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Research Article

Impact of Precipitation and Flow Rate Changes on the Water Quality of a Coastal River

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This paper aims to investigate the effects of natural variables, including precipitation and flow rate, on the quality of the Zarjoub River in Guilan province, Iran. The new hydrological insight in this study is a lack of national research focused on the dual effects of rainfall and flow rate on river water quality in coastal areas along the Anzali Wetland. To investigate the effect of precipitation and flow rate on river water quality, nine water quality variables were monitored during the 10-year period. In this article, (a) the existence of trends and the best fitted models of water quality parameters and the discharge and precipitation were analysed using statistical techniques and (b) the relationships between concentration of constituents with the discharge and precipitation on the up-stream and middle station were also examined. Box plots, for explaining the distribution of a data collection, were used. The results showed the existence of trend of water quality parameters with river flow and rainfall. As presented in Section 3, with increasing precipitation and flow rate, concentration of all constituents, except pH and SO_42, decreased. On the contrary, the maximum amount of water quality elements was observed in low precipitations; therefore, the maximum concentration occurred in less than 15 mm precipitation. Simple regression was used to evaluate the discharge concentration and precipitation concentration. According to the correlation coefficient (r), the relationship between concentration and precipitation is weaker than (0.238) discharge concentration (0.699). The results further showed climate change and river water quality to be related.

1. Introduction

Zarjoub is one of the rivers polluting Anzali Wetland, known as a habitat for migratory birds. This swampy area is the value of an officially registered wetland under the Ramsar Convention. Unfortunately, the wetland is declining in terms of the environment due to unsustainable human activities and infrastructure development. Water quality analysis as well as possible monitoring changes in water quality support decisions to manage coastal water resources. The water quality of creeks and rivers is very sensitive to human influences and natural processes, affecting their use for various agricultural, drinking, and industrial purposes [1–3]. Climate and seasonal changes lead to biological activity in the catchment area that affects the water quality of rivers [4–6]. Some researchers also have studied the effect of meteorological variables on water resource management [7, 8].

The river water quality is changed due to chemical properties, unlike seawater (due to chemical and biological interactions) [9–20]. Furthermore, many previous studies have suggested several strategies for improving water quality in different parts of the world [21–23].

Some studies have shown that meteorological (air, rainfall, solar radiation, and humidity) and hydrological (water discharge and groundwater percentage) parameters affect flow water temperature [24–29]. Also, temperature affects the creek's physical, biological, and chemical properties, including the levels of dissolvable oxygen in water, plant photosynthesis, and animal metabolism. River water quality can be affected by human activities, such as urban and rural land-use change [30–34], precipitation, and streamflow [35–37]. Several studies have investigated the impact of climate change on river water quality [38–40]. Evaluation of long-term changes in river water quality can help identify the most important factors affecting water quality as a suitable method for determining any environmental changes over time [22, 41]. Many other studies have focused on the effect of temperature rise on water quality [42–46]. In their study, Rueda et al. [47] and Chorus and Bartrum [48] have revealed that heavy rainfall transports 80% and 400% of the average annual inflow of nitrogen and phosphorus to rivers. Under changing weather conditions, variations in rainfall and its pattern constantly occur. Scientific studies using future precipitation scenarios have examined the impact of climate change on water quality [40, 49, 50]. Variations in surface runoff under climate changes lead to changes in the transfer of pollutants to waters [51, 52].

From the above viewpoint, the observed relationship of rainfall and flow with water quality suggests the importance of meteorological conditions, especially rainfall, in river water quality management. Although these cases have been investigated in the literature, the lack of studies of rainfall and flow impact on the quality of rivers in coastal basins in different seasons and the importance of quality protection of rivers ending to Anzali Wetland shows the necessity of further investigation. This research determines statistically (1) the relationships between concentration of physicochemical parameters and the discharge and rainfall at Zarjoub River and (2) the existence of trends and the estimate of the best-fitted trend models.

2. Materials and Methods

2.1. Study Area. A flowchart is done to arrange and explain all the main activities. Figure 1 shows the flowchart of research methodology.

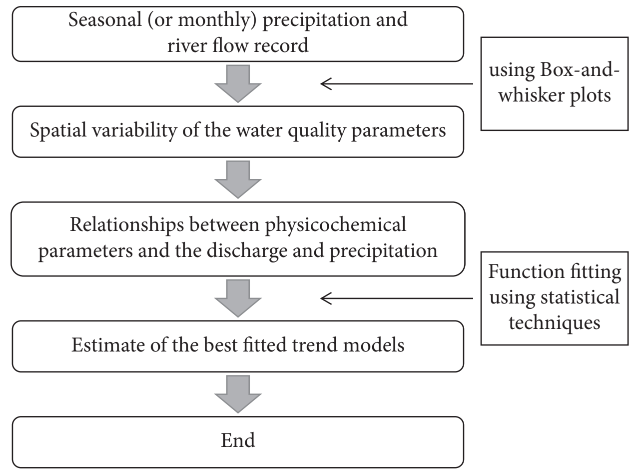


Figure 1: Research methodology flowchart.

Zarjoub River is one of the tributaries of Pirbazar River, which originates from the heights of the Jokolbandan Mountains located in the south of Rasht; after passing the eastern side of Rasht under the name of "Siahroud River," it finally flows into Anzali Wetland along the southern Caspian Sea which is one of the Ramsar sites in Iran. The environment of the wetland is deteriorating due to the entry of sewage and sediment from its catchment area. Measurements show that Anzali Wetland was much deeper in the past, but seems to be shallower due to sediment. The total amount of sediment entering the lagoon is estimated at approximately 400,000 tons per year. Zarjoub River transports large amounts of sediment to the lagoon and negatively affects the value of the system. The river length is about 41.30 km. The altitude of the study site varies from 2 to 750 meters above sea level, and the basin area is 162 square kilometers. The basin receives an average of 1300 to 1500 mm precipitation annually.

2.2. Water Quality, Flow, and Precipitation Data. Flow quality parameters were monitored by the Ministry of Energy of Iran on a monthly basis (2007–2017) in a period of 10 years. Presently, two hydrometric stations, one at the entrance to the plain (B) and the other in the middle section of the plain (W), are active (Figure 2). The (W) station was established in 1967 with a period of 39 years of statistics. It is hydraulically located in a suitable position, but hydrologically, its flow is more than that of the watershed due to being located inside the plain and thus receiving surface flows of several creeks and returned agricultural water, as well as part of urban sewage and plain drainage; however, given the project objectives and as it is located at the city entrance, it has a good position. The (B) station was established in 1987 with statistical age of 19 years. The above two stations are located at an altitude of 4 and 40 meters above sea level, respectively.

This article does not intend to examine specific parameters of water quality; thus, in total, nine hydrochemical parameters, including electrical conductivity (EC), alkalinity (PH), total dissolved solids (TDS), sulfate (SO_4^{2-}), calcium (Ca^{2+}), magnesium (mg^{2+}), sodium (Na^+), chlorine (Cl^-), and bicarbonate (HCO^{3-}), were measured and analysed at monthly intervals in two hydrometric stations of the Zarjoub River basin over a 10-year period by Iran Water Resources Management Company (IWRMC). The daily flow and precipitation data were collected from IWRMC. To gain insight into hydrological and hydrochemical processes in precipitations, the water quality response was analysed when in coastal watersheds. In order to receive significant changes in river water quality response, we selected precipitations that amounted to more than 10 mm at least 12 hours before and after.

Based on these criteria, 30 data collections were obtained about the water quality of the river for 30 rainfall events in the Zarjoub River coastal area. EC and pH were measured in the field by a portable multiparameter water quality meter. TDS were determined by gravimetric analysis. The dissolved water samples were shipped to the laboratories of IWRMC for analysis of Ca^{2+} and Mg^{2+} (by EDTA titration), Na^+ (by flame photometer), SO_4^{2-} (by barium chloride titration), HCO^{3-} (by sulfuric acid titration), and Cl^- (by silver nitrate titration).

2.3. Analysis Methods. Formal correlation analysis was used to investigate the relationship between flow and precipitation, as well as water quality in each station. An intense

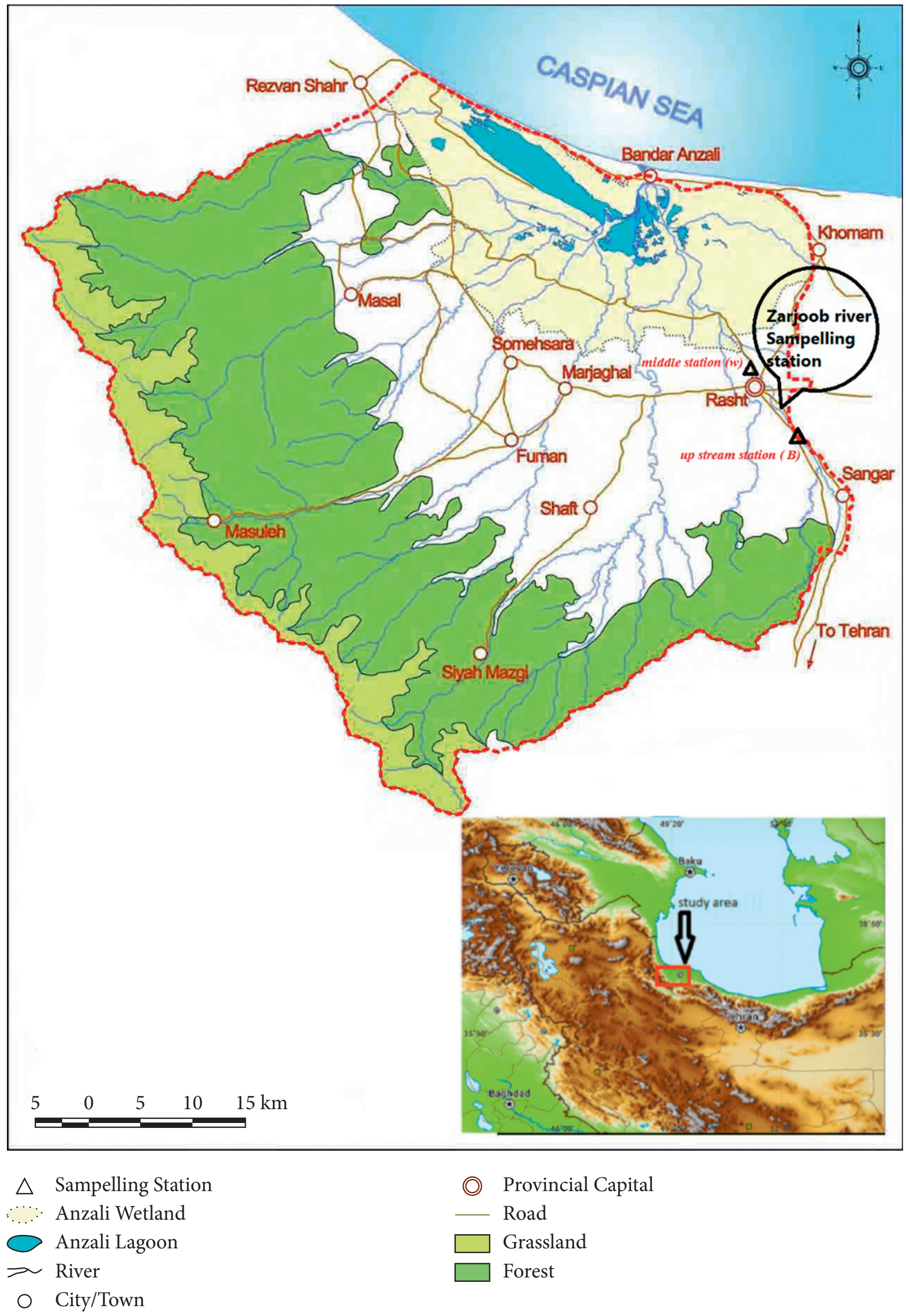


Figure 2: Study area and location of monitoring sites.

relationship between river chemistry and discharge at different spatial and temporal scales has been recognized [53]. Conventional methods and tests have adequate power since the data distribution is clear and the sample size is large in them; hence, they are preferred because, in this case, parametric methods are more accurate than nonparametric ones. Statistical analysis was performed for a 95% confidence level.

Several models were proposed to explain the relationship between concentration discharge [54, 55]. For this research, the linear ($\mathrm{Cij} = a + b\mathrm{Qj}$), the exponential ($\mathrm{Cij} = a \exp(\mathrm{bQj})$), the power ($\mathrm{Cij} = \mathrm{aQjb}$), and the logarithmic ($\mathrm{Cij} = a + b \ln(\mathrm{Qj})$) models were used.

Based on the correlation coefficient and the critical values for Pearson's r, the existence of a significant relationship between variables was investigated, and data testing was performed homogeneity. The model producing the highest coefficient of determination (R^2) was selected and used as the optimal model to investigate the impact of climate change on project water quality. Regression analysis in SPSS and correlation determination were performed using EXCEL software with supplement action.

3. Results and Discussion

3.1. Spatial Variability of the Water Quality Parameters. Some water quality variables show significant seasonal variations. For pH and Cl, at both the upstream and middle stations, the changes over time are relatively uniform. There is also variation in flow rate, rainfall, and concentration. These changes depend on the discharge and seasonality and the flow of domestic sewage into the river. Upstream fluctuations are greater than the midpoint. The ratio of the highest to the lowest concentration, flow rate, and rainfall for the upstream station are discharge (226.3 : 1), Cl^- (25.5 : 1), Na^+(17.01 : 1), Mg^{2+}(17.2 : 1), SO_4^{2-}(7.5 : 1), HCO^{3-}(5.8 : 1), rainfall 5.1; 1), TDS (5.04 : 1), EC (5.03 : 1), Ca^{2+}(3.3 : 1), and pH (1.2 : 1) and for the midstream station are discharge (57.8 : 1), Na^+(20.8 : 1), Cl^- (15.2 : 1), Mg^{2+}(10.3 : 1), SO_4^{2-}(8.1 : 1), EC (6.2 : 1), TDS (6.21 : 1), rainfall (5.7; 1), Ca^{2+}(4.3 : 1), HCO^{3-}(3.4 : 1), and pH (1.1 : 1). The predominant anions and cations in the water of the Zarjoub River are Cl^- and Na^+, respectively.

Box-and-whisker diagram of measured parameters at the two monitoring stations were plotted during 2007–2017 (Figure 3). The horizontal line inside the boxes represents the median and the upper and lower lines of the boxes indicate the 75 and 25% percentiles, respectively. The vertical lines indicate the minimum and maximum values for observations. The height of the box represents the variance among the 25 and 75% percentiles.

Figure 3 shows that, at both stations, there are large extremes for the variables Q, Na^+, Mg2$^+$, and Cl_. Extreme values of river water flow are due to flood conditions, but extreme values of other variables may be due to measurement errors in water samples.

According to box plots, minimum, maximum, and median of parameters in midstream station are more than the upstream station because of the influx of contaminated streams resulting from municipal runoff and domestic sewage. Also, variances of all parameters and flow in the midstream station are more than the upstream station.

3.2. The Dependence of Water Quality on Discharge and Precipitation. In this section, to analyse the relationship between water quality and discharge, the relationship between all factors and discharge was statistically investigated. The flow regime is regarded as the "main variable" since it directly and indirectly affects the river ecosystem [56–58].

One-way analysis of variance was used (Tables 1 and 2) for statistical analysis of data. There was a correlation between flow and precipitation ($r = 0.35$); the relationship direction was positive, and the correlation intensity was moderate. Researchers have reported different ranges of correlation coefficients in earlier studies; however, some [59, 60] have reported moderate-to-severe dependence between rainfall and river flow, arguing that the correlation coefficient is approximately 0.50. The mild correlation coefficient between rainfall and river flow can be due to the entry of a constant amount of domestic wastewater into the river, which is not affected by the amount of rainfall.

Figure 4(a) and 4(b) show the best fitted to the data regression models. A strong correlation between Zarjoub streamflow and water quality was observed in most parameters, same with some other studies [61–63].

On upstream station, the relationship between Na+ and discharge has best correlation coefficient value ($r = -0.88$), followed by EC ($r = -0.872$) and then by the other TDS, HCO^{3-}, and Cl^- ($r = -0.872$), ($r = -0.852$), and ($r = -0.815$) and then cations Mg^{2+} amd Ca^{2+}(($r = -0.803$) and ($r = -0.750$), while phosphate and pH show weaker relations.

Among the nine studied water quality parameters, only one parameter, alkalinity, had a positive relationship with river flow. Eight other parameters had a negative relationship with river flow. This is a dilution effect of surface runoff, during periods of heavy runoff in the catchment. According to the analysis results in Tables 1 and 2, a significant relationship was observed between all parameters and discharge except pH and SO_4^{2-} (at the upstream station). The salinity dispersion in different discharges was determined, as seen in Figure 4; therefore, with increasing discharge, the amount of electrical conductivity decreased; the maximum EC was observed at discharges of less than 5 m̃3/s. Some researchers have found seasonal differences in river water conductivity, generally due to a negative relationship with discharge volume [64, 65].

The total concentration of soluble salts varies with the flow rate, being higher in low flow times. Amazonian water is rich in electrolytes and high electrical conductivity, and when caused by heavy rains, the amount of this parameter decreases [66].

These results showed that the concentration of the parameters was primarily diluted by surface runoff produced by precipitation, same with the results of Budai and Clement [67] and Akbar et al. [68]. Overall, the water alkalinity is from limestone or dolomite in nature, which carries minerals through the rocks containing lime when rainwater passes over the Earth's surface. Therefore, the soil of the study area probably contained calcareous mode, which increased flow, leading to the alkalinity of water. Thus, it was expected to observe the positive correlation between the pH value and the flow. Higher pH values observed (in the research by [69]) show that the balance of carbon dioxide and bicarbonate carbonate is affected by changes in physicochemical conditions. The factors responsible for the change in pH values are the combined effect of increased rainfall, reduced temperature, and concentration of carbon dioxide in water due to the conversion of bicarbonate to carbonate [70–72].

Hydrological changes play a vital role in the structural biodiversity in river ecosystems since they change habitat conditions in rivers and floodplains [73, 74]. In order to investigate the effects of rainfall on quantitative and qualitative changes of Zarjoub River water in the scale of each precipitation, 30 index precipitates (above 10 mm) were selected, and simultaneously, the average flow rate over a period and also the average values of water quality factors corresponding to the same precipitation were extracted. Regression models examined the relationship between precipitation and water quality parameters of stations in the

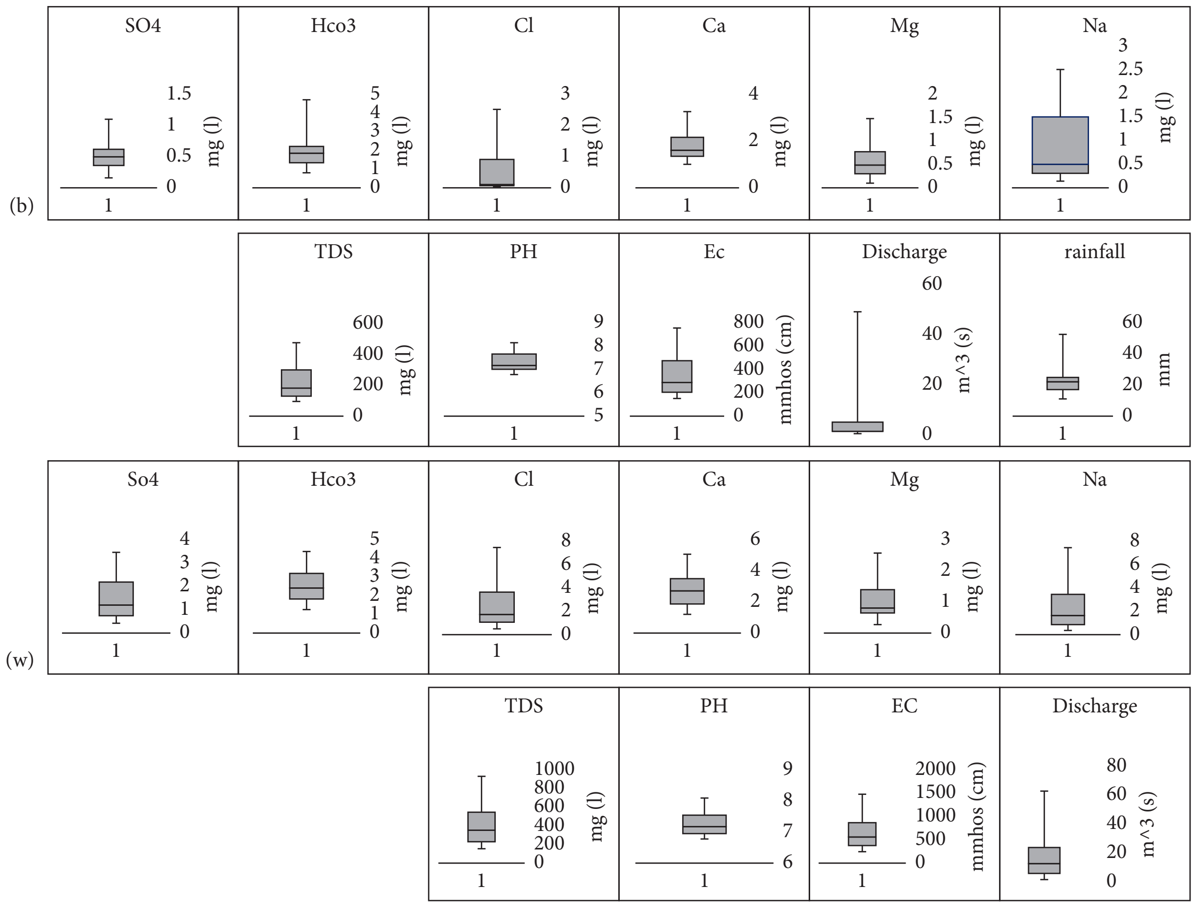


Figure 3: Box-and-whisker plots for the measured parameters at the two monitoring stations B (upstream) and W (middle).

Table 1: Correlation coefficients (r) of water quality concentrations with the flow rate at the upstream station (B).

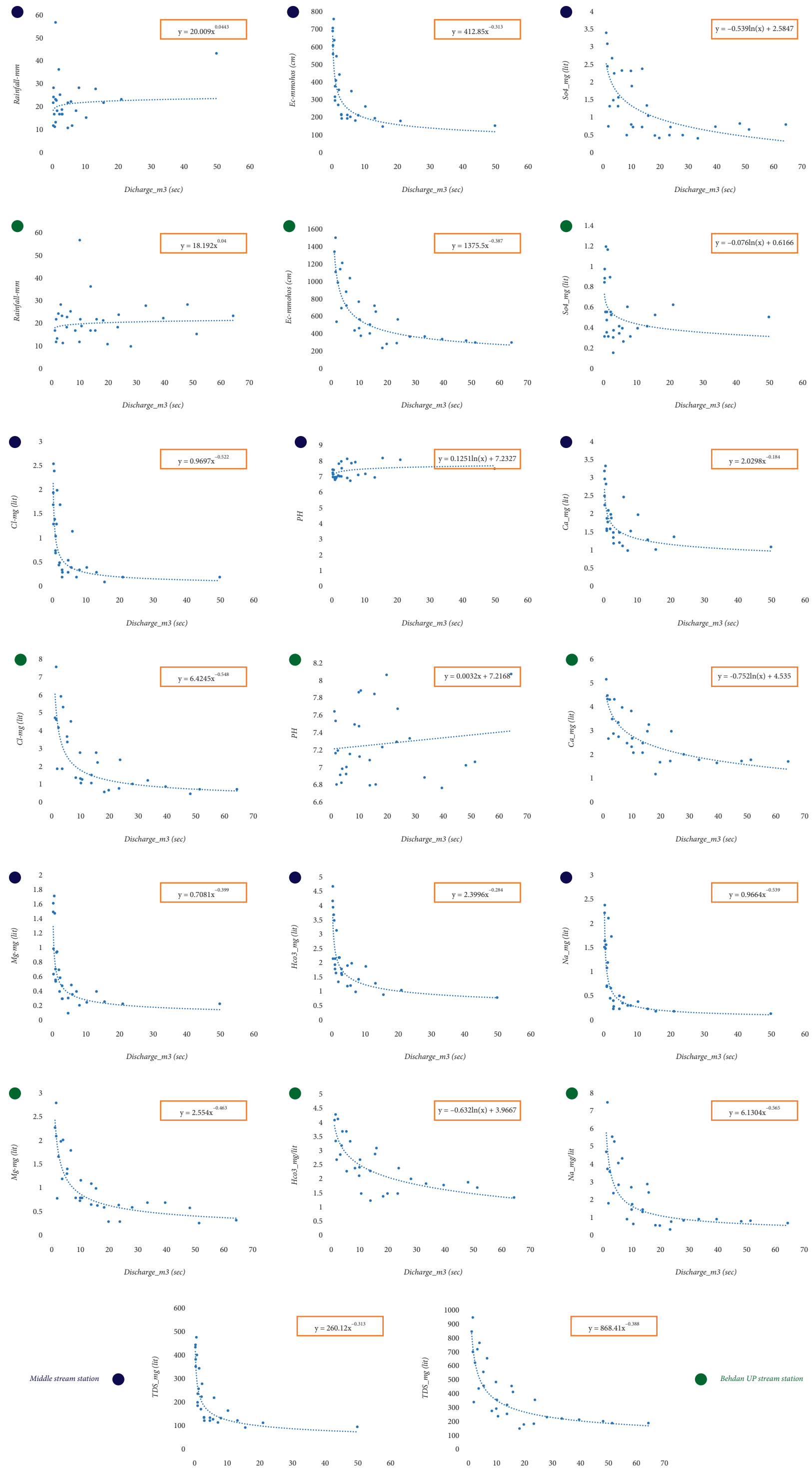
Appropriate equation	Power	Logarithmic	Linear	Exponentially	Equation parameter
$Y = 20.009X0.044$	0.361	0.124	0.351	0.351	Precipitation
$Y = 0.966X{-}0.539$	−0.88	−0.804	−0.471	−0.632	Na^+
$Y = 0.708X{-}0.399$	−0.803	−0.779	−0.428	−0.490	Mg^{2+}
$Y = 2.029X{-}0.184$	−0.750	−0.735	−0.435	−0.48	Ca2þ$^+$
$Y = 0.969X{-}0.522$	−0.815	−0.764	−0.447	−0.554	Cl^-
$Y = 2.399X{-}0.284$	−0.852	−0.811	−0.494	−0.624	HCO^{3-}
$Y = 0.125\ln(x)+7.232$	−0.233	**−0.399**	−0.138	−0.063	SO_4^{2-}
$Y = 260.12X{-}0.313$	−0.872	−0.841	−0.481	−0.563	TDS
$Y = -0.076\ln(x)+0.6166$	0.382	**0.389**	0.303	0.305	pH
$Y = 412.85X{-}0.313$	−0.872	−0.841	−0.481	−0.562	EC

Correlation coefficients underlined are not statistically significant at the significance level of 5%.

Table 2: Correlation coefficients (r) of water quality concentrations with the flow rate at the midstream station (W).

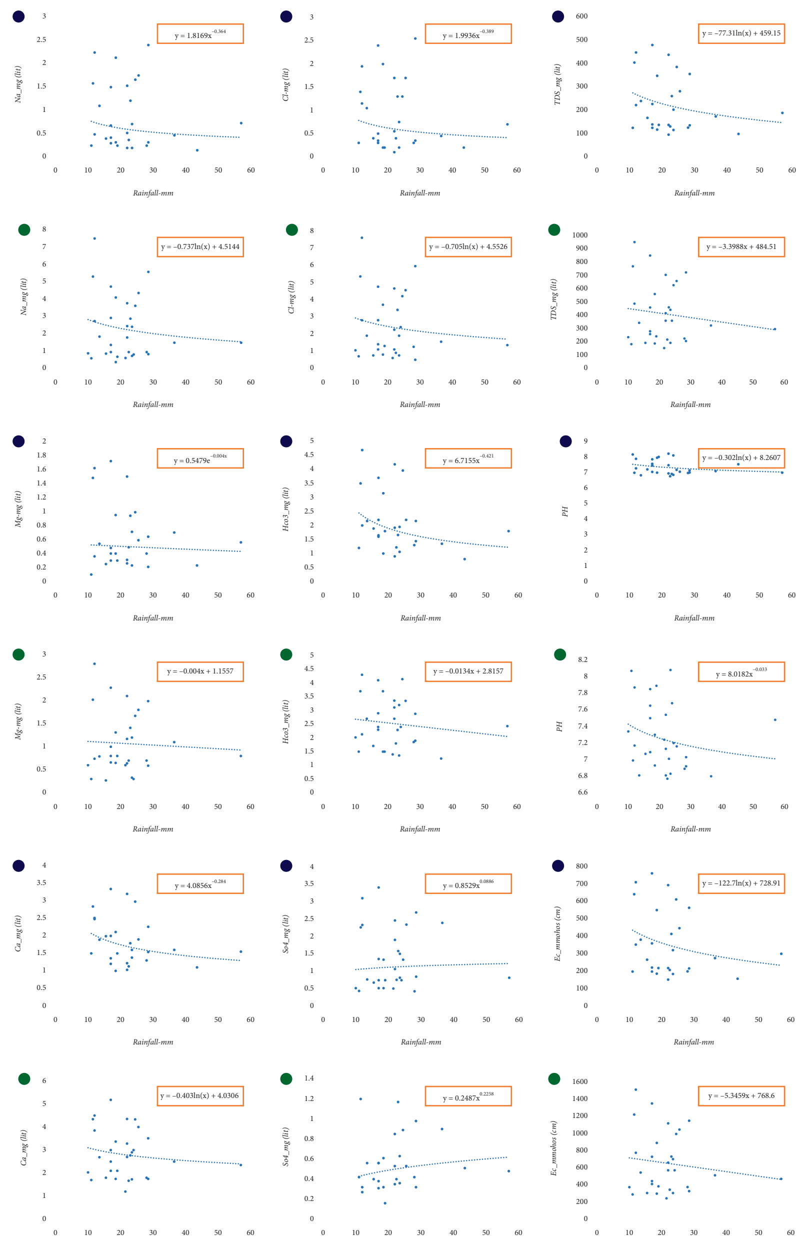
Appropriate equation	Power	Logarithmic	Linear	Exponentially	Equation parameter
$Y = 18.192X0.04$	0.322	0.105	0.045	0.084	Precipitation
$Y = 6.130X{-}0.565$	−0.783	−0.768	−0.605	−0.657	Na^+
$Y = 2.55X{-}0.463$	−0.832	−0.824	−0.657	−0.742	Mg^{2+}
$Y = -0.752\ln(x)+4.535$	−0.805	−0.813	−0.667	−0.691	Ca2þ$^+$
$Y = 6.424X{-}0.548$	−0.806	−0.775	−0.615	−0.715	Cl^-
$Y = -0.632\ln(x)+3.966$	−0.769	−0.794	−0.642	−0.646	HCO^{3-}
$Y = -0.539\ln(x)+2.584$	−0.677	−0.694	−0.541	−0.543	SO_4^{2-}
$Y = 868.41X{-}0.388$	−0.83	−0.825	−0.652	−0.709	TDS
$Y = 0.003X+7.216$	0.122	0.126	**0.130**	0.126	pH
$Y = 1375.5X{-}0.387$	−0.829	−0.824	−0.65	−0.708	EC

Correlation coefficients underlined are not statistically significant at the significance level of 5%.



(a)

FIGURE 4: Continued.



(b)

FIGURE 4: (a) Correlation of qualitative parameters in different river discharges. (b) Correlation of qualitative parameters in different precipitations.

study area of Zarjoub River. Based on the results in Tables 3 and 4, the qualitative parameter rainfall relationships show weaker correlation than that of qualitative parameter discharge. The correlation coefficients are low, $r = -0.349$ and $r = -0.319$, for the anion and cation HCO^{3-} and Ca^{2+}, respectively, and very low, $r = 0.167$ and $r = 0.164$, for Cl^- and Na^+.

t-test results of statistical significance of difference between mean values of physicochemical and precipitation. There was a significant difference between Ca2þ+, HCO3-, TDS, and EC concentrations at the upstream station, while other parameters were not significantly different ($P > 0.05$). As the results showed, in general, different water quality levels were observed in different amounts of rainfall; however, a limited number of the parameters showed a statistical difference with precipitation.

Based on the results, the trend of changes in the amount of each qualitative element followed that of precipitation; hence, with increasing amount of precipitation, the concentration of most elements decreased (Figure 4(b)), although the effect of precipitation on most elements was not statistically significant. As observed in Figure 4, the electrical

Table 3: Correlation coefficients (r) of water quality concentrations with the precipitation at the upstream station (B).

Appropriate equation	Power	Logarithmic	Linear	Exponentially	Equation parameter
$Y = 1.816X{-}0.364$	**−0.164**	**−0.138**	**−0.141**	**−0.155**	Na^+
$Y = 0.547\hat{e}{-}0.004$	**−0.055**	**−0.197**	**−0.176**	**−0.062**	Mg^{2+}
$Y = 4.085X{-}0.284$	−0.319	−0.316	−0.283	−0.281	Ca^{2+}
$Y = 1.993X{-}0.389$	**−0.167**	**−0.158**	**−0.155**	**−0.141**	Cl^-
$Y = 6.715X{-}0.421$	−0.349	−0.326	−0.307	−0.322	HCO^{3-}
$Y = 0.248X0.225$	**0.187**	**0.126**	**0.105**	**0.164**	SO_4^{2-}
$Y = -77.31\ln(x)+459.15$	−0.243	−0.251	−0.232	−0.219	TDS
$Y = -0.302\ln(x)+8.260$	**0.257**	**0.259**	**0.229**	**0.237**	pH
$Y = 412.85X{-}0.313$	−0.243	−0.251	−0.232	−0.219	EC

Correlation coefficients underlined are not statistically significant at the significance level of 5%.

Table 4: Correlation coefficients (r) of water quality concentrations with the precipitation at the midstream station (W).

Appropriate equation	Power	Logarithmic	Linear	Exponentially	Equation parameter
$Y = -737\ln(x)+4.514$	**−0.055**	**−0.152**	**−0.138**	**−0.045**	Na^+
$Y = -0.004X+1.155$	**−0.055**	**−0.045**	**−0.055**	**−0.032**	Mg^{2+}
$Y = -0.403\ln(x)+4.030$	**−0.110**	**−0.145**	**−0.145**	**−0.105**	Ca^{2+}
$Y = -0.013\ln(x)+4.552$	**−0.089**	**−0.141**	**−0.141**	**−0.095**	Cl^-
$Y = -0.013X+2.815$	**−0.118**	**−0.130**	**−0.134**	**−0.118**	HCO^{3-}
$Y = 0.852X0.088$	**0.055**	**0.032**	**0.032**	**0.032**	SO_4^{2-}
$Y = -3.398X+484.51$	**−0.077**	**−0.138**	**−0.138**	**−0.084**	TDS
$Y = 8.018X{-}0.033$	**0.230**	**0.230**	**0.167**	**0.164**	pH
$Y = -5.345X+768.6$	**−0.071**	**−0.138**	**−0.138**	**−0.077**	EC

Correlation coefficients underlined are not statistically significant at the significance level of 5%.

conductivity with precipitation was logarithmic, decreasing by increasing the amount of precipitation per rainfall; hence, the highest EC level was observed in rainfalls below 15 mm. Generally, changes in rainfall and flow at both river stations affected TDS and EC significantly. Therefore, their management should be considered under the influence of climate change to prevent further water quality degradation in the future. The results here help government managers in their related planning, such as releasing treated wastewater effluent into the river and using fertilizers in the agricultural sector by considering prior metrologic conditions, especially precipitation, to prevent the destructive effects of high-water concentrations. Furthermore, given that the number of significant relationships of parameters with precipitation at upstream and middle stations is not the same, the spatial variation of the precipitation effect on water quality along a river is observed.

3.3. Investigation of Regression Models. According to Table 5, in the relationship between discharge and quality parameters, 70%, 25%, 5%, and 5% of data fitting belonged to power, logarithmic, exponential, and linear models, respectively. However, in the relationship between precipitation and quality parameters, 45%, 30%, 5%, and 20% of data fitting belonged to power, logarithmic, exponential, and linear models, respectively. According to the present research results, the precipitation parameter (independent variable) in most cases has no significant relationship and the discharge parameter (independent variable) has a significant relationship with other qualitative parameters (dependent variables).

A noteworthy point in the final results of fitting and examining the relationship between discharge and precipitation with water quality parameters in this river is the existence of 7 significant relationships between discharge and other parameters at the upstream station, including EC, TDS, -Cl, HCO3-, Ca+ 2, Mg+ 2, and Na+, as well as the highest correlation coefficient with Na + (0.88) and the lowest correlation coefficient with water pH (0.389) The number of significant relationships, in the middle station, reaches 8 by adding the sulfate parameter to the above qualitative parameters. The increase in the correlation coefficient of discharge with sulfate ion in the middle station compared to that of upstream shows the vital role of human factors and sewage and chemical fertilizer discharge in the river bank. Snowmelt runoff causes a strong seasonal flow during the spring in the catchment area. The seasonal discharge and inverse relationships with the variables Ca^{2+} and Mg^{2+}, which have groundwater sources and Na^+, which is mainly a point pollutant, controls the patterns.

The tables show that the trends are not significant for each of the upstream and middle stations; however, the increase in flow is probably due to the overall increase in rainfall. Due to the general relationship between both rainfall and river flow with water quality, any slight change in rainfall, thus flow rate, can lead to significant changes in water quality parameters. Therefore, it can be concluded that rainfall may be the main factor in the water quality of the Zarjoub River. The results can provide important information needed to properly manage the Zarjoub River and ensure sustainable water resources for the industrial and agricultural sectors.

Table 5: Regression candidate models for calculation of correlation coefficients (r).

Station	Precipitation						Stream flow					
			Type of model						Type of model			
	Sum of parameters	Parameters with significant differences	Linear	Logarithmic	Exponentially	Power	Sum of parameters	Parameters with significant differences	Linear	Logarithmic	Exponentially	Power
Upstream station (B).	10	4	0	3	6	6	10	7	0	2	0	8
Midstream station (W).	10	0	4	3	0	3	10	8	0	3	1	6

Table 6: Worldwide comparison of river water parameters.

Mayur Rive *r* (c)	Nakdong River (b)	Nestos river (a)	Zarjoub river (middle-stream	Zarjoub river (up-stream)	Parameter
218.00	—	6.00	1.63	0.490	Na^{+}
24.36	—	5.70	0.80	0.480	Mg^{2+}
50.26	—	43.20	2.69	1.60	Ca2þ$^{+}$
240.77	—	5.70	1.72	0.52	Cl^{-}
346.38	—	164.90	2.40	1.84	HCO^{3-}
18.79	—	12.80	1.19	0.495	SO_4^{2-}
935.92	—	—	351	180.50	TDS
7.19	7.7–8.1	—	7.16	7.16	PH
1290	126.9–773.6	—	557	286.50	EC

Values are reported as average in mg/L, except for EC (μS/cm) and pH. ((a) Boskidis et al. [75]; (b) Jung et al. [76]; (c) Roy et al. [77]).

3.4. Comparison with Other Rivers in the Worldwide. The comparison study was performed with the water quality characteristics of other rivers in the world. In Table 6, a comparison is introduced between data collected in the present study on both stations and data from Nestos River collected in 2006–2009, together with data collected from Nakdong River, South Korea, in 2008–2012 and Mayur River in 2017–2018.

Comparing the two stations related to the water quality of Zarjoub River, the concentrations of some parameters measured in the middle station such as salinity and suspended solids are higher than the concentrations measured upstream, and a result that shows the condition of the river due to the entry of sanitary sewage and urban runoff has changed. The concentrations of $SO_4$2- and Na+ in Nestos are ten and three times more than the concentrations in Zarjoub on middle station. This difference in concentrations can be attributed to heavy rainfall along the Zarjoub basin and dilution of pollutants. Table 6 shows the parameters measured in Mayur. It is at a higher level than other rivers, which indicates the very poor environmental condition of the river, and as a result, more intense human activities in that area and the salinity of the river water due to its proximity to the sea.

4. Conclusion

Data of water quality variables and discharge and precipitation at the two station of the Zarjoub River in north of Iran were analysed using statistical methods and trend analysis. The monthly measured values of nine water quality variables (Na^{+}, Ca^{2+}, Mg^{2+}, Cl^{-}, $HCO3^{-}$, SO_4^{2-}, TDS, pH, and EC) over 10 years (2007–2017) are used for this analysis.

The statistical analysis of abovementioned variables resulted that

(1) Negative correlation with precipitation and discharge was calculated from all water quality parameters except pH and SO_4^{2-}.

(2) The concentration-rainfall relationships show weaker correlation than that of concentration discharge at all stations on the rivers.

(3) The maximum concentration of water quality elements is observed in low rainfalls so that the maximum concentration of these elements occurs in precipitations less than 15 mm.

(4) Only in the upstream station there is a significant relationship between bicarbonate, calcium, TDS and EC parameters with rainfall. Of course, significant differences in the concentrations of many water quality parameters were found among discharge.

(5) The logarithmic and the power models explain better the concentration-discharge and concentration-rainfall relationships.

This paper shows a significant dependence on some water quality parameters (such as EC and TDS) under climate change. Therefore, more efficient management should be created to target and eliminate these pollutants in order to reduce the impact of climate change. In addition, the results show the importance of storm water runoff management because it carries pollutants and has a positive dependence on rainfall and flow. The results of this study confirm the relationship between rainfall and river water quality over the past decade and show the effective role of rainfall on water quality. Therefore, the change in rainfall pattern under climate change has a direct impact on river water quality [78].

Nomenclature

r: Correlation coefficient
EC: Electrical conductivity
pH: Alkalinity
TDS: Total dissolved solids
SO_4^{2}-: Sulfate
Ca2^{+}: Calcium
Mg2+: Magnesium
Na+: Sodium
Cl_: Chlorine
HCO3-: Bicarbonate.

Data Availability

Requests for access to these data should be made to the corresponding author (email address: r-mastouri@iau-arak.ac.ir).

Additional Points

(1) Creating new hydrological insights on the dual effects of rainfall and flow rate on river water quality in coastal areas

(2) Valuable information about water quality changes in the coastal region of northern Iran in order to protect Anzali Wetland is internationally known as an important wetland and is registered as Ramsar site in 1975
(3) The maximum concentration of pollutants occurred in precipitation less than 15 mm
(4) More attention should be paid to emerging pollutants in coastal areas
(5) Negative correlation with precipitation and discharge was calculated from all water quality parameters except pH and $SO_4$2-

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] H. Jarvie, B. Whitton, and C. Neal, "Nitrogen and phosphorus in east coast British rivers: speciation, sources and biological significance," *Science of The Total Environment*, vol. 210–211, pp. 79–109, 1998.
[2] A. Ramírez, K. G. Rosas, A. E. Lugo, and O. M. Ramos, "Spatio-temporal variation in stream water chemistry in a tropical urban watershed," *Ecology and Society*, vol. 19, no. 2, 2014.
[3] J. Y. Kim and K.-G. An, "Integrated ecological river health assessments, based on water chemistry, physical habitat quality and biological integrity," *Water*, vol. 7, no. 11, pp. 6378–6403, 2015.
[4] G. E. Likens, *Biogeochemistry of a Forested Ecosystem*, Springer, Berlin, Germany, 1977.
[5] D. Sutcliffe and T. Carrick, "Chemical composition of water-bodies in the English Lake district: relationships between chloride and other major ions related to solid geology, and a tentative budget for Windermere," *Freshwater Biology*, vol. 13, no. 4, pp. 323–352, 1983.
[6] D. A. Burns, P. Murdoch, and R. Michel, "Effect of groundwater springs on NO3− concentrations during summer in Catskill mountain streams," *Water Resources Research*, vol. 34, no. 8, pp. 1987–1996, 1998.
[7] B. N. Ekwueme and J. C. Agunwamba, "Modeling the influence of meteorological variables on runoff in a tropical watershed," *Civil Engineering Journal*, vol. 6, no. 12, pp. 2344–2351, 2020.
[8] I. A. Guiamel and H. S. Lee, "Watershed modelling of the Mindanao river basin in the Philippines using the SWAT for water resource management," *Civil Engineering Journal*, vol. 6, no. 4, pp. 626–648, 2020.
[9] D. A. Livingstone, *Chemical Composition of Rivers and Lakes*, US Government Printing Office, Washington, DC, USA, 1963.
[10] J. Allan, *Stream Ecology. Structure and Function of Running Waters*, Chapman & Hall, London, UK, 1995.
[11] R. Collins and A. Jenkins, "The impact of agricultural land use on stream chemistry in the middle hills of the Himalayas, Nepal," *Journal of Hydrology*, vol. 185, no. 1-4, pp. 71–86, 1996.
[12] J. Hornbeck, S. W. Bailry, D. C. Buso, and J. B. Shanley, "Streamwater chemistry and nutrient budgets for forested watersheds in New England: variability and management implications," *Forest Ecology and Management*, vol. 93, no. 1-2, pp. 73–89, 1997.
[13] H. P. Jarvie and A. J. Robson, "Major ion concentrations and the inorganic carbon chemistry of the Humber rivers," *The Science of the Total Environment*, vol. 194, pp. 285–302, 1997.
[14] B. G. Fraser and D. D. Williams, "Accuracy and precision in sampling hyporheic fauna," *Canadian Journal of Fisheries and Aquatic Sciences*, vol. 54, no. 5, pp. 1135–1141, 1997.
[15] G. M. Lovett, K. C. Weathers, and W. Sobczak, "Nitrogen saturation and retention in forested watersheds of the catskill mountains, New York," *Ecological Applications*, vol. 10, no. 1, pp. 73–84, 2000.
[16] Y. Nakagawa and G. Iwatsubo, "Water chemistry in a number of mountainous streams of east Asia," *Journal of Hydrology*, vol. 240, no. 1, pp. 118–130, 2000.
[17] B. L. Turner, R. Baxter, N. Ellwood, and B. A. Whitton, "Seasonal phosphatase activities of mosses from upper Teesdale, northern England," *Journal of Bryology*, vol. 25, no. 3, pp. 189–200, 2003.
[18] R. Turner, N. Rabalais, D. Justic, and Q. Dortch, "Global patterns of dissolved N, P and Si in large rivers," *Biogeochemistry*, vol. 64, no. 3, pp. 297–317, 2003.
[19] D. S. Ahearn, R. W. Sheibley, R. A. Dahlgren, M. Anderson, J. Johnson, and K. W. Tated, "Land use and land cover influence on water quality in the last free-flowing river draining the western Sierra Nevada, California," *Journal of Hydrology*, vol. 313, p. 234, 2005.
[20] A. Hall, I. Valente, and B. R. Davies, "The zambezi river in moçambique," *Freshwater Biology*, vol. 7, no. 3, pp. 187–206, 1977.
[21] P. Luo, B. He, K. T. Takara, and B. H. N. Razafindrabe, "Spatiotemporal trend analysis of recent river water quality conditions in Japan," *Journal of Environmental Monitoring*, vol. 13, no. 10, pp. 2819–2829, 2011.
[22] D. J. Ballantine and R. J. Davies-Colley, "Water quality trends in New Zealand rivers: 1989–2009," *Environmental Monitoring and Assessment*, vol. 186, no. 3, pp. 1939–1950, 2014.
[23] M. Sayemuzzaman, M. Ye, F. Zhang, and M. Zhu, "Multivariate statistical and trend analyses of surface water quality in the central Indian river Lagoon area, Florida," *Environmental earth sciences*, vol. 77, no. 4, pp. 1–13, 2018.
[24] B. A. Sinokrot and J. S. Gulliver, "In-stream flow impact on river water temperatures," *Journal of Hydraulic Research*, vol. 38, no. 5, pp. 339–349, 2000.
[25] R. R. Gu and Y. Li, "River temperature sensitivity to hydraulic and meteorological parameters," *Journal of Environmental Management*, vol. 66, no. 1, pp. 43–56, 2002.
[26] M. Sophocleous, "Interactions between groundwater and surface water: the state of the science," *Hydrogeology Journal*, vol. 10, no. 1, pp. 52–67, 2002.
[27] M. W. Becker, T. Georgian, H. Ambrose, J. Siniscalchi, and K. Fredrick, "Estimating flow and flux of ground water discharge using water temperature and velocity," *Journal of Hydrology*, vol. 296, no. 1, pp. 221–233, 2004.
[28] L. Lambs, "Interactions between groundwater and surface water at river banks and the confluence of rivers," *Journal of Hydrology*, vol. 288, no. 3-4, pp. 312–326, 2004.
[29] M. A. O'Driscoll and D. R. DeWalle, "Stream–air temperature relations to classify stream–ground water interactions in a karst setting, central Pennsylvania, USA," *Journal of Hydrology*, vol. 329, no. 1-2, pp. 140–153, 2006.
[30] G. Brion, K. R. Brye, B. E. Haggard, C. West, and J. V. Brahana, "Land-use effects on water quality of a first-order stream in the Ozark highlands, mid-southern United States," *River Research and Applications*, vol. 27, no. 6, pp. 772–790, 2011.

[31] M. Soko and T. Gyedu-Ababio, "The spatial and temporal variations of Ichythyofauna and water quality in the Crocodile river (east), Mpumalanga, south Africa," *Journal of Water Resource and Protection*, vol. 7, no. 3, p. 152, 2015.

[32] S. Shrestha, B. Bhatta, M. Shreshtha, and P. K. Shreshtha, "Integrated assessment of the climate and landuse change impact on hydrology and water quality in the Songkhram river basin, Thailand," *The Science of the Total Environment*, vol. 643, pp. 1610–1622, 2018.

[33] B. Wijesiri, K. Deilami, and A. Goonetilleke, "Evaluating the relationship between temporal changes in land use and resulting water quality," *Environmental Pollution*, vol. 234, pp. 480–486, 2018.

[34] A. Gohari, S. Eslamian, J. Abedi-Koupaei, A. M. Bavani, D. Wang, and K. Madanic, "Climate change impacts on crop production in Iran's Zayandeh-Rud river basin," *The Science of the Total Environment*, vol. 442, pp. 405–419, 2013.

[35] H. Tabari, S. Marofi, and M. Ahmadi, "Long-term variations of water quality parameters in the Maroon river, Iran," *Environmental Monitoring and Assessment*, vol. 177, no. 1, pp. 273–287, 2011.

[36] Y. Xie, X. Li, L. Wang, and X. Qu, "Seasonal and spatial variation in hydrochemical characteristics of a semi-arid river basin, China," *Human and Ecological Risk Assessment: An International Journal*, vol. 21, no. 3, pp. 845–861, 2015.

[37] J. Murphy and L. Sprague, "Water-quality trends in US rivers: exploring effects from streamflow trends and changes in watershed management," *Science of The Total Environment*, vol. 656, pp. 645–658, 2019.

[38] X. H. Xia, "Potential impacts of climate change on the water quality of different water bodies," *Journal of Environmental Informatics*, vol. 25, no. 2, pp. 85–98, 2015.

[39] J. Tu, "Combined impact of climate and land use changes on streamflow and water quality in eastern Massachusetts, USA," *Journal of Hydrology*, vol. 379, no. 3-4, pp. 268–283, 2009.

[40] M. Fan and H. Shibata, "Simulation of watershed hydrology and stream water quality under land use and climate change scenarios in Teshio river watershed, northern Japan," *Ecological Indicators*, vol. 50, pp. 79–89, 2015.

[41] S. M. Goodrow, A. A. Procopio, L. Korn, and M. Paul, "Long-term temporal water-quality trends within the Barnegat Bay watershed, New Jersey," *Journal of Coastal Research*, no. 78, pp. 22–33, 2017.

[42] M. Bani-Domi, "Trend analysis of temperatures and precipitation in Jordan," *Umm Al-Qura University Journal of Educational, Social Sciences & Humanities*, vol. 17, no. 1, pp. 15–36, 2005.

[43] M. Benítez-Gilabert, M. A. Cobelas, and D. G. Angeler, "Effects of climatic change on stream water quality in Spain," *Climatic Change*, vol. 103, no. 3, pp. 339–352, 2010.

[44] J. S. Clark, E. K. Yiridoe, N. D. Burns, and T. Astatkie, "Regional climate change: trend analysis of temperature and precipitation series at selected Canadian sites," *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie*, vol. 48, no. 1, pp. 27–38, 2000.

[45] T. Fukushima, N. Ozaki, H. Kaminishi, H. Harasawa, and K. Matsushige, "Forecasting the changes in lake water quality in response to climate changes, using past relationships between meteorological conditions and water quality," *Hydrological Processes*, vol. 14, no. 3, pp. 593–604, 2000.

[46] J. A. Marengo and C. C. Camargo, "Surface air temperature trends in southern Brazil for 1960–2002," *International Journal of Climatology*, vol. 28, no. 7, pp. 893–904, 2008.

[47] F. J. Rueda, W. E. Fleenor, and I. D. Vicente, "Pathways of river nutrients towards the euphotic zone in a deep-reservoir of small size: uncertainty analysis," *Ecological Modelling*, vol. 202, no. 3-4, pp. 345–361, 2007.

[48] I. Chorus and J. Bartram, *Toxic Cyanobacteria In Water: A Guide To Their Public Health Consequences, Monitoring And Management*, CRC Press, Boca Raton, FL, USA, 1999.

[49] P. G. Whitehead, R. L. Wilby, R. W. Battarbee, M. Kernana, and J. Wade, "A review of the potential impacts of climate change on surface water quality," *Hydrological Sciences Journal*, vol. 54, no. 1, pp. 101–123, 2009.

[50] F. Dyer, S. Elsawah, and B. Croke, "The effects of climate change on ecologically-relevant flow regime and water quality attributes," *Stochastic Environmental Research and Risk Assessment*, vol. 28, no. 1, pp. 67–82, 2014.

[51] D. Hongve, G. Riise, and J. Kristiansen, "Increased colour and organic acid concentrations in Norwegian forest lakes and drinking water–a result of increased precipitation?" *Aquatic Sciences*, vol. 66, no. 2, pp. 231–238, 2004.

[52] I. Delpla, E. Baures, A. V. Jung, and O. Thomas, "Impacts of rainfall events on runoff water quality in an agricultural environment in temperate areas," *The Science of the Total Environment*, vol. 409, no. 9, pp. 1683–1688, 2011.

[53] S. Larsen, B. Kronvang, and L. M. Svendsen, "Trends in diffuse nutrient concentrations and loading in Denmark: statistical trend analysis of stream monitoring data," *Water Science and Technology*, vol. 39, no. 12, pp. 197–205, 1999.

[54] A. Oborne, "The chemistry of the river wye," *Journal of Hydrology*, vol. 45, no. 3-4, pp. 233–252, 1980.

[55] J. Piñol, A. Avila, and F. Roda, "The seasonal variation of streamwater chemistry in three forested Mediterranean catchments," *Journal of Hydrology*, vol. 140, no. 1-4, pp. 119–141, 1992.

[56] V. H. Resh, A. V. Brown, A. P. Covich et al., "The role of disturbance in stream ecology," *Journal of the North American Benthological Society*, vol. 7, no. 4, pp. 433–455, 1988.

[57] J. D. Kiernan and P. B. Moyle, "Flows, droughts, and aliens: factors affecting the fish assemblage in a Sierra Nevada, California, stream," *Ecological Applications*, vol. 22, no. 4, pp. 1146–1161, 2012.

[58] J. D. Olden and R. J. Naiman, "Incorporating thermal regimes into environmental flows assessments: modifying dam operations to restore freshwater ecosystem integrity," *Freshwater Biology*, vol. 55, no. 1, pp. 86–107, 2010.

[59] L. Prathumratana, S. Sthiannopkao, and K. W. Kim, "The relationship of climatic and hydrological parameters to surface water quality in the lower Mekong River," *Environment International*, vol. 34, no. 6, pp. 860–866, 2008.

[60] T. Jiang, B. Su, and H. Hartmann, "Temporal and spatial trends of precipitation and river flow in the Yangtze river basin, 1961–2000," *Geomorphology*, vol. 85, no. 3-4, pp. 143–154, 2007.

[61] M. J. Bowes, H. Jarvie, P. S. Naden et al., "Identifying priorities for nutrient mitigation using river concentration–flow relationships: the Thames basin, UK," *Journal of Hydrology*, vol. 517, pp. 1–12, 2014.

[62] C. Nilsson and B. M. Renöfält, "Linking flow regime and water quality in rivers: a challenge to adaptive catchment management," *Ecology and Society*, vol. 13, no. 2, 2008.

[63] S. J. Interlandi and C. S. Crockett, "Recent water quality trends in the Schuylkill river, Pennsylvania, USA: a preliminary assessment of the relative influences of climate, river discharge and suburban development," *Water Research*, vol. 37, no. 8, pp. 1737–1748, 2003.

[64] B. Caruso, "Temporal and spatial patterns of extreme low flows and effects on stream ecosystems in Otago, New Zealand," *Journal of Hydrology*, vol. 257, no. 1-4, pp. 115–133, 2002.

[65] J. R. Gray, "Conductivity analyzers and their application," *Environmental instrumentation and analysis handbook*, Wiley Online, Hoboken, NJ, USA, 2004.

[66] F. Gessner, "Der sauerstoffhaushalt des amazonas," *Internationale Revue der gesamten Hydrobiologie und Hydrographie*, vol. 46, no. 4, pp. 542–561, 1961.

[67] P. Budai and A. Clement, "Estimation of nutrient load from urban diffuse sources: experiments with runoff sampling at pilot catchments of Lake Balaton, Hungary," *Water Science and Technology*, vol. 56, no. 1, pp. 295–302, 2007.

[68] T. A. Akbar, Q. Hassan, and G. Achari, "Clusterization of surface water quality and its relation to climate and land use/cover," *Journal of Environmental Protection*, vol. 4, pp. 333–343, 2013.

[69] K. Karanth, *Ground Water Assessment: Development and Management*, Tata McGraw-Hill Education, New York, NY, USA, 1987.

[70] M. Sarbar, "Carbon dioxide and weak acid content of Wasia Water," in *Proceedings of the International Conference on Chemistry in Industry*, Manama, Bahrain, November 1992.

[71] A. Shaban, *An Ecological Study on Phytoplankton in Dokan Lake*, M. Sc. thesis, University of Salahaddin, Arbil, Iraq, 1980.

[72] J. J. Toma, "Limnological study in dokan lake, kurdistan region of Iraq," *Journal of Environmental Studies*, vol. 6, pp. 1–12, 2011.

[73] N. L. Poff and J. V. Ward, "Implications of streamflow variability and predictability for lotic community structure: a regional analysis of streamflow patterns," *Canadian Journal of Fisheries and Aquatic Sciences*, vol. 46, no. 10, pp. 1805–1818, 1989.

[74] R. A. Lusardi, M. Bogan, P. B. Moyle, and R. A. Dahlgren, "Environment shapes invertebrate assemblage structure differences between volcanic spring-fed and runoff rivers in northern California," *Freshwater Science*, vol. 35, no. 3, pp. 1010–1022, 2016.

[75] I. Boskidis, G. D. Gikas, G. K. Sylaios, and V. A. Tsihrintzis, "Hydrologic and water quality modeling of lower Nestos river basin," *Water Resources Management*, vol. 26, no. 10, pp. 3023–3051, 2012.

[76] K. Y. Jung, K. L. Lee, T. H. Im et al., "Evaluation of water quality for the Nakdong river watershed using multivariate analysis," *Environmental Technology & Innovation*, vol. 5, pp. 67–82, 2016.

[77] K. Roy, M. R. Karim, F. Akter et al., "Hydrochemistry, water quality and land use signatures in an ephemeral tidal river: implications in water management in the southwestern coastal region of Bangladesh," *Applied water science*, vol. 8, no. 2, pp. 1–16, 2018.

[78] W. M. Lewis and D. P. Morris, "Toxicity of nitrite to fish: a review," *Transactions of the American Fisheries Society*, vol. 115, no. 2, pp. 183–195, 1986.