Kocaeli University

Kocaeli Journal of Science and Engineering

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Determination of Groundwater Quality Index in Rural Area: The Case of Bartın City

Gülten GÜNEŞ [1, *], Burak AKTAŞ [2], Mert Buğra BAHAR [3], Eftal AVCI [4]

[1] *Department of Environmental Engineering, Bartın University, Bartın, 74110, Turkey,* ***ORCID:*** *0000-0002-1760-2695*
[2] *Department of Environmental Engineering, Bartın University, Bartın, 74110, Turkey,* ***ORCID:*** *0000-0001-7864-7136*
[3] *Department of Environmental Engineering, Bartın University, Bartın, 74110, Turkey,* ***ORCID:*** *0000-0001-6844-8416*
[4] *Department of Environmental Engineering, Bartın University, Bartın, 74110, Turkey,* ***ORCID:*** *0000-0002-3249-1815*

Article Info

Research paper

Received : *September 11, 2022*
Accepted : *December 6, 2022*

Keywords

Groundwater
Water Quality Index
Irrigation Water Quality
Nitrate
Phosphate

Abstract

The aim of the study is to determine the change of groundwater quality in rural areas in rainy and dry periods with respect to physicochemical parameters. pH, total dissolved solids, electrical conductivity, nitrate, sulfate, phosphate hardness, chloride, turbidity and color parameters were investigated. The water quality index (WQI) is widely used for detecting and evaluating water pollution. Water quality index was determined to be 35 and 32 in rainy and dry periods for drinking water. It was also calculated to be 37 for the rainy and dry periods according to the irrigation water limit values. As a result, since WQI<50, groundwater can be used as irrigation water as well as in domestic, industrial use. The difference between the rainy and dry period concentrations of some parameters (color, turbidity, PO_4^{-3}) was significant in the rural area. Color and turbidity were higher in the rainy period unlike TDS, EC and PO_4. In the urban area, significant increases were detected in NO_3^-, SO_4^{-2}, Cl^- concentrations in the rainy period. According to the correlation matrix, groundwater quality in rural areas is affected by multiple sources (aquifer geology, rocks, domestic wastewater, animal waste, river water interference).

1. Introduction

Groundwater is an important water resources used in homes, industrial facilities and agricultural activities [1]. Groundwater is used by approximately 30% of the world's population as drinking water or for various purposes at home [2]. Studies on groundwater quality [3-5] improve processes that manage groundwater quality and ensure effective management of groundwater resources [6]. For this reason, monitoring groundwater quality and determining the factors affecting its quality are important in terms of water quality management. Groundwater chemistry and properties are affected by many sources such as aquifer mineralogy, geochemical processes, excessive land use, source of recharge waters and anthropogenic sources [6-9]. For this reason, the sources that affect the groundwater quality can be categorized in two classes as geological and anthropogenic sources. In recent years, it has been determined that especially anthropogenic activities (urbanization, rapid population growth, industrialization and agricultural activities) negatively affect groundwater quality [10, 11]. Domestic, industrial wastewater discharges and animal wastes are anthropogenic sources that affect groundwater quality. Groundwater flow direction, topographic features, hydrological processes, different rock types are natural sources that affect groundwater metal concentration [10]. Local and regional geology, water/rock interaction, as well as the dilution effect of rainwaters affect groundwater quality [12, 13].

Agricultural activities, animal wastes and septic tanks in rural villages are considered as the most important anthropogenic sources affecting groundwater quality in this study area. Natural and synthetic fertilizers, pesticides, which are generally used during agricultural activities carried out in the gardens of houses or in greenhouses, are considered as other potential pollutants for groundwater. Since there is no sewerage system in the villages, the

* Corresponding Author: ggunes@bartin.edu.tr

collection of domestic wastewater in septic tanks is estimated as another source of pollution for groundwater. In addition, it is thought that the leakages that will occur as a result of the storage of animal wastes in the gardens or the use of fertilizers will be effective especially in the rainy period.

For this reason, in this study, it is aimed to: 1) determine the groundwater quality index in rural areas for rainy and dry periods, 2) determine the water quality index according to the limit values reported for irrigation water, and 3) estimate the sources that may be effective in rainy and dry periods using the correlation matrix 4) compare the water quality determined for rural areas and urban areas.

2. Materials and Methods

2.1. Sampling Area

Bartın is a city in the western Black Sea region of Turkey. Due to its geological structure, Bartın City offers a suitable formation environment especially for hard coal and industrial raw material deposits. The geological structure of Bartın province and its surroundings generally consists of formations containing shale, sandstone, limestone, dolomitic limestone, dolomite, claystone and marl. The formation carrying groundwater in the borders of the Central District is alluvial. The Eocene Flysch, which dominates almost the entire area, is alternated with abundant clayey and silty units. The annual rain average is 1049 mm. The average rain amounts for the winter and summer seasons are 112.8 mm and 70 mm. There are significant seasonal variations in monthly precipitation throughout the year in the Bartın region. The rainiest month in the Bartın region is December, with an average precipitation of 85 millimeters. The least rainy month in the Bartın region is May, with an average precipitation of 33 millimeters. The groundwater level in the study area is quite high and varies between 2 and 5 m. There is no regular storage area for solid wastes in the city and wastes are stored irregularly. In addition, the Bartın River, which passes through the city center, is fed by two separate branches as Kocaçay and Kocanaz Stream, and the river it forms is approximately 15 km. It reaches the Black Sea from the Bosphorus location by traveling a long way. Its flow rate is 12 m per minute and it discharges 1,000,000,000 m^3 of water into the sea every year [14].

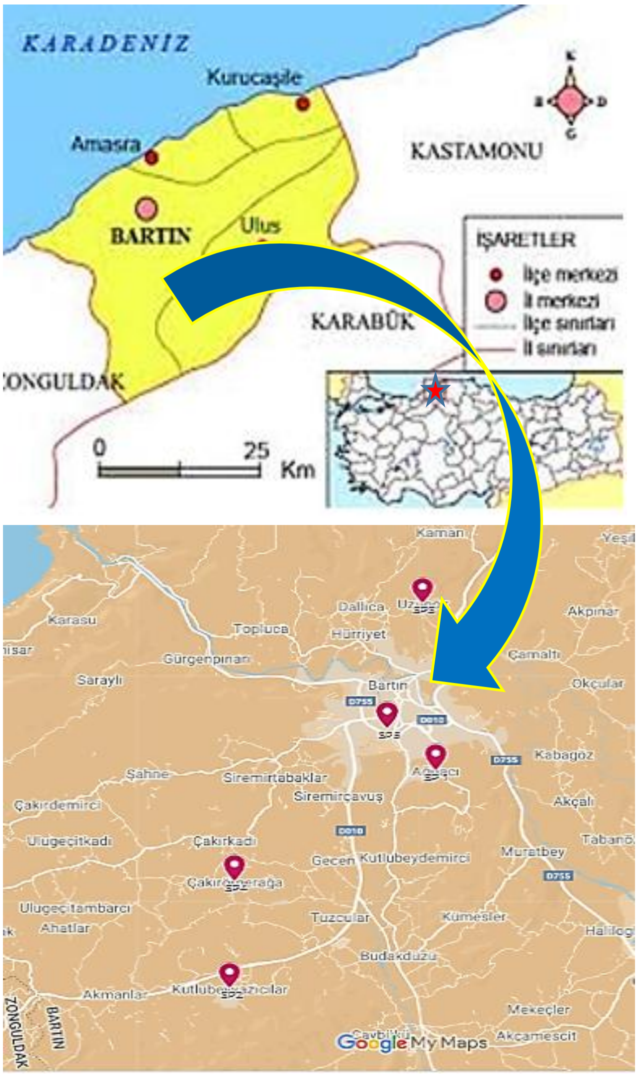

Figure 1. Groundwater sampling points

2.2. Sampling and Analysis

Samples were collected from 5 points in rainy (March and April) and dry (end of may and early october) periods. The reason for choosing the months of March and April is that the water level in the wells is high after rain and snowfall in winter. In May and October, the water level in the wells is low since it is after the dry period. In terms of representing the rural area, water samples were collected from 4 different villages. Water was sampled from only one point in the urban area to compare with the results obtained for the rural area. The shortest distance between sampling points is approximately 2.2 km, while the longest distance is 13 km (Figure 1). Samples for physicochemical analysis were collected with sterile plastic bottles in accordance with method ISO 5667-3:2018 [15]. Total dissolved solids, electrical conductivity, total hardness, turbidity, sulphate, nitrate, phosphate, chloride concentrations were determined. Phosphate, nitrate, sulphate and total hardness (TH) analyzes were made according to the American Public Health Association Method [16]. Total hardness and chloride concentrations were determined by the titrimetric method. Phosphate, nitrate and sulphate were determined according to the spectrophotometric method by UV-VIS Spectrophotometer (HACH Lange 6000 DR). Turbidity and color were determined by turbidimetric (Hach 2100 Q Portable Turbidimeter) and colorimetric (Hach Lico 620) methods, respectively. pH, electrical conductivity (EC), temperature (T), total dissolved solids (TDS) were measured in situ (Hanna HI 9812-5) according to the electrode method. All calculations for the evaluation of the data were made with Microsoft Excel 2016 program.

2.3. Groundwater Quality Index (GWQI)

The water quality index is a widely used metric for detecting and evaluating water pollution. This index allows the water quality to be summed up with a single value and is calculated according to Eq. (1), Eq. (2), Eq. (3) and Eq. (4) [17]. According to this index, water quality can be categorized in 5 classes: <50: excelllent, 50-100: good water, 100-200: poor water, 200-300: very poor water, > 300: unfit for drinking [17]. The relative weight values (W_i) for each parameter were calculated according to Eq. (1).

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \quad (1)$$

where Wi is the relative weight, wi is the weight of each parameter (Table 1) [17, 18] and n is the number of parameters.

$$q_i = \frac{C_i}{S_i} \times 100 \quad (2)$$

where q_i= quality rating, C_i= concentration of each chemical parameter in each water sample in mg/L, S_i = drinking water standard value for each chemical parameter in mg/L except for conductivity (µS/cm) and pH. S_i^*= Irrigation water standard value for each chemical parameter in mg/L except for conductivity (µS/cm) and pH.

$$SI_i = W_i \times q_i \quad (3)$$

where SI_i is the sub-index of the ith parameter; qi is the rating based on concentration of i^{th} parameter and n is the number of parameters.

$$GWQI = \sum SI_i \quad (4)$$

3. Results and Discussion

3.1. Evaluation of groundwater quality

The results of the physicochemical parameters are shown in Table 2. pH is an indicator of the acidic-basic interaction of the organic components of water and some minerals [13, 19]. pH was determined to be 8.5 and 8.3 for the dry and rainy periods, respectively, and showed slightly alkaline properties. In other studies, while acidic pH values were generally determined for industrial areas, it has been reported that pH changes from acidic to basic in rural, semi-urban and urban areas [17]. All pH values were in accordance with WHO [20] and TS [21] standards for drinking water (Table 2).

Total dissolved solids in groundwater are mainly related to inorganic salts and dissolved organic matter [22]. Salts can be of geogenic origin (decomposition of rocks) or anthropogenic origin (domestic/industrial wastewater discharge, pipe material feature in the water transport line) [23].

Table 1. Standard values, weightage factors and relative weights of water quality parameters.

	Weightage (w_i)	Relative weight (Wi)	S_i (standard values for drinking water) [20]	S_i^* (standard values for irrigation water) [24]	S_i^*(standard values for irrigation water) [25]
pH	4	0.16	6.5-8.5	8.5	9
TDS	4	0.16	1500	2000	>2100
EC	1	0.04	2500	3000	>3000
TH	2	0.08	500	120	
Phosphate	2	0.08	0.5[a]	6.13	
Sulfate	4	0.16	250	960	>960
Chloride	3	0.12	200	1063	>710
Nitrate	5	0.2	50	44	>50
	Σw_i=25	ΣW_i=1			

a Tirkey et al. [17], All parameters mg/L except pH and EC (µS/cm)

In this study, the TDS values were determined to be 273 mg/L and 504 mg/L for the rainy and dry periods, respectively. These values are suitable for drinking water according to the limit values reported in WHO standards. The higher concentration in the dry period indicates that the TDS is of geogenic origin, especially related to aquifer geology. While the lower groundwater level in this period causes the TDS concentration to increase, the increased amount of water during the rainy period may cause a dilution of TDS concentration.

The electrical conductivity is related to dissolved solids in water. It was determined to be 543 µS/cm and 964 µS/cm for the rainy and dry periods, respectively. According to WHO [20] and TS [21] standards, groundwater is suitable as drinking water in terms of EC. TDS and EC are directly proportional to each other. Therefore, the explanations for TDS also apply to the EC parameter. In a study conducted in Ghana, it was reported that the TDS concentration was higher in the dry period [26]. Mean values for TDS and EC in Arabia (Hail Zone) were reported to be 1119 mg/L and 2239 µS/cm, respectively [13]. For a rural area in India (Ranchi City), TDS and EC have been reported in the ranges of 51.4 -434 mg/L and 101-855 µS/cm, respectively [17]. In another study in Zimbabwe, EC was reported in the range of 169.1-922 µS/cm (452 µS/cm) [27].

The mean NO_3^- concentration (2.2 mg/L) was much lower than the limit values reported in WHO [20] and TS [21] standards. Although the concentration determined for the rainy period (2.24 mg/L) was higher than the concentration for the dry period (2.17 mg/L), the difference between both periods was insignificant. It is known that nitrate compounds in groundwater are related to nitrogen oxides in rain waters, leakage from nitrogen-containing fertilizers, interference from river water contaminated with NO_3^-, bacteriological conversion of NH_4^+ to NO_3^- in an oxygenated environment, and industrial discharges [6, 28]. In this study, the increase in concentration determined during the rainy period can be explained by the high solubility of nitrate in water [13] and the transport of nitrate compounds in the soil to the groundwater together with the rain waters. Since the sampling points are located in rural areas, it is thought that the nitrate compounds found naturally in the soil or those that may have leaked from manure, animal waste and septic tanks were transported to groundwater with rain waters.

In another study, it was determined that the NO_3^- concentrations in the groundwater samples (92 pieces) collected in July in the Amik Plain (Turkey) ranged between 0.38 and 300 (23.16) mg/L and only 2 samples exceeded the limit value (50 mg/L) reported for drinking water [29]. In another study conducted in Batman (Turkey), it was reported that NO_3^- concentrations ranged from 1.9-50.4 mg/L in 30 groundwater samples [30]. Again, in this study, it was determined that the limit value was exceeded in areas with agriculture and livestock activities, and it was reported that the highest concentrations were determined in the city center where anthropogenic sources (fertilizer and pesticide use) were effective [30]. In Ghana, it was reported that the NO_3^- concentration ranged from 0.4 mg/L to 48.4 mg/L (18.7 mg/L) (36 samples) and the limit value (50 mg/L) was not exceeded at any sampling point [31]. In another study conducted in Zimbabwe, the NO_3^- concentration was in the range of 0.032-3.22 mg/L, and the average concentration (1.45 mg/L) was close to that of this study [27].

Phosphate, on the other hand, showed an opposite trend compared to nitrate, and the concentration determined for the dry period (0.51 mg/L) was higher than the concentration of rainy period (0.29 mg/L). Although the average phosphate concentration was lower than the limit value reported in the literature [17], it exceeded the limit value, especially in the urban area during the dry period (Table 2). The concentration difference between the two periods was significant. The high concentration determined during the dry period can be explained by 2 reasons: 1) The low amount of water in the dry period and the longer contact of the water with the aquifer rocks 2) The phosphate compounds that can leak from the septic tanks. In addition, these results indicate that phosphate transport from the soil was not effective during the rainy season. This can be explained by the low solubility of phosphate [32] and its strong adsorbability on soil particles [17]. In Ghana [31] and Arabia [13], the mean phosphate concentrations were reported to be 0.4 mg/L (0.1 -1.2 mg/L) and 0.1 mg/L (0.01-0.43 mg/L), respectively [13].

Since the average sulfate concentration was determined to be 38 mg/L, it complies with the relevant standard values (Table 2). The concentrations were detected to be 40 mg/L and 36 mg/L for the rainy and dry periods, respectively. According to WHO [20] and TS [21] standards, groundwater is suitable as drinking water in terms of sulfate. Although there is no significant difference between the two periods, the high concentration in the rainy period can be explained by the dissolution of sulfate minerals in soil and rocks in rain waters.

In a study conducted in Zimbabwe, the SO_4^{-2} concentration was determined in the range of 0.146 to 12.7 mg/L (5.3 mg/L), which is lower than the concentration in this study [27]. In a study in India (Ranchi City), concentrations were reported in the range of 0-152.82 mg/L [17]. The concentrations determined in Arabia are in the range of 16.8-1242 mg/L (266 mg/L) [13], which is considerably higher than this study and other studies.

The average Cl^- concentration for the rainy period (18 mg/L) was higher than the dry period (13 mg/L) while there was no significant difference between them. The mean values determined for the chloride concentration were considerably lower than the limit values reported in the WHO [20] and TS [21] standards. These results for chloride are consistent with the results for nitrate and sulfate. Chloride mixes with groundwater from many sources, including natural (sea water intrusion, sedimentary rocks, soil minerals) and anthropogenic (domestic waste, animal waste, industrial waste) [17, 33]. As a result, the higher concentration in the rainy season for these 3 compounds can be explained by the contact of the soil or rocks with rainwater or the transfer of leakages from the sewage system or septic tanks to the groundwater with rainwater. It is known that domestic wastewater is one of the anthropogenic sources for NO_3^-, SO_4^{-2}, Cl^- salts dissolved in groundwater [6, 34].

The average TH concentrations were found to be 244 and 259 mg $CaCO_3$/L for the rainy and dry periods, respectively in this study area. According to the limit value (500 mg $CaCO_3$/L) reported in TS [21], groundwater is suitable as drinking water. According to the classification reported by [35], groundwater is in the hard water class since the average concentrations were in the range of 150-300 mg $CaCO_3$/L.

Similar to the phosphate compound, the total hardness was also higher in the dry period. Hardness in groundwater is related to the rocks with which groundwater interacts and to the soil mineralogy containing Ca^{+2} and Mg^{+2}. Dolomite ($CaCO_3$, $MgCO_3$), which is one of the most important sources of industrial raw materials in Bartın, may be the cause of the total hardness in groundwater.

Turbidity and color were detected to be higher in the rainy season. The average values were detected to be 6.09 NTU and 54 Pt-Co in the rainy period. These values were higher than the limit values reported in the relevant standards (Table 2). Suspended solids such as clay and silt particles, organic matter, microscopic organisms and colloids cause turbidity in natural waters [36]. The dominance of silty and clay units in this study area also supports this idea. Fulvic and humic acids dissolved in water cause color formation in water [36]. Suspended or dissolved substances in water also affect the color of the water. In this study, it is thought that suspended solids and dissolved substances carried by rain waters cause color and turbidity in groundwater. At the sampling points where the color parameter was higher, the yellow color of the water may be related to the presence of fulvic and humic acids dissolved in the water [37].

Although the aim of the study was to determine the groundwater quality in the rural area, one of the sampling point was in the urban area and the results from rural area samples and urban area sample were compared.

Table 2. Summary of measured water quality parameters

	Rural			Urban							
	Dry	Rainy	Mean	Dry	Rainy	Mean	Tirkey et al. [17]	WHO [20]	TS [21]	Irrigation [24]	**S_i*(standard values for irrigation water) [25]**
TDS	504	273	388	498	320	409		1000		2000	>2100
EC	964	543	753	990	650	820		2500	2500	3000	>3000
NO_3^-	2.17	2.24	2.20	3.4	4.9	4.2		50	50		>50
NO_3-N	0.49	0.51	0.5	0.77	1.11	0.95				10	
PO_4^{-3}	0.51	0.29	0.40	0.57	0.24	0.403	0.5				
PO_4-P	0.17	0.09	0.13	0.08	0.19	0.13				2	
SO_4^{-2}	36	40	38	37	69	53		250	250	960	>960
Cl^-	13	18	16	18	30	24		200	250	1063	>710
TH	259	244	251	281	295	288		500	500		
pH	8.5	8.3	8.4	7.9	8.4	8.2		6.5-8.5	6.5-9.2	8.5	9
Turbidity	0.87	6.09	3.5	0.33	2	1.0		5.0	1.0		
Color	13	54	33	3	25	14		15	20		

All parameters in mg/L except EC: (µs/cm). Turbidity: NTU. Color: Pt-Co (PCU). T:ºC. TH: Total hardness. TDS: Total dissolved solid. EC: Electrical conductivity

TDS, EC, NO_3^-, SO_4^{-2}, Cl^-, TH were detected higher in urban area unlike pH, turbidity and color. The sampling point in the urban area is located very close to the river (30-40 m). For this reason, it is thought that the river-groundwater interaction or leakage from the sewer line may be effective at the point in the urban area. The largest concentration difference between rural and urban areas was determined for NO_3^-. In general, the variation of parameters during rainy and dry periods is similar for both locations. In both settlements, NO_3^-, SO_4^{-2}, Cl^-, pH, color and turbidity parameters were higher in the rainy season. This situation can be explained by the transport from the soil during the rainy period, the interaction of river and groundwater, and the transportation of leakages from the sewage systems with the rain waters. The concentration difference of NO_3^-, SO_4^{-2}, Cl^- between both periods was greater in the urban area. In previous studies, it has been reported that Cl^-, SO_4^{-2}, NH_4^+, and NO_3^- salts dissolved in groundwater are related to landfill leakage, domestic wastewater, agricultural chemicals, industrial chemicals, and recharge waters [6, 34]. Similar to the rural area, the higher phosphate concentration in the urban area in the dry season indicated that phosphate may be related to aquifer geology and wastewater leakage. In the urban area, only PO_4^{-3}, turbidity and color exceeded the limit values reported in the relevant standards. According to the classification reported by [35], groundwater is in the hard water class since the TH concentration is in the range of 150-300 mg $CaCO_3$/L.

3.2. Evaluation of Suitability as Irrigation Water

According to the irrigation water standard values (Table 2), the groundwater was suitable as irrigation water in both periods. In another classification, irrigation water quality is categorized in 5 classes according to EC values [38]: EC<250 (Excellent), 250-750 (Good), 750-2000 (Permissible), 2000-3000 (Doubtful), >3000 (Unsuitable).

In this study, irrigation water quality was determined in the good quality class (EC=250-750 µs/cm) in the rainy period, while detected in the permissible quality class (750-2000 µs/cm) in the dry period.

The suitability of groundwater as irrigation water is categorized in 4 classes according to their total hardness [39]: <60 mg $CaCO_3$/L (soft), 60-120 mg $CaCO_3$/L (medium hard), 120-180 mg $CaCO_3$/L (hard), >180 mg $CaCO_3$/L (very hard). It was determined that the groundwater in the rural area is in the very hard water class as irrigation water in this study. One of the indexes used to determine the quality of irrigation water is the potential salinity, which is determined according to the SO_4^{-2} and Cl^- anions in the water. Potential salinity was calculated according to Eq. (5) [40]. Cl^- and SO_4^{-2} concentrations are taken as meq L^- in the equation.

$$PS = Cl^- + 0.5SO_4^{-2} \quad (5)$$

Potential salinity values were determined in the range of 0.51-0.92 (0.74) in the dry period and between 0.78-1.04 (0.93) in the rainy period. Since PS<3 in both periods, groundwater is suitable as irrigation water. It was determined that groundwater could be used as irrigation water according to the water quality parameters determined for the urban area. According to the EC parameter, the groundwater is in the permissible quality class (750-2000 µs/cm) as irrigation water for both periods. Similar to the rural area, the groundwater in the urban area is in the very hard water class as irrigation water.

3.3. Assessment of Water Quality Index

The water quality index was calculated according to the standard values reported for both drinking water and irrigation water for the samples collected from rural areas, and the average values are shown in Figure 2. Since the average WQI was calculated to be 35 and 32 for the rainy and dry periods, the groundwater was determined to be in the good quality class in both periods. According to the reported standard values for irrigation water, average WQI was calculated to be 37 for rainy and dry periods, and it was determined that groundwater was suitable for irrigation water. WQI values determined according to drinking water standard values showed that groundwater at all sampling points can be used in homes and industries as well as irrigation water.

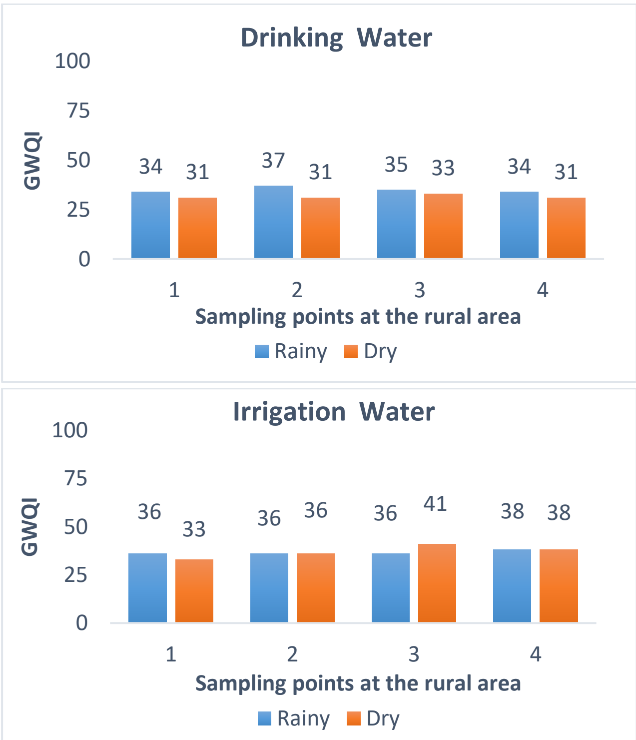

Figure 2. Water quality index values for groundwater

3.4. Correlation Matrix

The relationships between the physicochemical parameters of groundwater can demonstrate the processes that generated the water composition [6, 41]. In this study, the correlation matrix was created only for the rural area and is shown in Table 3. Significant negative correlations were determined between SO_4^{-2} and TDS/EC/PO_4^{-3}/Cl^- during the rainy season. This shows that there is an inversely proportional linear relationship between SO_4^{-2} and these compounds. Inorganic salts can be formed from geogenic sources as well as from anthropogenic sources (domestic and industrial wastewater discharges) [23]. Geogenic sources may be related to soil mineralogy and aquifer geology. TDS/EC/PO_4^{-3}/Cl^- parameters may be related to geogenic sources, especially aquifer geology, as well as leakages from septic tanks. While rain waters cause some minerals in the soil to dissolve and move to groundwater, it may cause dilution of some minerals related to aquifer geology.

Table 3. Correlation matrix for physicochemical parameters.

Parameters	TDS	EC	NO_3^-	PO_4^{-3}	SO_4^{-2}	TH	pH	Turbidity	Color	Cl^-
TDS	1	1.00	0.44	0.26	-0.71	-0.34	-0.93	-0.52	-0.04	-0.18
EC	0.92	1	0.45	0.25	-0.71	-0.32	-0.94	-0.53	-0.05	-0.19
NO_3^-	0.50	0.79	1	-0.38	-0.07	0.40	-0.70	-0.33	-0.55	-0.33
PO_4^{-3}	-0.10	-0.01	0.35	1	-0.85	-0.99	0.05	0.59	0.95	0.85
SO_4^{-2}	-0.26	-0.34	-0.55	-0.93	1	0.87	0.49	-0.20	-0.65	-0.56
TH	0.62	0.56	0.12	-0.83	0.58	1	0.01	-0.50	-0.93	-0.79
pH	-0.77	-0.78	-0.68	-0.55	0.81	0.00	1	0.65	0.35	0.39
Turbidity	0.18	0.24	0.46	0.96	-0.99	-0.65	-0.76	1	0.77	0.92
Color	0.03	0.11	0.40	0.99	-0.97	-0.75	-0.65	0.99	1	0.93
Cl^-	0.25	0.53	0.61	-0.46	0.32	0.64	0.04	-0.42	-0.45	1

Pink: rainy period; blue: dry period.

According to the positive correlation between chloride and phosphate, the sources of these compounds may be similar. Contrary to the positive significant correlation between TH and SO_4^{-2}, detected negative correlation between TH/PO_4^{-3} indicates that SO_4^{-2} and TH may be related to similar geogenic sources or river water intrusion.

Another remarkable point is the positive correlations between color/turbidity/phosphate/chlorine. This indicates that the sources of these parameters are the same. On the other hand, the negative correlation between color/turbidity and TH/SO_4^{-2} indicates that the sources of TH and SO_4^{-2} may differ from color and turbidity. The positive correlation between PO_4^{-3}, Cl^-, turbidity and color indicated that leakage from septic tanks, animal waste, and fertilizers can be effective in the rainy season. Additionally, the compounds in the soil can be dissolved by rain waters and transported to the groundwater.

A significant relationship was found between TDS and EC/TH/NO_3^- in the dry period. Similar to the rainy season, positive correlation coefficients indicate that turbidity, color and PO_4^{-3} are affected by the same sources during the dry period. Unlike the rainy period, a positive correlation was found between Cl^- and NO_3^-/TH in this period. This indicates that different sources such as river water intrusion and irrigation water may be effective as well as geological sources and septic tanks in dry period.

These correlations indicated that SO_4^{-2} and TH could be affected by the same sources (geogenetic structures or river water inflow) in both periods. Color, turbidity and PO_4^{-3} may have been affected by anthropogenic sources, particularly leakage from septic tanks or animal waste. The results showed that the groundwater quality was affected by multiple pollution sources in both periods. In another study, no correlation was found between physicochemical parameters except EC/Cl^-/Salinity [31]. It has been reported that groundwater may be affected by multiple sources, since no direct correlation could be determined between the pollution parameters (NO_3^-, PO_4^{-3}, Cl^-) [31]. In the study conducted in Arabia (Hail Region), a significant correlation was determined between TDS, EC, Cl^-, SO_4^{-2}, but no correlation was found between pollution indicators (NO_3^-, PO_4^{-3}, Cl^-) [13].

4. Conclusions

Groundwater samples collected from rural areas comply with the reported standard values for drinking water according to WHO [20] and TS [21] standards. TDS, EC, PO_4, TH and pH were higher in the dry period. However, the concentration difference between the two periods of TDS, EC and PO_4^{-3} was greater. According to irrigation water quality standards, groundwater is of suitable quality as irrigation water. While groundwater is suitable as irrigation water according to the potential salinity index (PS<3) determined for SO_4^{-2} and Cl^- anions (except SP4 in the dry period), it is in the very hard water class according to the hardness parameter. TDS, EC, NO_3^-, SO_4^{-2}, Cl^-, TH were detected higher in urban area unlike pH, turbidity and color. The river-groundwater interaction or leakage from the sewer line may be effective at the point in the urban area. NO_3^-, SO_4^{-2}, Cl^-, pH, color and turbidity parameters were higher in the rainy season in both settlements. Concentration difference of nitrate between rural and urban areas was higher than other parameters.

According to the WQI values calculated according to the drinking water and irrigation water quality standard values, groundwater is suitable for both drinking water and irrigation water for both periods (WQI<50). According to the correlation matrix, a significant positive correlation was determined between Cl^-, PO_4^{-3}, turbidity and color during the rainy season. For this reason, it was estimated that the sources of these parameters were the same during the rainy season and they could be related to domestic wastewater or animal waste. The correlation between TH and SO_4^{-2} in the rainy season showed that these compounds may be related to geogenic sources (soil mineralogy, rocks) or river water intrusion. In the dry period, a significant positive correlation was determined between PO_4^{-3}/turbidity/color and SO_4^{-2}/TH as in the rainy period. A significant positive correlation was determined between Cl^-/NO_3^-/TH, different from the rainy period. As a result, it is thought that groundwater quality in rural areas is affected by many sources, including anthropogenic and geogenic sources.

Declaration of Ethical Standards

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This study was supported by the TUBITAK 2209-A Program (Project number: 1919B011703668).

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