Comparison between the Temporal Variations of Ground and Surface Water Quality Parameters (Case Study: Ajichai Basin)

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Abstract: Groundwater is considered as the most important source of fresh water in many parts of the world. Since, it supplies the demands of growing industries, agriculture, fisheries, mining, and manufacturing and the municipal water in the regions, where the quality or quantity of the surface water sources is weak. So that any changes in the quality of ground water may affect human, nature and wild life. Furthermore, the relationships between the quality of ground and surface water quality is well known in many parts of globe. The main objective of the present study was to investigate the relationships between the changes in the surface and ground water quality in Ajichai River basin, as one of the major sub-basins of the Great Salt Lake of Urmia, located to the northwest of Iran. For this purpose the mean annual time series of the water quality parameters Na (mg/l), Mg (mg/l), Ca (mg/l), Cl (mg/l), SO4 (mg/l), CO3 (mg/l), HCO3 (mg/l), TDS (mg/l), EC (dS/m2), SAR and pH with respect to the surface and ground water in the study area were applied to trend analysis using modified Mann-Kendall method. Furthermore, in order to investigate the magnitude of the trends, Sen's slope estimator approach was utilized. The results obtained in the present study revealed the fact that, there at least two separated aquifers in the study area. Of which the water quality of one varies in line with surface water quality in the area and the trends observed in the other aquifer have no link to the trends observed in surface water quality.
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1. Introduction

Groundwater is considered as the most important source of fresh water in many parts of the world. Since, it supplies the demands of growing industries, agriculture, fisheries, mining, and manufacturing and the municipal water in the regions, where the quality or quantity of the surface water sources is low, such as Tabriz watershed. So that, in order to protect these fresh sources of water which may barely be named as the renewable water resources an integrated water resources planning and efficient management of groundwater is considered as an essential task in different regions, worldwide. Especially in arid and semi-arid regions, where water crisis is very sensible. Since, the intake of fresh water from surface water sources and also precipitation and snow is negligible and the water demands are mostly supplied via ground water sources. Furthermore, in order to be able to well monitor the groundwater sources it is essential to have information about the changes in the concentration of hydro-geochemical elements of ground and surface water. Thus, the detection of trends in ground and surface water quality parameters is very essential.

Nowadays, researchers have developed various analytic methods for studying the trends of hydrological parameters. Of which, non-parametric methods seems to have received more attention, due to their less sensitivity to the existence of breaks and outliers in the series of data. Gehrels et al. (1994) analyzed the fluctuations in surface water and groundwater levels in the Netherlands, and have reported that the groundwater levels have declined over the wide area due to the drainage, drought and excess overdraft by the farmers. Chen et al. (2004) investigated the correlation between the climatic parameters and the groundwater levels in the Manitoba (Canada) by using the data of the mean, the maximum and the minimum temperatures and precipitation during the hundred-year period from 1900 to 2000. The mean annual temperature and precipitation were found to be significantly correlated with the ground water in the Manitoba. Almedeij and Al-Ruwaih (2006) investigated the fluctuations in the groundwater levels in the residential areas of Kuwait. They found that the groundwater levels were negatively correlated with temperature and positively correlated with precipitation. Jan et al. (2007) examined the effects of rainfall intensity and its distribution on the fluctuations of the groundwater levels in Taiwan and reported a linear correlation between the groundwater levels and the precipitation. Panda et al. (2007) investigated the influence of drought and anthropogenic effects on groundwater levels in Orissa (India) by using the Mann–Kendall (MK) non-parametric test for trend analysis in the pre-monsoon and post-monsoon groundwater level records of 1,002 monitoring stations during the period 1994–2003. They reported that the drawdown due to deficient rainfall during dry years, high temperatures and anthropogenic pressure were not recovered through the recharge in wet years. In the pre-monsoon (the post-monsoon) season, about 59 % (51 %) of the monitoring stations experienced decline in the groundwater in Orissa. Lee et al. (2007) investigated the variability in the groundwater levels at Daegu, Korea and reported that the construction of subway tunnels could have the caused the decline in the ground water levels.

Zhang et al. (2009) examined the temporal and spatial variability in annual extreme water level in the Pearl River Delta region, China. They reported that the water levels declined (increased) in the upper parts (the middle and the lower parts) of the Delta region. Shahid and Hazarika (2009) examined the groundwater drought in the northwestern districts of Bangladesh in 85 wells from 1998 to 2002. Analysis of groundwater hydrographs and rainfall revealed that ever increasing groundwater extraction for irrigation in the dry season and recurrent droughts were the two main causes of the drop in the groundwater levels in the region. They found the groundwater scarcity in about half of the area studied in each year in the region. Shamsudduha et al. (2009) studied the recent trends in groundwater levels from the period 1985 to 2005 in a highly seasonal hydrological system in the Ganges–Brahmaputra–Meghna Delta of Bangladesh by using the nonparametric seasonal-trend decomposition procedure. They found that seasonality dominated the observed variance in groundwater levels but declining groundwater levels (1 m/year) were detected in urban and peri-urban areas, and at the rate of 0.1–0.5 m/year where intensive abstraction of groundwater was conducted for the dry-season rice cultivation. However, rising groundwater levels (0.5–2.5 cm/year) were observed in the estuarine and southern coastal regions.

2. Material and Methods

The main objective of the present study is to analyze the trends of surface and ground water quality parameters in the Ajichai River basin in Tabriz, Iran to understand the relationships between the variations of ground and surface water parameters in the Ajichai River basin. Ajichai River basin is considered as one of the most important sub-basins of the Great Salt Lake of Urmia watershed, which covers an area of about 12790 Km2 and is located between $37^\circ\,42'N - 38^o30'$N and $45^o40'$E $- 47^o53'E$. Figure 1 provides information about the location of the Ajichai River basin. For this purpose, the mean annual records of the water quality parameters Na (mg/l), Mg (mg/l), Ca (mg/l), Cl (mg/l), SO4 (mg/l), CO3 (mg/l), HCO3 (mg/l), TDS (mg/l), EC (dS/m2), SAR and pH with respect to the surface and ground water in the study area were obtained from the water and electricity organization of the East Azerbaijan (Iran). In addition to the above mentioned parameters, in order to analyze the relationships between the variations of the mentioned water quality parameters and the quantity of surface water discharge in the study area, the mean annual records of Ajichai River discharge in were also obtained from water and electricity organization of the East Azerbaijan.

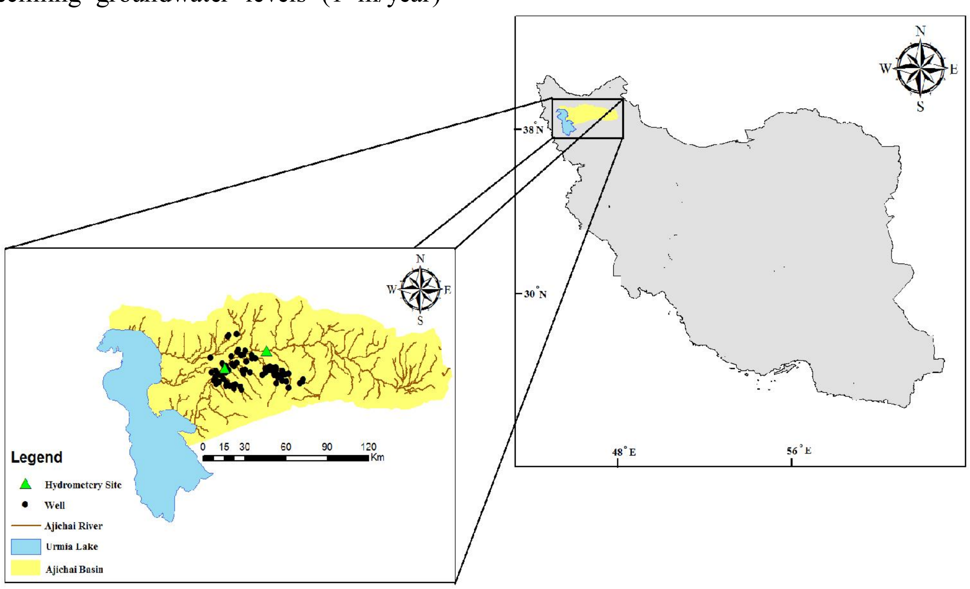

Figure 1. Geographical location of the Ajichai Reservoir.

In order to analyze the variations of the abovementioned parameters, the data with respect to an overall number of 400 wells and 6 hydrometery sites located in the Ajichai River basin were obtained from the water and electricity organization of the East Azerbaijan. Of which, due to the following criteria, the data with respect to merely 7 wells and 2 hydrometery sites were chosen for further analysis: (I) Availability of at least ten years of data, (II) Availability of uniform records for all of the stations during the study period, (III) Wells having relatively close location to the hydrometery sites. The information regarding to the hydrometery sites and the wells utilized in this study are provided in Table 1 and Table 2, respectively.

Table 1. Details of the hydrometery used in this study.

Station Name	Latitude	Longitude	Time period
Akhula	38° 01′ N	46° 03′ E	1983-2014
Vaniar	38° 07′ N	46° 24′ E	1983-2014

Table 2. Details of the wells used in this study.

Well ID	Latitude(N)	Longitude	Time period	Type
92	38°00′	45° 58′ E	2003-2014	Deep
101	38°03′	46° 01′ E	2003-2014	Deep
120	38°01′	46° 03′ E	2003-2014	Deep
126	37°59′	46° 01′ E	2003-2014	Semi-deep
158	37°59′	45° 59′ E	2003-2014	Deep
188	38°01′	46° 03′ E	2003-2014	Deep
192	37°58′	46° 01′ E	2003-2014	Deep

From the data given in the Table 1, it can be seen that the time period for both of the hydrometery sites chosen for this study is 1983-2014, while, according to the information provided in Table 2, it is 2003-2014 for the wells. So that, in order to consider the same time period for both the wells and the hydrometey sites, the period of 2003-2014 was chosen as the time period of this study.

In order to analyze the trends in the series of data in the present study, the non-parametric method modified Mann-Kendall (Mann 1945, Kendall 1975) method according the methodology provided in Vousoughi et al. (2011) was applied. Furthermore, to indicate the magnitude of the trends, the method provided by Sen (Sen 1968) was utilized. The reasons for choosing this method for this study are as follows: (I) it does not require the data to be normally distributed and (II) it is not sensitive to existence of breaks and/or outliers in the series of data.

3. Results

The main objective of the present study was to evaluate the relationships between the variations of the ground and surface water quality parameters and also the amount of river discharge in the Ajichai river basin in Tabriz, Iran. The results of trend analysis based on the modified MK method for the two hydrometery sites studied are presented in Table 3. According to this data, almost all of the surface water quality parameters seemed to have decreased during 2003-2014 in both of the stations. The calculated slopes, however show a more steep decrease in the hydrometery site Vaniar in comparison with the hydrometery site Akhula. Overall, despite quantity of almost all of the water quality parameters studied except the parameters pH, CO3 and HCO3, seems to have decreased between 2003 and 2014 in both sites, merely five significant trends was observed in the surface water parameters studied. The element Na seems to have decreased by -0.93 (mg/l/year) and -1.80 (mg/l/year) in the sites Akhula and Vaniar, respectively, the MK method showed that the less steep decrease was significant only at 10% level of significance. Moreover, a significant decreasing trend at 1% level of significance was also observed in SAR in the site Akhula, being equal to -0.51 (per year). According to the data given in the Table 3 also, the amount of SO4 in the surface water at the site Akhula has significantly (at 1% level of significance) decreased by -0.24 (mg/l/year) during 2003-2014. In contrast, however, a non-significant upward trend was observed in the amount of CO3 and pH at the site Akhula.

In terms of the hydrometery site Vaniar, as it can be inferred from the data provided in the Table 3, a downward trend in the quantity of flow was observed at 1% level of significance, being equal to -1.41 (m3/year). HCO3 also showed a significant decreasing trend at 1% significant level, being -0.07 (mg/l/year). In contrast, pH seems to have increased by 0.02 (not significant). A comparison between the trend slopes obtained for the parameters analyzed in the hydrometery sites Akhula and Vaniar shows that, the detected trend slopes at the site Vaniar are mostly by far greater than those of the site Akhula. This fact may lay beyond the higher concentration of the contaminants in the surface water in the Vaniar site, in comparison with the site Akhula. Time series of the studied parameters are provided in Figure 2. From the data provided in the Figure 2 it can be seen that, the amount of EC, TDS, SO4, Na, Cl, SAR, Ca and Mg in the Ajichai River, measured at the site Vaniar are by far greater than those measured at the site Akhula.

Table 4 and Figure 3 provide information about the results of trend analysis and times series of the groundwater quality parameters in the Ajichai River basin, respectively. According to the data given in Figure 3 and Table 4 it can be realized that the is a vast difference between the amount of water quality parameters of the wells selected for this study. However, a more precise comparison between the time series of the wells shows that, the wells number 92, 126 and 158 have relatively close values to each other and may have been digged in the same aquifer (Aq. 1). The wells number 101, 126 and 158 also seem to have almost similar values and should have been digged the same aquifer (Aq. 2). This implies that, there were two different aquifers in the study area. According to the trend results for groundwater quality given in Table 4, TDS has decreased in two out of the seven selected wells (one were significant at 10% significance level) and increased in five other stations (4, 3 and 2 were significant at 10%, 5% and 1% level of significance). The downward trends in TDS were mostly observed in Aq. 1 and the upward trends were observed in Aq. 2 wells.

Table 3. Results of trend analysis for the surface water quality and river discharge in the two hydrometery sites studied.

Station	Slopes (unit/year)											
	Q	TDS	EC	pH	CO3	HCO3	Cl	SO4	Ca	Mg	Na	SAR
Akhula	-0.68	-57.48	-104.03	0.03	0.01	0.00	-1.08	**-0.24****	-0.05	-0.01	**-0.93**	**-0.51****
Vaniar	**-1.41****	-247.09	-411.77	0.02	0.00	**-0.07****	-1.40	-0.79	-0.15	-0.21	-1.80	-0.14

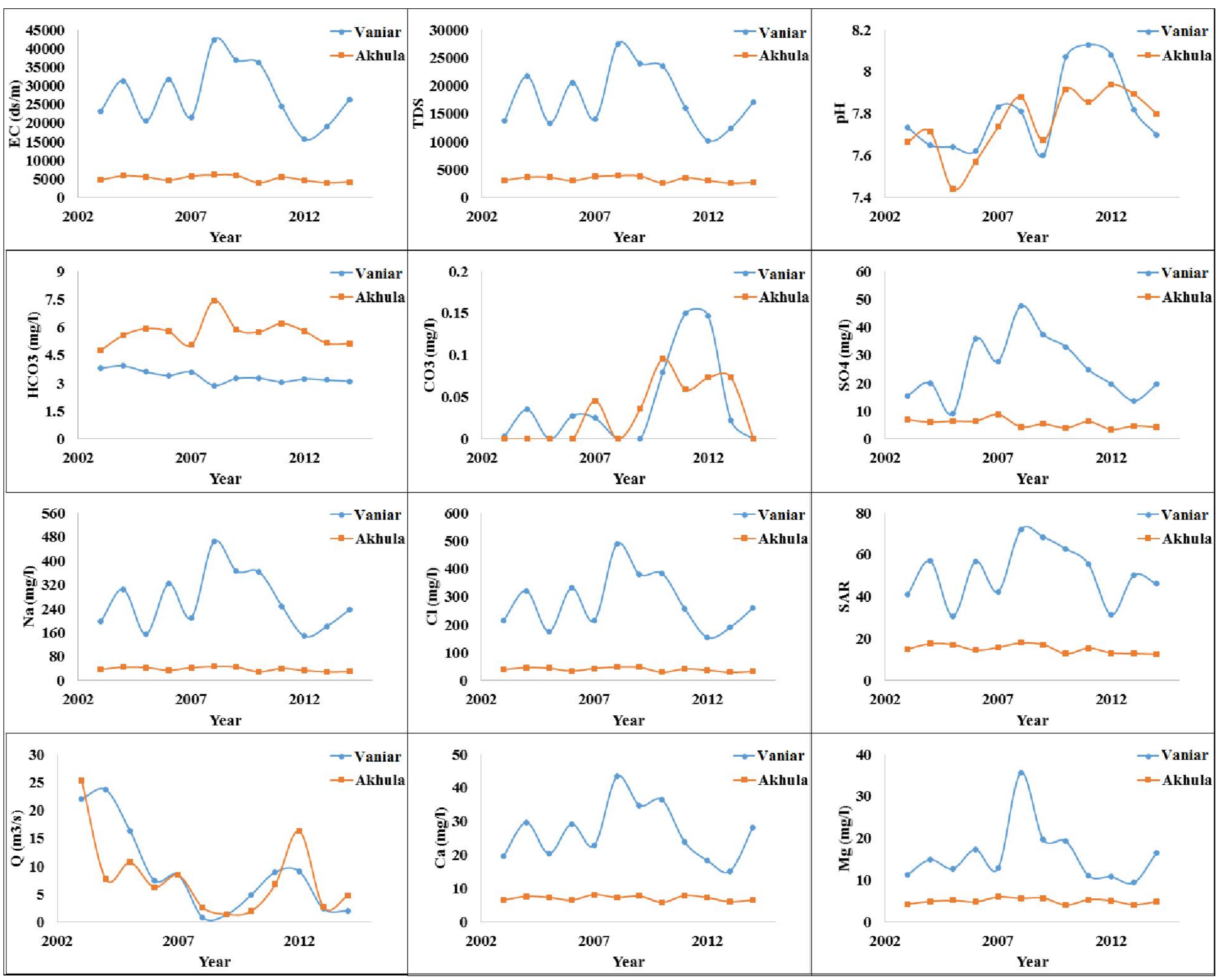

Figure 2. Time series of the analyzed surface water parameters in the hydrometery sites Akhula and Vaniar.

Table 4. Results of trend analysis for the groundwater quality parameters.

Well ID		Slopes (unit/year)										
	Aq	TDS	EC	pH	CO3	HCO3	Cl	SO4	Ca	Mg	Na	SAR
92	1	**53.19****	**88.94****	-0.08	**-0.03****	0.04	**1.17****	-0.08	**0.20****	**0.31****	**0.45****	0.13
101	2	**-12.36**	**-15.08**	0.03	0.00	**0.18***	**-0.13**	**-0.07***	-0.04	-0.02	-0.07	-0.02
120	*	**398.86***	**613.63***	0.09	0.01	**-0.22***	3.36	**-0.33***	1.19	-0.37	1.19	0.04
126	1	**223.44**	**326.70**	**0.05**	0.00	**0.16****	**2.88***	-0.12	**1.81****	0.88	0.17	-0.07
158	1	7.82	12.02	0.03	0.00	0.00	0.14	0.05	-0.34	-0.29	0.44	0.22
188	2	-9.75	**-15.00**	0.02	0.00	0.04	**-0.67****	**0.13***	0.07	-0.03	-0.35	-0.14
192	2	**45.20****	**68.77****	0.06	0.00	0.00	**0.35**	**0.48***	0.01	0.04	**0.62****	**0.16****
Median (total)		26.51	40.40	0.04	0.00	0.02	0.25	-0.02	0.04	0.01	0.44	0.09
Median (Aq. 1)		45.20	68.77	0.05	0.00	0.00	0.35	0.05	0.01	0.04	0.44	0.16
Median (Aq. 2)		-9.75	-15.00	0.02	0.00	0.04	-0.13	-0.07	0.07	-0.02	-0.07	-0.02

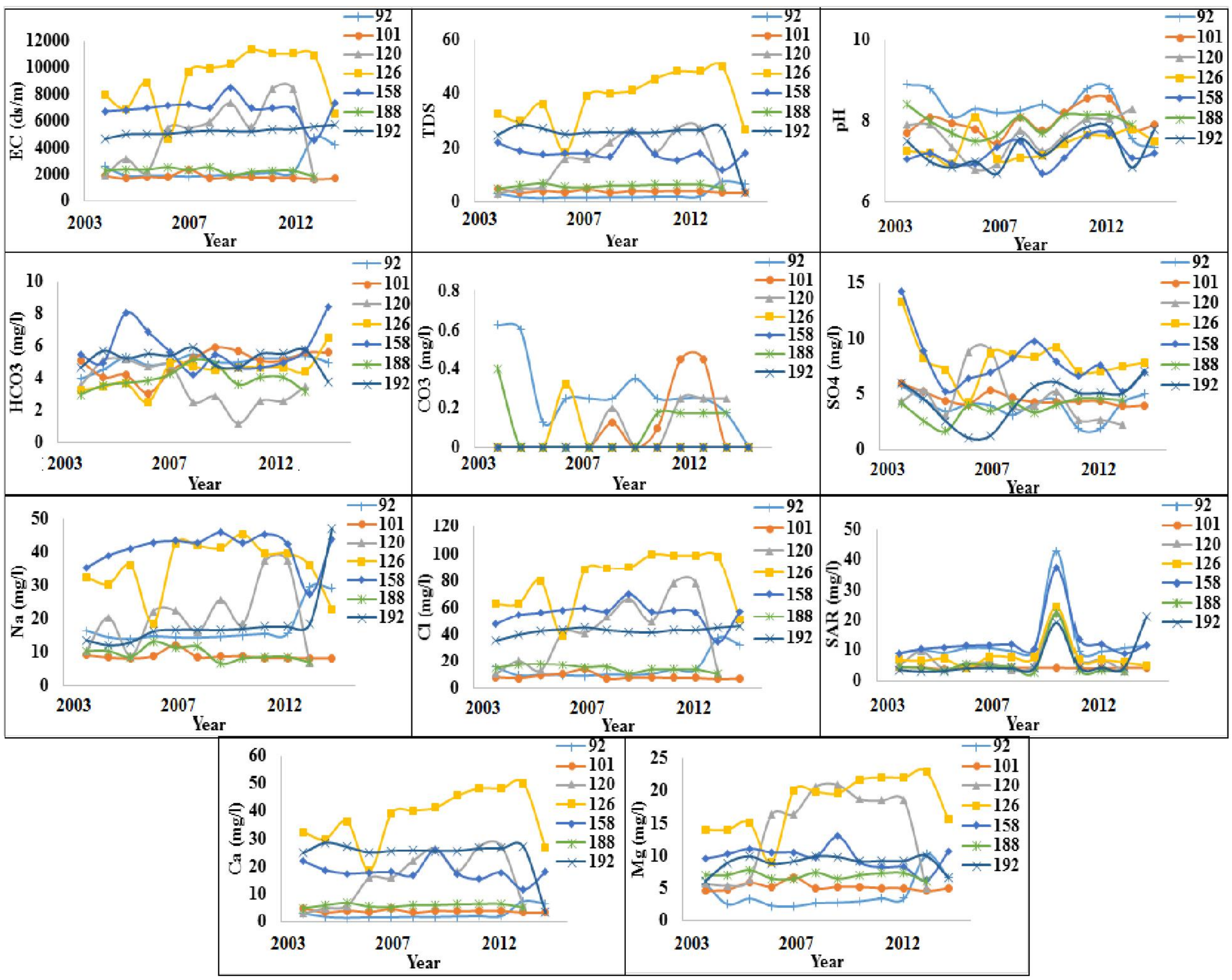

Figure 3. Time series of the analyzed groundwater parameters in the wells studied.

EC also seems to have varied in line with TDS, thought there were two significant downward trends at 10% in EC (Aq. 1 wells). In case of pH, all of the wells except well number 92 showed upward trends, of which merely one was significant at 10% significance level. Table 4 also shows that CO3 has not changed in 5 out of the 7 wells studied. It has also decreased by -0.03 (mg/l/year) in the 92 (significant at 1% significance level) and increased by 0.01 (mg/l/year) (not significant). Whereas, HCO3 has not changed in line with CO3. A total number of four upward trends was observed in HCO3 between 2003-2014, of which two were significant at 5% and one was significant at 1%, and merely one downward trend was observed in HCO3 during 2003-2014 and it was significant at 1%, being -0.22 (mg/l/year). In terms of Cl, an overall number of 5 upward and 2 downward trends was observed. Of which, two of the downward trends and three of the upward trends were significant at 10% level of significance. As to SO4, four out of the seven studied wells showed significant trends at 5%, of which two were upward and two were downward. Two of the selected wells also showed significant upward trends in Ca, being equal to 0.20 (mg/l/day) and 1.81 (mg/l/day) (both significant at 1% significance level). In terms of Mg and SAR also just one significant trend was detected, being 0.31 (mg/l/year) and 0.16 (per year) (significant at 1%). From the data represented in the Table 4, it can also be seen that SAR and Na seem to have mostly varied in line with each other except in case of the well number 126. According to median of the trend slopes given in Table 4, it can be seen that negative trends were observed in the Aq. 2 wells in seven out of the eleven parameters studied. Meanwhile, the median of the wells with respect to Aq. 2 showed upward trend during 2003-2015.

4. Conclusion

The main purpose of the present study was to study the relationships between the trends of surface and ground water quality parameters in Ajichai River reservoir which is considered as one of the most important sub-basins of the Great Salt Lake of Urmia watershed. The results of the present study reviled the fact that, there are at least two separate aquifers in the study area which there is vast difference between the qualities of water with respect to these two aquifers. Furthermore, a comparison between the trends and the time series of these two aquifers and the surface flow quality characteristics shows that, the quality of water with respect to the wells digged in the aquifer number 2 seems to have varied in line with the surface water quality parameters. This may imply that, the water in the aquifer 2 and surface water in the area have more or less been affected by similar phenomenon.

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