collected water samples, the main anion is chloride. As can be seen from Figure 6, the water of the borehole located in the Pashka wintering area (F8) is magnesium and sodium chloride water in terms of salt composition, the water from the Shunkyrkul (F10) and Aykhan (F12) wintering areas contains sodium/magnesium chloride, the water from Narolgen (F11) wintering area contains magnesium/calcium/sodium chloride, the water from the Akbot (F1), Temirlan (F2), Kadyrbolat (F6), and Aizhanar wintering areas (F7) contains sodium chloride, the water from the Karakaduk wintering area well (F3) contains magnesium/sodium/calcium chloride, the water from the Akkurai wintering area (F4, F5) contains sodium/magnesium chloride, and the water from Kazkuduk wintering area (F9) contains calcium/sodium chloride.

6. DISCUSSION

The organization of pasture water supply is directly dependent on the availability of water resources. Hydrochemical analysis of water samples allows for the assessment of the suitability of these water sources for supplying water to pasture lands.

Despite the great diversity of the composition and mineralization of groundwater, we established patterns in the change of hydrochemical parameters, which, depending on the water body feeding conditions, the intensity of water exchange, the nature and composition of water-bearing rocks and water-soluble salts, are not the same in different areas and aquifer complexes.

Poor water quality can negatively impact water and feed intake, nutrient utilization, and overall animal health and productivity. Reliable water quality assessments are essential initial information sources for identifying potential water quality issues. Cows and young calves at the onset of lactation are sensitive to poor water quality, such as high mineralization and increased sulfate concentrations, which can result in inadequate water consumption, poor growth, or reduced lactation performance.

According to research results, the maximum values of water quality parameters allowed for watering farm animals are as follows: calcium and chlorides: 100mg/l, magnesium, sodium, and sulfates: 50mg/l, potassium: 20mg/l, bicarbonates: 1,000mg/l, and mineralization: 960mg/l. Concentrations above which problems may occur in farm animals have the following limits: bicarbonates: 1,000mg/l, calcium: 200 and more than 500mg/l, sodium: 300mg/l for all types of livestock [10], 20mg/l for calves, chlorides: 300mg/l, sulfates: 300 and more than 2,000mg/l, magnesium: 100 and more than 125mg/l, potassium: 20mg/l, and mineralization: 3,000 and more mg/l [40-42].

Relatively high concentrations of sodium, potassium, and calcium in natural waters are generally not considered problematic for cattle and sheep. The presence of salts of alkaline earth metals like calcium or magnesium in drinking water is desirable since calcium and magnesium salts are necessary for the animal body. They give the water a certain taste and to an extent prevent its contamination. However, a high content of these salts is undesirable. Studies of the concentration and effect of chlorides on the animal body show that disturbances in the physiological reactions of the body are possible only with fairly large amounts of these elements in water (500mg/l or more). Sulfates give the water a bitter taste and have a laxative effect at elevated concentrations (750mg/l or more). High concentrations of sulfates (1,000mg/l) can cause disorders of the secretory activity of the stomach, digestion, and absorption processes. The concentration of sulfates in drinking water is allowed in the range of no more than 500mg/l [30].

Despite the significant attention given to other essential nutrients by animal scientists and livestock breeders, water quality has not been adequately studied. Most discrepancies in water quality recommendations arise from the limited information on the effects of different concentrations of drinking water on ruminant health and productivity [43]. Mineral element concentrations, a partial indicator of water quality, vary significantly not only across the country but also within specific geographical regions. Natural groundwater and surface waters, often unsuitable or suboptimal for human consumption due to high concentrations of chemical compounds (e.g., certain mineral elements), are already used in animal husbandry [40-42]. This trend is expected to become more prevalent in the future. Therefore, it is crucial to understand whether and how lower-quality water can be utilized or treated, or both, to make it suitable for the livestock industry without compromising animal health, productivity, or possibly product quality (e.g., dairy products) [44, 45].

In studies of water supply for pasture lands in the West Kazakhstan region, the problems of pasture water supply were most severe in the semi-desert zone, where a significant portion of pastures was underutilized due to the lack of drinkable water. In pasture livestock rearing, the most accessible water supply is surface water. The highest density of surface water sources for pasture water supply is found in the steppe and dry steppe zones of the region. Approximately half of the region requires additional water supply for pasture lands. Many farms rely on shaft wells drilled over 40 years ago, which have low flow rates (0.01-0.09 l/s). In some farms, boreholes drilled in recent years for livestock watering have high water mineralization levels (up to 41,300mg/dm3) and are not used due to unsuitability, leading to an acute shortage of suitable water for livestock [46]. It can be seen from previous studies that, along with measures contributing to the improvement and development of pasture cattle rearing, which can be used for water supply pastures and are certainly of great importance at present in the Kaztal district, the problem of highly mineralized underground water sources remains unresolved. Pastures in rural districts are not in common use, and each farm has the boundaries of its pastures. The animals do not have the opportunity to move from their pastures to others in search of water suitable for livestock. Therefore, the farmers must solve the water problem in their pastures based on the available water resources. In many farms, groundwater is highly mineralized, and in this situation, desalination is the solution to the problem. The territories of Western Kazakhstan with groundwater resources suitable for domestic drinking water supply with a predominant mineralization of up to 1g/l equals 144.2 thousand km^2 (19.8% of the total area of the region). The territories with groundwater resources that are conditionally suitable for domestic drinking water supply without desalination and everywhere with desalination with a mineralization of up to 3g/l, is estimated at 142.5 thousand km^2 (19.6%); and the area with groundwater resources suitable for domestic drinking water supply with pre-desalination with a mineralization of more than 3g/l equals 269.4 thousand km^2 (37.0%). The area of the places with the predominant distribution of unpromising aquifers and groundwater with a mineralization of more than 10g/l or practically waterless territories equals 172.58 thousand km^2 (23.7%). During the monitoring of boreholes, it was observed that about 31% of boreholes in the Kaztal district of the region were not being operated due to the high mineralization of groundwater. To solve the problems of the development of pasture cattle rearing, there is a need for the rational use of groundwater, including mineralized water, after desalination by various methods that do not require significant energy costs. In this case, it is possible to supply the source water with a mineralization of 2-7g/l to the watering place of animals without treatment. According to hydrochemical indicators, brackish and saltwater springs need filtration and desalination, while deep desalination is necessary for boreholes with heavily salted water.

The restoration of the water infrastructure due to the widespread use of groundwater will increase the area of pastures with sufficient feed productivity for the maintenance of beef cattle on them.

Studies of water sources for pasture supply allow us to state the direction of pasture land water supply due to the use of easily accessible groundwater from the surface of aquifers.

7. CONCLUSIONS

Thus, the vast territory of northwestern Kazakhstan, covering the Kaztal district of the West Kazakhstan region, with its rich pasture lands, has favorable conditions for the intensive development of pasture cattle rearing. These are prerequisites for the successful development of the area.

For the intensive development of pasture cattle rearing, it is necessary to take measures to effectively use pasture lands and provide them with water resources. Underground water sources play an important role in providing water supply to pasture lands in the region. Despite the significant diversity of chemical composition and degree of mineralization, there are significant reserves of groundwater located at various depths and aquifers. Many boreholes and wells with highly mineralized waters require desalination of water, since there is no alternative source of water for watering livestock in these pastures.

Future research should establish long-term monitoring programs to track changes in groundwater quality and quantity over time, assessing the effectiveness of implemented desalination technologies. Comprehensive studies on the impact of improved water quality on livestock health, productivity, and product quality, including meat and dairy, are needed.

Improving water quality for livestock has the potential to significantly enhance agricultural productivity and sustainability in the region.

ACKNOWLEDGMENT

This study was funded by the Ministry of Science and Education of the Republic of Kazakhstan within the framework of project AR19679003 "Development of the technology of watering with desalination of mineralized groundwater by filtration using natural non-carbon modified sorbents".

REFERENCES

[1] Heinke, J., Lannerstad, M., Gerten, D., Havlik, P., Herrero, M., Notenbaert, A.M.O., Hoff, H., Müller, C. (2020). Water use in global livestock production-Opportunities and constraints for increasing water productivity. Water Resources Research, 56(12): e2019WR026995. https://doi.org/10.1029/2019WR026995

[2] Kashina, E., Yanovskaya, G., Fedotkina, E., Tesalovsky, A., Vetrova, E., Shaimerdenova, A., Aitkazina, M. (2022). Impact of digital farming on sustainable development and planning in agriculture and increasing the competitiveness of the agricultural business. International Journal of Sustainable Development and Planning, 17(8): 2413-2420. https://doi.org/10.18280/ijsdp.170808

[3] Ansari-Renani, H.R., Rischkowsky, B., Mueller, J.P., Momen, S.M.S., Moradi, S. (2013). Nomadic pastoralism in southern Iran. Pastoralism: Research, Policy and Practice, 3: 1-25. https://doi.org/10.1186/2041-7136-3-11

[4] Ibidhi, R., Ben Salem, H. (2019). Water footprint assessment of sheep farming systems based on farm survey data. Animal, 13(2): 407-416. https://doi.org/10.1017/S1751731118001593

[5] Chikwanha, O.C., Mupfiga, S., Olagbegi, B.R., Katiyatiya, C.L., Molotsi, A.H., Abiodun, B.J., Dzama, K., Mapiye, C. (2021). Impact of water scarcity on dryland sheep meat production and quality: Key recovery and resilience strategies. Journal of Arid Environments, 190: 104511. https://doi.org/10.1016/j.jaridenv.2021.104511

[6] Tugjamba, N., Walkerden, G., Miller, F. (2021). Climate change impacts on nomadic herders' livelihoods and pastureland ecosystems: A case study from Northeast Mongolia. Regional Environmental Change, 21(2): 1-16. https://doi.org/10.1007/s10113-021-01829-4

[7] Anokhina, M., Abdrakhmanov, R., Gridneva, Y.E., Arrieta-López, M., Dzhalilova, N.R., Meza-Godoy, A. (2020). Formation of the competitive potential of the agricultural territories. Entrepreneurship and Sustainability Issues, 7(3): 1921-1936. https://doi.org/10.9770/jesi.2020.7.3(32)

[8] Mekonnen, M.M., Hoekstra, A.Y. (2012). A global assessment of the water footprint of farm animal products. Ecosystems, 15(3): 401-415. https://doi.org/10.1007/s10021-011-9517-8

[9] Rochford, L.M., Bulovic, N., Ordens, C.M., McIntyre, N. (2023). What makes them pump? Factors influencing groundwater extraction for cattle grazing in a semi-arid region. Agricultural Water Management, 279: 108158. https://doi.org/10.1016/j.agwat.2023.108158

[10] Beede, D.K. (2012). What will our ruminants drink? Animal Frontiers, 2(2): 36-43. https://doi.org/10.2527/af.2012-0040

[11] Shilnikova, I. (2023). Water energy as a factor of industrialization in Russia at the beginning of the twentieth century (based on the materials of industrial censuses). History Magazine-Researches, 6: 1-17. https://doi.org/10.7256/2454-0609.2023.6.68830

[12] Narozhnykh, K.N., Petukhov, V.L., Syso, A.I., Konovalova, T.V., Korotkevich, O.S., Sebezhko, O.I. (2024). Specific of accumulation of manganese in organs and tissues of Hereford cattle. Brazilian Journal of Biology, 84: e282174. https://doi.org/10.1590/1519-6984.282174

[13] Lardner, H.A., Braul, L., Schwartzkopf-Genswein, K., Schwean-Lardner, K., Damiran, D., Darambazar, E. (2013). Consumption and drinking behavior of beef cattle offered a choice of several water types. Livestock Science, 157(2-3): 577-585. https://doi.org/10.1016/j.livsci.2013.08.016

[14] Nasiyev, B., Shibaikin, V., Bekkaliyev, A., Zhanatalapov, N.Z., Bekkaliyeva, A. (2022). Changes in the quality of vegetation cover and soil of pastures in semi-deserts of West Kazakhstan, depending on the grazing methods. Journal of Ecological Engineering, 23(10): 50-60. https://doi.org/10.12911/22998993/152313

[15] Bugubayeva, A.U., Chashkov, V.N., Valiev, K.K., et al. (2024). Improving the level of water quality and plant species diversity in the reservoir accumulating natural effluents from the reclaimed uranium-containing industrial waste dump. Brazilian Journal of Biology, 84: e282386. https://doi.org/10.1590/1519-6984.282386

[16] Hapke, H.J. (2000). Effect of drinking water on animal health: Toxicologic health risks. Deutsche Tierarztliche Wochenschrift, 107(8): 335-336.

[17] Valente-Campos, S., Spry, D.J., Palhares, J.C.P., Rudez, L.M.J., Umbuzeiro, G.D.A. (2019). Critical issues and alternatives for the establishment of chemical water quality criteria for livestock. Regulatory Toxicology and Pharmacology, 104: 108-114. https://doi.org/10.1016/j.yrtph.2019.03.003

[18] Ongayev, M., Denizbayev, S., Ozhanov, G., Yesmagulova, B., Umbetkaliyev, N., Shadyarov, T. (2023). Analysis of hydrochemical parameters of surface water sources used for watering pastures to improve the water quality. Caspian Journal of Environmental Sciences, 21(4): 875-883. https://doi.org/10.22124/cjes.2023.7145

[19] Dinka, M.O., Loiskandl, W., Ndambuki, J.M. (2015). Hydrochemical characterization of various surface water and groundwater resources available in Matahara areas. Fantalle Woreda of Oromiya region. Journal of Hydrology: Regional Studies, 3: 444-456. https://doi.org/10.1016/j.ejrh.2015.02.007

[20] Khan, M.Y.A., Gani, K.M., Chakrapani, G.J. (2017). Spatial and temporal variations of physicochemical and heavy metal pollution in Ramganga River-a tributary of River Ganges, India. Environmental Earth Sciences, 76(5): 231. https://doi.org/10.1007/s12665-017-6547-3

[21] Khan, M.Y.A., Tian, F. (2018). Understanding the potential sources and environmental impacts of dissolved and suspended organic carbon in the diversified Ramganga River, Ganges Basin, India. Proceedings of the International Association of Hydrological Sciences, 379: 61-66. https://doi.org/10.5194/piahs-379-61-2018

[22] Sharma, M.K., Kumar, P., Prajapati, P., Bhanot, K., Wadhwa, U., Tomar, G., Goyal, R., Prasad, B., Sharma, B. (2022). Study of hydrochemical and geochemical characteristics and solute fluxes in Upper Ganga Basin, India. Journal of Asian Earth Sciences: X, 8: 100108. https://doi.org/10.1016/j.jaesx.2022.100108

[23] Asadulagi, M.A.M., Pershin, I.M., Tsapleva, V.V. (2024). Research on hydrolithospheric processes using the results of groundwater inflow testing. Water, 16(3): 487. https://doi.org/10.3390/w16030487

[24] Qiu, W., Ma, T., Wang, Y., Cheng, J., Su, C., Li, J. (2022). Review on status of groundwater database and application prospect in deep-time digital earth plan. Geoscience Frontiers, 13(4): 101383. https://doi.org/10.1016/j.gsf.2022.101383

[25] Chambefort, I., Stefánsson, A. (2020). Fluids in geothermal systems. Elements: An International Magazine of Mineralogy, Geochemistry, and Petrology, 16(6): 407-411. https://doi.org/10.2138/gselements.16.6.407

[26] Turbekova, A., Balgabaev, N., Turbekov, S., Solovyov, O., Savin, T., Tokbergenov, I., Zhumagulov, I., Yermekov, F., Topayev, S. (2023). Influence of water-saving irrigation technology on the yield of grain crops in the northern region of Kazakhstan. Caspian Journal of Environmental Sciences, 21(5): 1093-1104. https://doi.org/10.22124/CJES.2023.7397

[27] Zhyrgalova, A., Yelemessov, S., Ablaikhan, B., Aitkhozhayeva, G., Zhildikbayeva, A. (2024). Assessment of potential ecological risk of heavy metal contamination of agricultural soils in Kazakhstan. Brazilian Journal of Biology, 84: e280583. https://doi.org/10.1590/1519-6984.280583

[28] Nokusheva, Z.A., Kantarbayeva, E.Y., Ormanbetov, M.B., Yermagambet, B.T., Kassenova, Z.M., Kazankapova, M.K. (2023). Development and implementation of effective schemes for the use of mineral fertilizers in the forest-steppe zone of the north kazakhstan region. OnLine Journal of Biological Sciences, 23(3): 313–322. https://doi.org/10.3844/ojbsci.2023.313.322

[29] Ilyushin, Y., Afanaseva, O. (2020). Modeling of a spatial distributed management system of a preliminary hydro-cleaning gasoline steam column. International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM, 20(2.1): 531-538. https://doi.org/10.5593/sgem2020/2.1/s08.068

[30] Serekpayev, N., Popov, V., Stybayev, G., Nogayev, A., Ansabayeva, A. (2016). Agroecological aspects of chickpea growing in the dry steppe zone of Akmola region, Northern Kazakhstan. Biosciences Biotechnology Research Asia, 13(3): 1341-1351.

[31] De Graaf, I.E., Gleeson, T., van Beek, L.P., Sutanudjaja, E.H., Bierkens, M.F. (2019). Environmental flow limits to global groundwater pumping. Nature, 574(7776): 90-94. https://doi.org/10.1038/s41586-019-1594-4

[32] Ongayev, M., Sultanova, Z., Denizbayev, S., Ozhanov, G., Abisheva, S. (2019). Engineering and process infrastructure of the agro-Industrial complex. International Journal of Emerging Trends in Engineering Research, 7(12): 879-885. https://doi.org/10.30534/ijeter/2019/257122019

[33] Ongayev, M., Denizbayev, S., Ozhanov, G., Shadyarov, T. (2021). Underground water supply to pastures. International Journal of Mechanical Engineering, 6(3): 98-103. https://kalaharijournals.com/ijme-v6-3-2021.php

[34] Ongayev, M., Denizbayev, S., Umbetkaliyev, N., Yesmagulova, B., Shadyarov, T., Ozhanov, G. (2022). The zonality of underground water supply sources for pastures in the West Kazakhstan region. Journal of Ecological Engineering, 23(8): 56-65. https://doi.org/10.12911/22998993/150612

[35] Kozhanov, N.N., Mirdadaev, M.S., Ustabaev, T.S., Ismailov, B.D., Kabyl, T.M. (2021). Some issues of watering of pastures in Kazakhstan. In: Actual Problems of Science and Technology, pp. 49-58.

[36] Tumlert, V.A., Grankin, Y.Y., Tumlert, E.V. (2015). Groundwater by the reverse osmotic method on an apparatus located in the borehole. Science and Peace, 28: 55-57.

[37] Shah, A., Arjunan, A., Baroutaji, A., Zakharova, J. (2023). A review of physicochemical and biological contaminants in drinking water and their impacts on human health. Water Science and Engineering, 16(4): 333-344. https://doi.org/10.1016/j.wse.2023.04.003

[38] Masmoudi, T., Benakcha, M., Abdennour, M.A., Bouzekri, A., Amrane, A., Alcala, F.J. (2024). Groundwater quality evaluation for drinking and agricultural purposes. A case study in semi-arid region (Zab El-gharbi SE-Algeria). Desalination and Water Treatment, 100476. https://doi.org/10.1016/j.dwt.2024.100476

[39] Díaz-González, L., Uscanga-Junco, O.A., Rosales-Rivera, M. (2021). Development and comparison of machine learning models for water multidimensional classification. Journal of Hydrology, 598: 126234.

https://doi.org/10.1016/j.jhydrol.2021.126234
[40] Adams, R.S., Sharpe, W.E. (1995). Water Intake and Quality for Dairy Cattle. Pennsylvania State University, University Park, PA. http://www.das.psu.edu/research-extension/dairy/nutrition/pdf/water.pdf, accessed on Aug. 10, 2024.
[41] Socha, M.T., Ensley, S.M., Tomlinson, D.J., Johnson, A.B. (2003). Variability of water composition and potential impact on animal performance. In Proc. from the Intermountain Nutrition Conference, Salt Lake City, UT. Utah State University, Logan, pp. 85-96.
[42] US Environmental Protection Agency (EPA). (2009). National primary drinking water regulations. EPA. https://www.nrc.gov/docs/ML1307/ML13078A040.pdf, accessed on Aug. 10, 2024.
[43] Kochish, I.I., Kalyuzhny, N.S., Volchkova, L.A., Nesterov, V.V. (2008). Zoohygiene. Lan. https://fermer.ru/files/v2/blog/212757/721132e19d1kochishiikalyuzhnyynsidrzoogigiena.pdf, accessed on Aug. 10, 2024.
[44] Haileslassie, A., Blümmel, M., Clement, F., Ishaq, S., Khan, M.A. (2011). Adapting livestock water productivity to climate change. International Journal of Climate Change Strategies and Management, 3(2): 156-169. https://doi.org/10.1108/17568691111128995
[45] Meyer, J.A., Casey, N.H. (2012). Establishing risk assessment on water quality for livestock. Animal Frontiers, 2(2): 44-49. https://doi.org/10.2527/af.2012-0041
[46] Korotkih, P.S., Neverov, E.N., Korotkiy, I.A. (2023). Assessment of carbon dioxide exchange processes between water bodies and the atmosphere. Caspian Journal of Environmental Sciences, 21(5): 1239-1245. https://doi.org/10.22124/cjes.2023.7419