International Journal of Innovation in Agriculture Sciences and Rural Development
Vol.4, NO.1 , P:7 - 15
Received: 20 December 2021
Accepted: 24 January 2022

# Evaluating the salinity in shallow and deep aquifers of Gorganrood basin, Iran

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## Abstract

Increasing groundwater salinity in countries facing water scarcity has raised severe environmental and health concerns. One of the best ways to prevent groundwater pollution is to study groundwater quality's spatial variation and identify vulnerable aquifer areas. The aim of the present study was to evaluate the quality of groundwater in shallow and deep aquifers of the Gorganrood basin. To achieve this goal, values of electrical conductivity of groundwater in mentioned aquifers were measured in situ for wet and dry periods. According to obtained results, groundwater salinity in shallow aquifer is considerably greater than that in the deep aquifer. Moreover, the salinity of groundwater in both aquifers (shallow aquifer in particular) for the wet period has been diminished compared to that for the dry period. Also, it can be seen that the values of salinity of both aquifers are greater than that of springs, located in the boundary of geological formations and alluvial deposits. Another important thing that may be observed is the role of recharging flows to both shallow and deep aquifers in the southern boundary of the Gorganrood basin, which has decreased the values of salinity of groundwater in this part of mentioned aquifers.

**Keywords**: Gorganrood, Salinity, Groundwater, shallow and deep aquifers

## 1. Introduction

Groundwater constitutes a primary source of freshwater for many populations around the globe, especially regions where rainfall is scanty, surface water sources are absent, and all domestic and agricultural needs are fulfilled with groundwater. However, overexploitation of groundwater, inappropriate temporal and spatial distribution of rainfall, and lack of natural nutrition compared to the amount of harvest, the cause of groundwater salinization, and gradually lead to freshwater aquifers' pollution (Bhakar and Singh, 2019; Böhlke and Denver, 1995; Jafari et al., 2018; Michael et al., 2017; Mosaffa et al., 2021; Pacheco Castro et al., 2018; Sherwood and Klein, 1963; Jafari et al., 2018).

The presence of saline groundwater is one of the most conspicuous problems globally. Decreased groundwater quality often leads to tensions in the water management and distribution system and poses a serious threat to aquifers and freshwater. Therefore, understanding the salinity distribution in the aquifers as well as the past and future is important for managing groundwater resources (Barlow and Reichard, 2010; Poole, 1963; Klassen and Allen, 2017; Wu et al., 2019).

Water salinity is a significant factor in soil salinity; soil salinization is a significant issue in arid and semi-arid areas, which has a major impact on decreasing soil fertility and is a significant factor in desertification processes world's dryland (Wei et al., 2019). Therefore, timely detection of groundwater salinity and evaluation and monitoring of its intensity and extent are necessary to manage the negative aspects such as destroying the soil structure, reducing the biodiversity and agricultural production, water pollution, and problems for human health (Allbed and Kumar, 2013; Banda et al., 2019; Majeed and Muhammad, 2019; Naser et al., 2020; Sahour et al., 2020).

Factors leading to the salinization problem may be natural or anthropogenic. Natural factors include a wide range of various factors such as evaporation, low annual rainfall (for aquifer recharge), filtration from surface saline water, the upward intrusion of brines from deeper aquifers, accumulation of salt from rainfall over many thousands of years, or from the weathering of rocks, etc.
Human activities can cause salinity through the following factors: use of salt-rich irrigation water, use of chemical fertilizer, rising water table and bringing salt to the surface due to human activities (filtration from unlined canals and reservoirs), increase land use such as agricultural, industrial and urban development, high pumping rates from groundwater, poor drainage conditions, etc (Abu-Alnaeem et al., 2018; Argamasilla et al., 2017; Gutiérrez et al., 2018; Ledesma-Ruiz et al., 2015; Shamsi et al., 2019 ; Mirzavand et al., 2020; Rajmohan et al., 2021).

In Iran, rapid developments in the agricultural sector and unplanned industrial growth have led to increased use of the shallow aquifer. Agriculture (80%-90%) and then industry are the primary consumers of groundwater in this country. High pumping rates have led to low groundwater levels, salinization of groundwater, and nitrate accumulation in shallow aquifers. Therefore, survival and sustainable development in arid and semi-arid regions directly depend on effective management to maintain groundwater resources, quantity, and quality (Bagheri et al., 2020; Baniasadi et al., 2019; Davoodi et al., 2019; Hosseini et al., 2019; Li and Gao, 2019; Odeh et al., 2019; Tavakoli-Kivi et al., 2019; Troudi et al., 2020).

Therefore, new approaches to salinity modeling and forecasting are essential as a fundamental approach to effective resource management. Numerous articles have been performed using statistical, numerical, hydrological, and physical models to predict groundwater salinity (Abulibdeh et al., 2021; Choudhury and Saha, 2004; Dieng et al., 2017; Ferchichi et al., 2018; Gašparović and Singh, 2020; Gholami et al., 2017; Hasan et al., 2017; Haselbeck et al., 2019; Maliqi et al., 2020). Abulibdeh and co-workers evaluate the impact of evaporation on groundwater salinity in the arid coastal aquifer using geochemical and multivariate statistical tools. PHREEQC model was used to reveal groundwater minerals in this study. Using various methods, they explained that non-saline sources and processes, namely evaporation, reverse ion exchange, mineral dissolution, and wastewater infiltration, mainly affect the water chemistry in this aquifer (Abulibdeh et al., 2021). The salinity of groundwater coastal wetlands was assessed as moderate to high latitude with four natural reserves with contrasting hydrological and climatic conditions. The results show a saline groundwater increase along a latitudinal gradient with electrical conductivities varying from 0.3 mS/cm at 34°47′ S to 154 mS/cm at 42° 25′ S. Tidal floods are also influential in controlling ionic content so that electrical conductivity varies from 0.3 mS/cm in the estuary to 52 mS/cm in the seawater (Galliari et al., 2021). In another study, using stable isotope tracers and spatial analysis with GIS tools, the groundwater salinity in the Azarshahr and Shabestar-Sufyan aquifers located in the Urmia Basin, northwestern Iran, was investigated. The results of this study showed that isotope concentrations are dependent on evaporation and dissolution of evaporation rocks in the study area and there was no significant relationship between precipitation and the Urmia Lake (Mosaffa et al., 2021). Sahour et al. (2020) mapping groundwater salinity using hydrogeology and hydrometeorology data and statistical and machine learning techniques in the southern coastal aquifer of the Caspian Sea. Aquifer transmissivity, distance from the sea, the mean annual precipitation, the mean annual evaporation, elevation, and the depth to the water table were considered for this study. Results showed that the aquifer transmissivity is the most crucial parameter affecting groundwater salinity in the region. Naser et al. (2020) The quality of drinking water affects the lives of humans, especially children. Therefore, in a study, the relationship between drinking water salinity and infant mortality was investigated. The salinity of groundwater was assessed using point data of electrical conductivity in the area. The results showed that a U-shaped correlation was found between drinking water salinity and infant mortality, with high and low salinity affecting infant mortality. Troudi et al. (2020) monitoring the groundwater quality situation showed the nitrate and salinity are one of the prime pollutants in the groundwater in the shallow aquifer of Guenniche (Northern Tunisia). Results indicate that Nitrate and salinity variations during the period 2006–2015 follow the rainfall fluctuation patterns.

Using hydrogeochemical and multi-isotopic methods, Mirzavand et al. (2020) found that the source of salinity in groundwater in the Kashan plain aquifer is the dissolution of halite and gypsum in water. Heavy pumping has also increased halite and gypsum, which combine with fresh groundwater. Also, the results of studies Odeh et al. (2019) indicate that continuous pumping reduces the groundwater level and increases the salinity of some areas in Irbid governorate, northern Jordan, by about 1000 μS / cm. Wu et al. (2019) showed that in addition to human activities, mineral dissolution, rainfall, evaporates and soil leaching, land use, climate, etc., are also effective factors in determining groundwater quality. In Michigan, managing nonpoint-source (NPS) pollution of groundwater systems assessed by the system-based approach to integrated groundwater quantity–quality dynamics associated with the brine upwelling process. In this research, the effect of natural upwelling of deep brines was investigated using a combination of groundwater/geologic data, groundwater salinity, and water well dataset (Curtis et al., 2019). Azizi et al. (2019) applied a hydrogeological-based method to assess Iran's Malekan coastal aquifer's vulnerability to saltwater intrusion from Lake Urmia. Five factors include the magnitude of saltwater Intrusion, groundwater level, existing Distance between the aquifer and the shore, recharge, and the aquifer's saturated thickness, were used to implement the model. Results showed that the vulnerability index was most significantly influenced by recharge. Salinity, a major agricultural problem, has important implications for crop productivity and management strategies. Therefore, different models have been performed to predict and model salinity in aquifers and groundwater in different conditions with various drainages (Banda et al., 2019; Majeed and Muhammad, 2019; Tavakoli-Kivi et al., 2019). DRAINMOD-S model was evaluated to predict the salinity of the subsurface drainage effluents using measurements of groundwater table depths and drainage water salinity data (Davoodi et al., 2019).

Resently, a few case studies have been carried out on nitrate concentration in limited parts of the Gorganroud basin (Azad et al., 2018; Mahzari et al., 2016). In this research, the main nitrate source is referred to as agricultural activities (especially nitrogen fertilizers) and urban and rural sewage. There is no comprehensive study on the salinity of groundwater for the entire Gorganroud basin by reviewing the work done. Considering that the amount of groundwater salinity in surface and deep aquifers in the Gorganroud basin is significantly different, the lack of comprehensive study finds more importance.

In this research, the study's main objective is to investigate the salinity of groundwater in two surface and deep aquifers of the Gorganroud basin. To achieve this goal, the electrical conductivity of water in two parts of the surface and deep aquifers has been measured in wet and dry periods in the Gorganroud basin. Water salinity, or in other words, total dissolved solids, is one of the most important water quality criteria (Fetter, 2018). One of the most common methods of measuring water salinity is the measurement of electrical conductivity, which is carried out with electrical conductivity meter devices with high precision and ease.

## 2. Study area

Golestan Province, with an area of about 21000 km2, consists of five watershed basins of Atrek, Qaraosu, Gorganroud, Gorgan Gulf, and Nekarod. This province has a border with Turkmenistan internationally from the south and is neighboring Semnan, Mazandaran, and North Khorasan from the south, west, and east. The province is located in the geographical coordinates of 53° 51' to 56° 14' E and 36° 44' to 38° 5' N. Figure 1 shows the map of Golestan province and the fivefold watershed basins contained therein. The study area in this research is the Gorganroud basin, which is the most extensive and most important watershed basin in the province. Most of the province's agricultural land use surface water and groundwater in the basin. Also, drinking water from many of the major cities of the province (including Kalaleh, Galikesh, Minoodasht, Gonbad, Azadshahr, Khan Babin, Ali Abad, Gorgan, Aq-Qala and Bandar-Turkman) is provided by the Gorganroud river. Gorganroud Basin is limited to the Atrek basin from the north to the Mazandaran Sea and Qara-Souz basin from the west and the elevations of Semnan and Khorasan provinces from the east to the mountains of Semnan province and the Nakarod basin from the south. The area of the basin is 10197 km2. The elevations of the basin are mainly covered with forest and part of the Gorganroud basin, includinffg sub-basins of Rebate Qarah Bil, Plain, and Nardin, is located in the provinces of Semnan and North Khorasan.

### 2.1. Climatic conditions of the region

The studied area has a great variety of climates due to its vast expanse and topographic conditions. There are in the west of semi-arid, moderate semi-humid climates and in the east of the dry, cool semi-arid climates, which are affected by geographical factors such as the vicinity of the Caspian Sea and enclosed by the Alborz Mountains. As the sea moves eastwards, air humidity decreases, and air dryness increases. In this basin, annual precipitation decreases from west to east. The average annual precipitation in the basin's western regions is about 450 mm and in the eastern regions of the basin is about 180-250 mm. The minimum and maximum annual temperatures are 11 °C and 18 °C, respectively. From low-rise coastal areas to elevations, temperature decreases, reaching about 9 degrees in elevations (Lar Consulting Engineers, Meteorological Report, 2020).

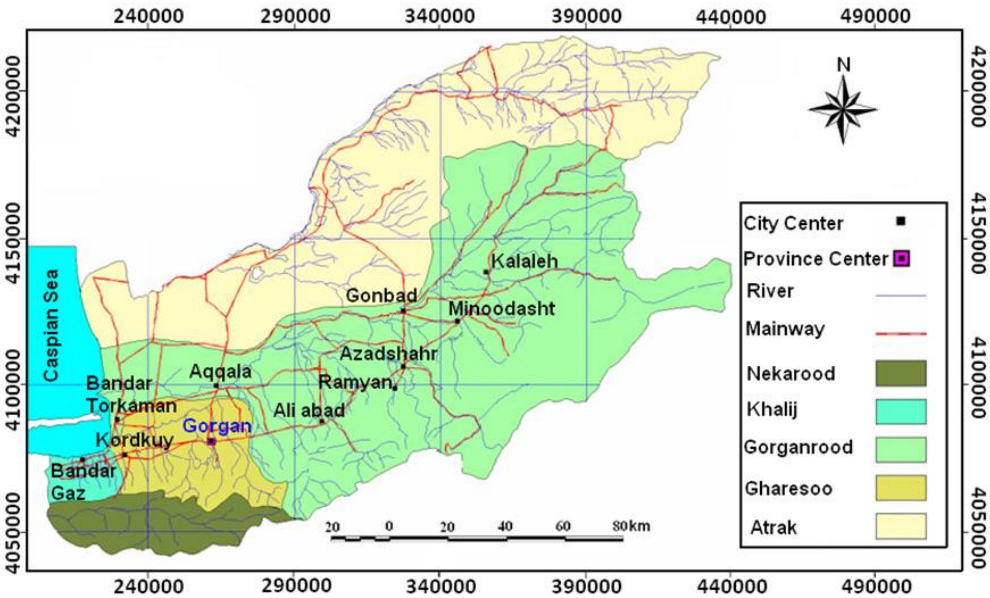


**Figure 1 Map of Golestan province and its fivefold watershed basins**

**2.2. The vegetation of the region**

About 30% of the study region area, especially in mountainous and upland areas, is covered by forests and woodland. Golestan National Park, with a forest area of about 40,000 hectares, is located in this region. The basin studied in Rabat Cheshme-Khan and Dasht branches have rangeland and forest vegetation. In elevations, sometimes without vegetation, and after the intersection of Rabat branch and Dasht basin, there is dense and protected forest vegetation without any operation. This basin's forests can be divided into two categories of semi-humid broad-leaved forests and drought-tolerant resinous forests. Two species of hornbeam and oak are the most abundant tree species in this area, but in southward slopes, this ratio changes in favor of oak. Many of these species play an essential role in preventing evaporation, soil conservation, and erosion prevention. Because the moisture content decreases from west to east, this has a unique effect on the shape, species, and formation types (Lar Consulting Engineers, Forest Report, 2020). The region's rangelands are from the viewpoint of geographical and climatic conditions, including Yaylak and Kishlak rangelands used for livestock forage. In the margins of villages and demographic areas, forest vegetation has gone away and has been burned down and sometimes turned into agricultural land.

**2.3. General geology of the region**

Based on the studied basin's geological studies, the intersection of two important geological zones in the northeast of the country is named the eastern Alborz zone (Binaloud) and Kopet Dagh zone (khosrotehrani, 1989). The boundary of this zone is along the Gorgan-Bojnourd road. The stratigraphy of the rocks and deposits of various geological periods from the Paleozoic to the present time is in the study area. There are no outcrops of metamorphic rocks in the studied area, but some extrinsic species of igneous rocks are in this region.

The mainly region's stone units are sedimentary rocks, including limestone, sandstone, shale, dolomite, marl, conglomerate, clay, and alluvial deposits. Because the most ancient deposits of the Kopet Dagh zone are related to the second geological period, a significant part of the basin is covered by Jurassic period rocks. Limestone rocks of formation of Chaman Bid, Mazdavand, Lar, and sandstones and shales of Shemshak are among the most enriched rock units (khosrotehrani, 1989). In Paleocene, there is the sedimentation of semi-condensed conglomerate with weak cement. In the glacial period, extensive loess deposits consist of silt and clay in the form of high hills in the north basin. Quaternary deposits, alluvial plain, and bedrock deposits are widely distributed in different areas of the basin. In terms of tectonics, the studied area is the intersection of Kopet Dagh and East Alborz. Due to this, properties and structural conditions such as folding and thrust can be observed in the region. The presence of folded deposits in the area indicates tectonic activity related to different geological times, which, along with other stresses in the late Cenozoic, has had the most significant impact on the area's present morphology. The main system of the faults in the study area is the thrust fault, most of them along the northeast-southwest, showing movement from northwest to southeast and causing several classes to move on to each other. The severity of these faults' operation in parts of the study area is such that it causes the creation of crushed areas (khosrotehrani, 1989). Among the study area's important faults are the faults of Alborz, Rebate Qarah Bil, Tang Rah, and Golestan fault. The major part of the construction site's geomorphology has been affected by the thrust fault as anticline and syncline areas. The hydrographic network is mainly aligned with the tectonic fault network of the region.

## 3. Materials and Methods

To evaluate the salinity situation in surface and deep aquifers of the Gorganroud basin, the electrical conductivity values were measured in 105 wells in November 2019 and 92 wells in May 2020. The Hach Co. Conductivity Meter 50150 to measure water samples' electrical conductivity at the sampling site was used. Figures 2 (a) and (b) show the position of sampling wells in November 2019 and May 2020, respectively. As shown in Figures 2 (a) and (b), sampling wells have been distributed reasonably well throughout the Gorganroud watershed basin's plain section. Of course, the number of wells in the north part of the Gorganroud plain is slightly lower because of the inappropriate water and soil resources in this part of the plain. Since the surface and deep groundwater aquifers are two separate aquifers and their salinity is entirely different, they are discussed separately in this research. In addition to the wells, electrical conductivity measurements for 12 springs located on the border between the complex formations and alluvial deposits of the Gorganroud basin, have also been carried out. The springs' electric conductivity values are used as control samples and compared the wells' electrical conductivity values with the springs' values. The measurement of electrical conductivity for these springs was done only in November 2019. The reason for this is that springs are relatively small. The dominant current is Diffuse flow, and according to various researchers (Raeisi and Karami, 1997; Shuster and White, 1971; White, 1988), the physical and chemical characteristics of these springs are very small. Therefore, it is not necessary to measure the electrical conductivity in different seasons. As mentioned, the electrical conductivity measurement in the wells of the area was carried out in two distinct periods, November 2019 and May

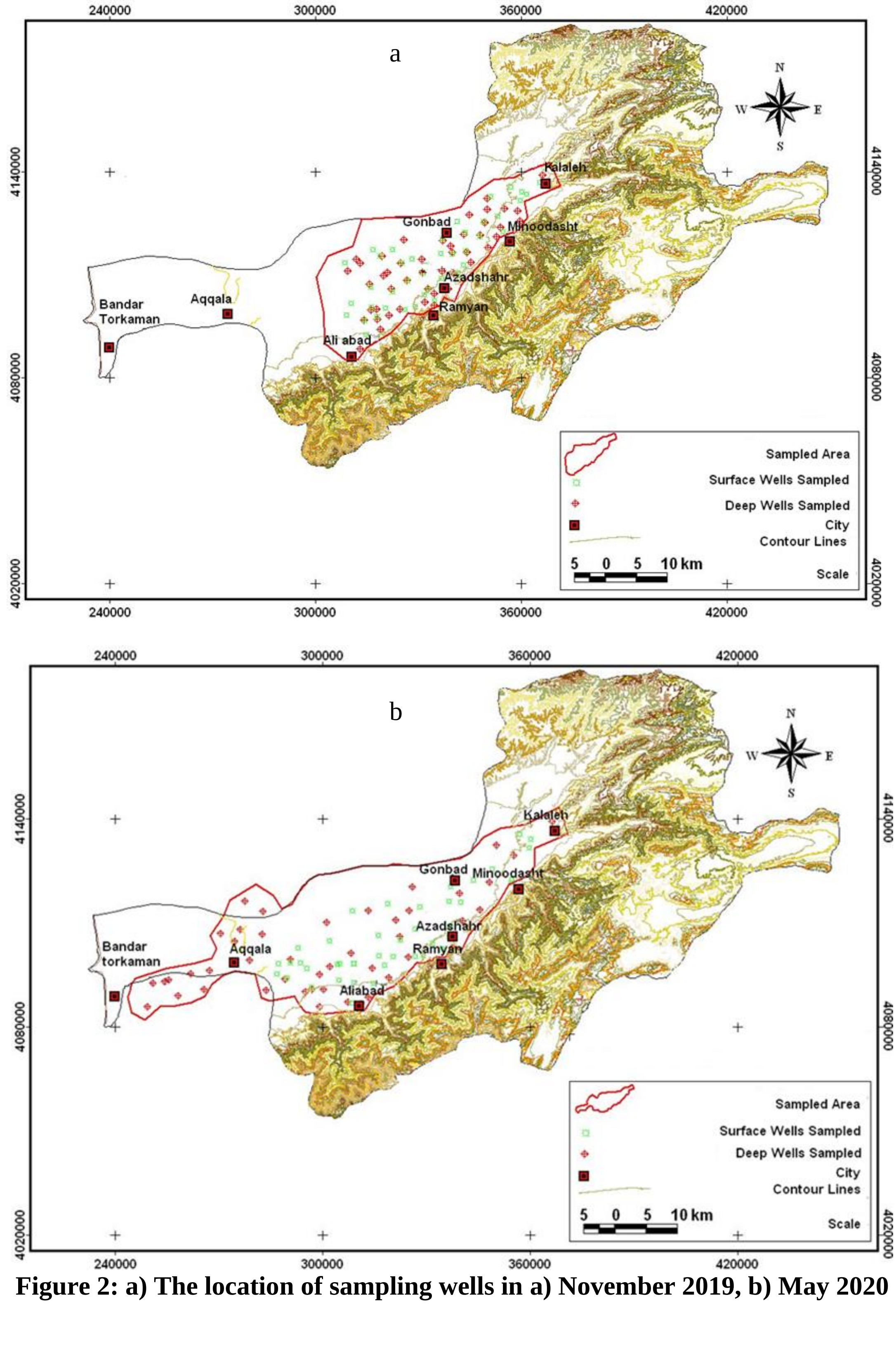


**Figure 2: a) The location of sampling wells in a) November 2019, b) May 2020**

2020. Before examining different qualitative maps in these two periods, precipitation in the Gorganroud basin is compared in these two periods. To compare the precipitation in November 2019 and May 2020 in Gorganroud basin, the precipitation data of 7 stations are located in different parts of the Gorganroud basin was collected. Figure 3 shows the histogram of the monthly precipitation of these stations and their average in November. It is also observed that the average precipitation in these two months was 58.1 and 93.1 mm, respectively. Regarding the average rainfall in the Gorganroud basin, which is usually more rainfall than in May, compared to November, the precipitation situation in these two months was contrary to the situation that occurred in previous years.

## 4. Result and discussion

### 4.1. Investigation of the electrical conductivity of groundwater in surface wells

The values of electrical conductivity of groundwater in surface wells were measured in two periods, November 2019 and May 2020, and Figures 4 (a) and (b) show electrical conductivity maps of surface aquifers in November 2019 and May 2020, respectively. As shown in Fig. 4-a, the maximum electrical conductivity associated with the surface wells, which was sampled in November 2019, is related to the well of Kuchek Khortum, which is 8350 µmho/cm. The reason for this is likely to be the presence of sediments containing high-solubility materials and, consequently, degradation of water quality. One of the important reasons is that the high solubility of these materials in these sediments, its fine grain content and, consequently, the rise of water due to the capillary force and its evaporation, and the remaining salts in the surface of these sediments. Of course, the Caspian fault can also be considered as a weak possibility. In this way, the operation of this fault has transmitted deep water to the surface aquifers

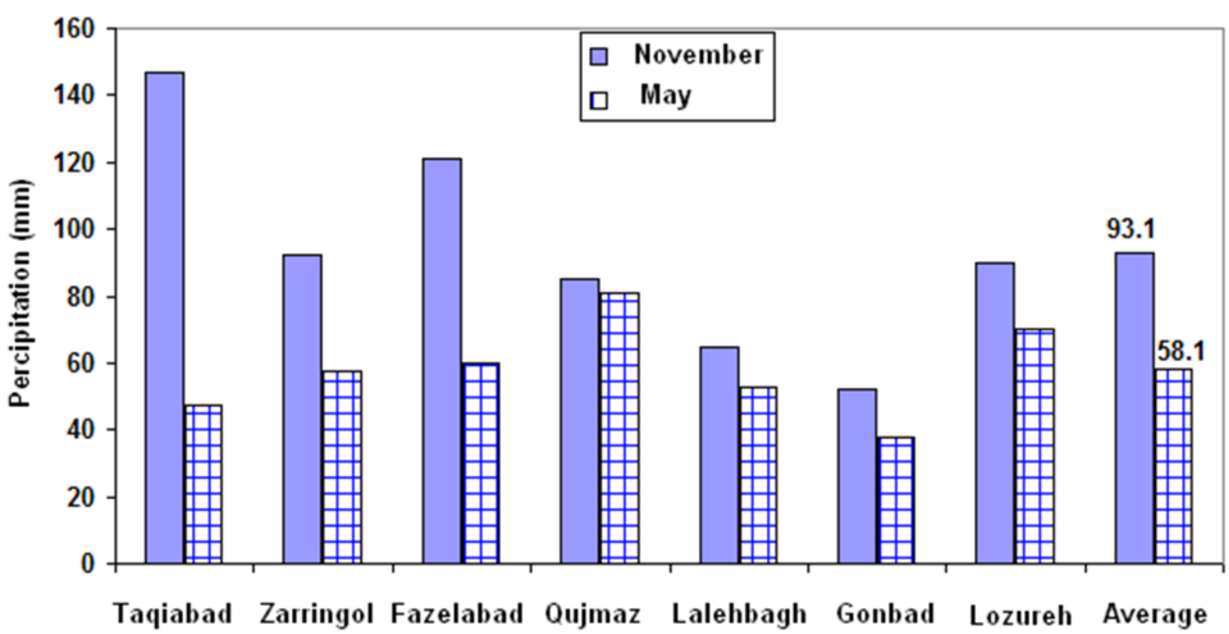


**Figure 3. Comparison of precipitation of stations in the region and their average in November**

The amount of electrical conductivity in the southern margin of the Gorganroud basin (for example, the range of Kalaleh to the southwest of Minoodasht, Azadshahr range to Khan Bebin and Aliabad area) is low. Thus, the electrical conductivity is in the range of 400 to 700 μmho/cm. Due to the low level of electrical conductivity in this area, the groundwater aquifers are fed by underground freshwater theater (especially in the limits of the rivers feeding groundwater aquifers, including the rivers of Ağan, Chehel Chay, Khormalou, Qurchay, and Zarringol). Due to the entry of a relatively salty water theater from the Tamar river basin, the groundwater quality has been destroyed within the range of the north of Kalaleh and, gradually, the electrical conductivity improves by mixing this flow with inadequate quality with the mainstream of the region, which is relatively good quality. In this way, the electric conduction from the north of Kalaleh to the Doogh River decreases. In the area of Gonbad Kavus to the east of Aq-Qala, groundwater quality is inappropriate, so that the electrical conductivity in this range reaches more than 6000 μmho/cm. This saline water flow, which originates mainly in saline flows in the north part of Gorganroud (between Gonbad Kavus and Aq-Qala), causes groundwater quality degradation moving from the south and southeast to Gorganroud. About 10 km north of Khan Bebin, there is a very high electrical conductivity range (more than 8000 μmho/cm). Also, in the southwestern of Gonbad Kavus, high electrical conductivity areas (between 4000 and 6000 μmho/cm) are considered. In the areas mentioned, the cause of high groundwater salinity is the same as explained at the beginning of this section. The range of electrical conductivity changes in surface wells in May 2007 is 318 μmho/cm in the well of the northern part of Khan Bebin up to a maximum of 10855 μmho/cm in the surface wells of Kord village (east Aq-Qala). Based on the electrical conductivity map of the surface aquifer in May 2020 (Fig. 4-b), although the general trend of electrical conductivity change is more or less in line with the trend of the electric conductivity map of November 2019, however, it also includes changes that are presented briefly:One of the most significant differences between the surface aquifer's electrical conductivity map in May 2020 and November 2019 is that in May 2020, all electrical conductivity values increased more or less. Thus, the electrical conductivity in the southern margin of the Gorganroud basin varies from 600 to about 1000 μmho/cm. Also, in the northern part of Khan Bebin, the electrical conductivity is over 8800 μmho/cm. Also, in the range of Kalaleh in November 2019, the electrical conductivity in the west Kalaleh was about 1000 or less than 1000 μmho/cm. However, in May 2020, the electrical conductivity in the west Kalaleh reaches about 4000 μmho/cm. The reason for the significant difference in the electrical conductivity in different parts of the Gorganroud basin in May 2020 compared to November 2019 is that in November 2019, the precipitation was very high, and even during sampling, there has been precipitation that diluted solids soluble in groundwater and thus reduced the electrical conductivity of these waters. Investigation of the electrical conductivity of groundwater in deep wellsFigures 5 (a) and (b) show electrical conductivity maps of deep wells in November 2019 and May 2020, respectively. As shown in Figures 5 (a) and (b), electrical conductivity in November 2019 is significantly lower than in May 2020 because surface currents feed the southern margin of the Gorganroud basin, and the coarse-grained alluvium, more surface nutrition, and precipitation effects are quite evident. However, in the north of the Gorganroud basin, which has relatively low permeability and no feeding rivers, electrical conductivity

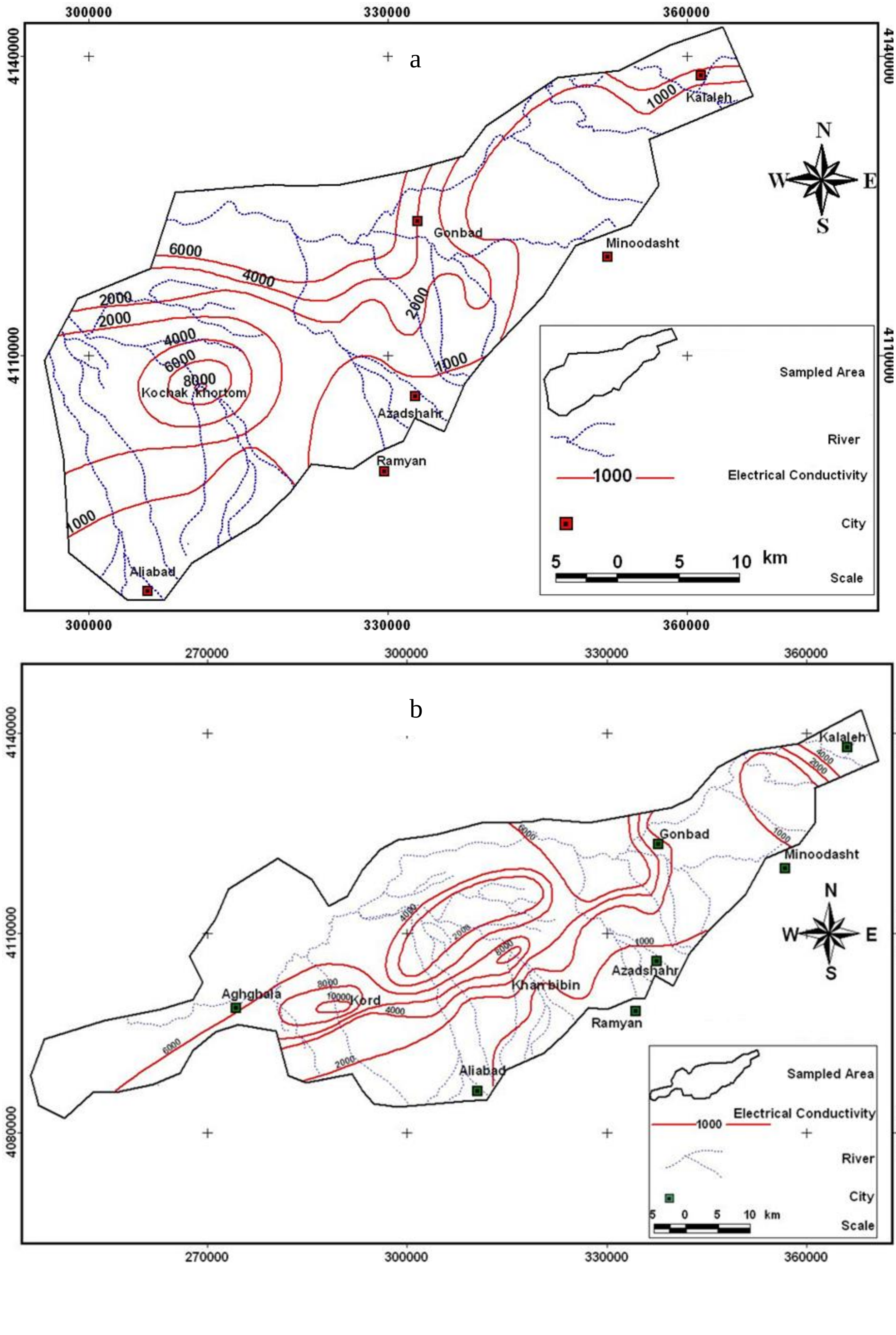


**Figure 4. The map of electric conduction of surface aquifers in a) November 2019; and b) May 2020**

does not significantly differ. In November 2019, the electric conductivity in deep wells varied from the minimum 426 µmho/cm in Ramian well to the maximum of 1422 µmho/cm in Haji Akhond (in the west of Gonbad Kavus). It is noted that the minimum and the maximum of electrical conductivities are related to the south and north of the basin, respectively. In the south of the basin with the lowest electrical conductivity, feeding rivers' entry improves water quality and reduces electrical conductivity. In the north of the basin, the water quality is reduced due to the desert area's passage, where the groundwater level is relatively high. The lowest electrical conductivity in deep wells, which was sampled in May 2020, is located in the deep well of Neoghak, north of Minudasht, with a value of 619 µmho/cm., and most of it is related to the deep well of Agh Ghabr located in the north of Aq-Qala, which is equal to 2085 µmho/cm. Comparison of salinity in the area aquifers with springs As noted in Section (5), in addition to the wells in the area, electrical conductivity measurements for 12 springs, located at the boundary between the complex formations and alluvial deposits of separately and compared with the mean values of the electrical conductivity of the springs (Figure 6). As can be seen from Fig. 6, the mean values of electrical conductivity in the surface aquifer are significantly higher than that of the deep aquifer and, in addition, for both surface and deep aquifers (in particular the surface aquifer), the mean electrical conductivity values during the wet period have significantly decreased. The reason for this is that during the wet period, both the aquifers (especially the surface aquifer) are fed with rainwater or surface currents. Since the solids of the solution in the rain and the surface currents are far lower than groundwater aquifers, this reduces the salinity of groundwater aquifers. According to Fig. 6, it is also seen that the mean electrical conductivity values of both groundwater aquifers, even in the wet period, are significantly higher than the mean values of the electrical conductivity of the springs. This is due to that the flow of groundwater during the upstream movement solves more solids in itself, increasing the amount of electrical cnductivity in the Gorganroud Plain compared with the beginning of the range of alluvial aquifers (where the aquifers are located).

## 5. Conclusion

According to the electrical conductivity maps (Figs. 4 to 5), it is observed that the amount of electrical conductivity of groundwater in surface and deep aquifers as well as in different parts of the basin is significantly different. In both surface and deep groundwater aquifers, the water quality is appropriate in the south of the basin where nutrient flows enter the basin, while water quality is degraded towards the center and north of the basin. For example, in the surface aquifer in the south and east of the basin, groundwater's electrical conductivity is about 1000 µmho/cm or less. However, in the center of the basin, for example, 20 kilometers northeast of Ali Abad, or 20 kilometers east of Aq-Qala, the electrical conductivity reaches over 5000 µmho/cm or more. In electrical conductivity maps in the deep aquifer, the amount of electrical conductivity and variations exhibit a slightly different behavior from the surface aquifer. Thus, the amount of electrical conductivity is the same in most of the Gorganroud basin from the east of Kalaleh to the west in the Aq-Qala area and from the south to the north, with slight changes. However, in this aquifer, the groundwater quality in the region of Aq-Qala to the west and northwest is relatively degraded. By comparing the mean values of electrical conductivity in surface and deep aquifers, it is observed that the water quality in the deep aquifer is significantly higher. For both surface and deep aquifers (especially

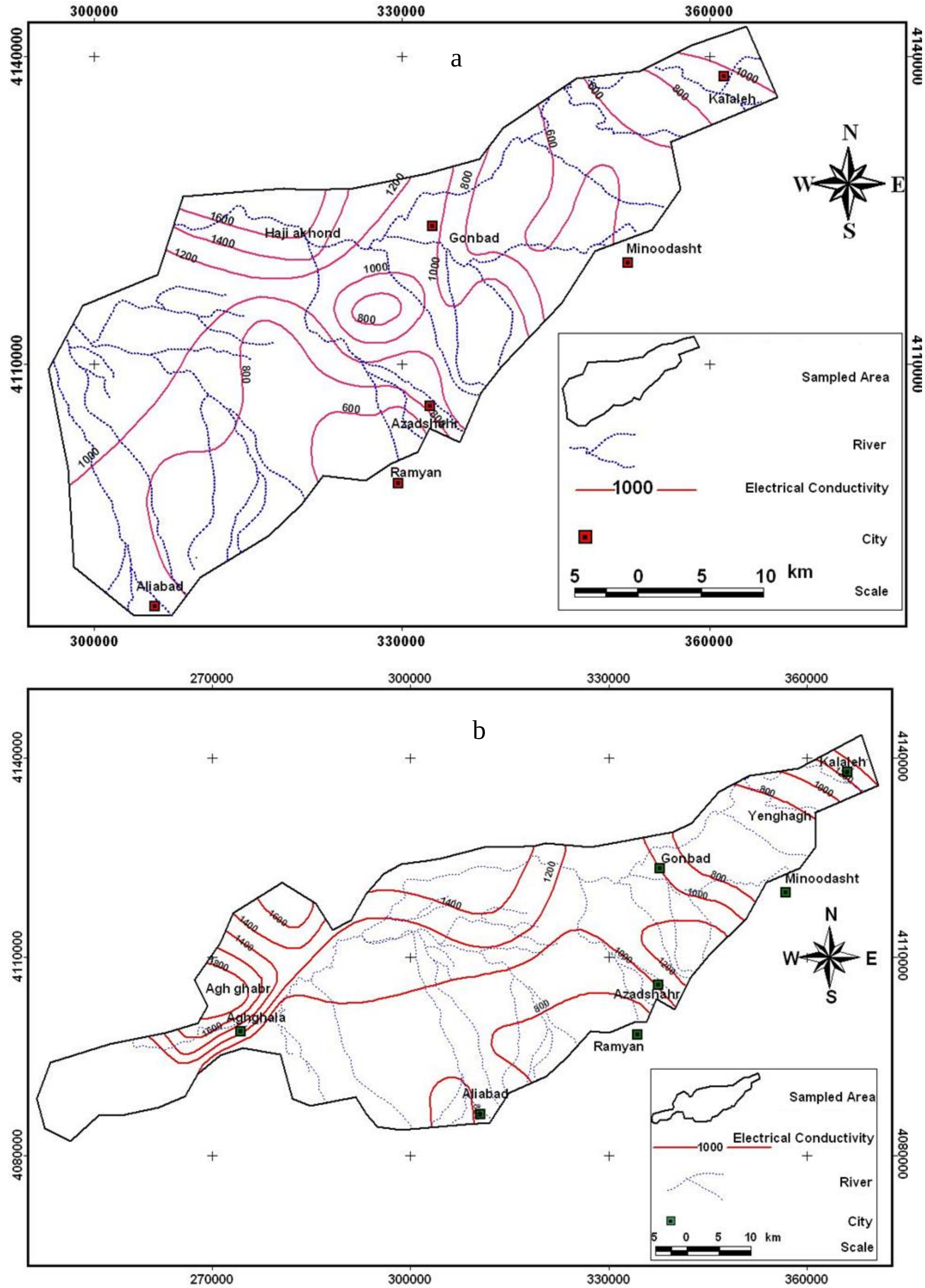


**Figure 5. The map of electric conduction of deep aquifers in a)November 2019; and b) May 2020**

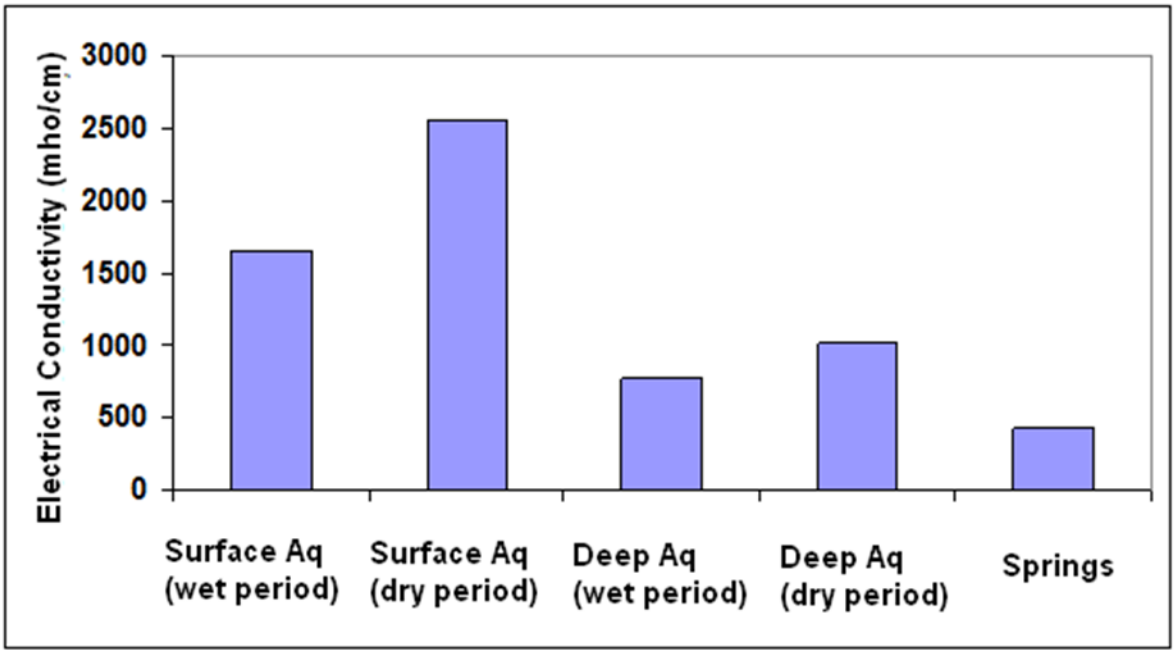


**Figure 6. The comparison of the average electrical conductivity in surface and deep aquifers with springs**

surface aquifer), water quality has improved considerably due to aquifers' feeding (especially surface aquifer) during the wet period. Also, the mean comparison of the electrical conductivity values of both groundwater aquifers with the mean values of the springs' electrical conductivity indicates that water quality in both aquifers has decreased significantly compared to the springs (located at the beginning of the alluvial aquifer). The main reason for this is the increase in the length of the groundwater flow in groundwater aquifers.

**Acknowledgment**

This article is part of the findings of a research project sponsored by the Golestan Regional Water Company and Gorgan Agricultural Sciences and Natural Resources Research Center, which is gratefully acknowledged.

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