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Evaluation of Karun River Quality for Irrigation in Khuzestan Province of Iran and Statistical Relationship of TDS and EC in Classified Flow Rates

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ABSTRACT: Hydro-Chemical Studies that using regression tests would be efficient operational to save the time and cost, If the regression tests confirm the correctness of regression analysis. In this study, Total Dissolved Solids (TDS) and Electrical Conductivity (EC) of Karun River that are varies by flow rates of river, has been separated in three categories, less than 400 Cubic Meters per Second, between 400 and 800 CMS and more than 800 CMS. TDS and EC rate data were analysed using SPSS 18.0 with linear regression model from October 1971 to September 2012. Correctness of estimated values of TDS which estimated with obtained regression equations was evaluated using the t-test, in these way residuals of obtained regression equations should be distributed normally around zero. The values of Sodium Absorption Ratio and Electrical Conductivity of water of Karun River were plotted in the US salinity laboratory diagram for irrigation water in three categories. For classified discharges, respectively about 64.5%, 91.8% and 78.7% of the water samples fall in the field of C3S1, will indicate low sodic waters. The water will cause high salinity hazards with a fairly severe effect on the soil properties, but are suitable for irrigation purpose which requires special careful application.

Keywords: EC, Flow Rate, Hydro-Chemical, Regression, TDS, USSL.

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INTRODUCTION

Has long been rivers for the exploitation of water for drinking, industry and agriculture are in human attention, as human societies are usually organized around river. Community development and population growth over time and consequently increase the use of water resources and abnormal manipulation cause that river water quality reduced. Measurement, analysis and interpretation of water quality data of streams facilitate the possibility to adopt appropriate management methods and progressively reduce the pollution of rivers. Thus, water quality studies and reviews the trend of river for adopt management decisions in basin is essential (Tiri and Boudoukha, 2010). Groundwater (springs, wells and Qanats), water in the atmosphere (rain and snow), surface water (oceans, seas, lakes and rivers) are the most important resources on Earth. The ocean is about 1, 320 cubic kilometres (97.2%), The glaciers by about 25 cubic kilometres (1.8%), approximately 13 million cubic kilometres of aquifers (0.9%) found in freshwater sea, lakes and rivers, about 250 thousand cubic kilometres (0.02%) and approximately 13 thousand cubic kilometres of water vapour in the atmosphere are allocated to (7). Always there are some solutes, suspended solids and gases in this water. Some of these minerals are essential for human health. Also, excessive amounts of these substances are very harmful and can cause a lot of risks. Therefore, in order to understand the water quality parameters, will be explain. The chemical composition of water and its mineralization process are imperative in classifying and assessing drinking water quality (Deutsch, 1997; WHO, 2004; Kozisek, 2005) while irrigation water quality criteria can be used as a guideline by farmers for selecting appropriate management practice to overcome potential salinity hazard (Gupta et al., 2009; Ramesh and Elango, 2012).

The Ndop plain is a semi-urban community where groundwater, as well as surface water, is a critical resource for human livelihood. The plain has an estimated population of over 200,000 people with ca. 70% involved in subsistence farming. Many ethnic groups have been attracted to the area as a result of fertile soils (Ndzeidze, 2008; Fonge et al., 2012). This has been followed by high demand for water and other natural resources (Fonge et al., 2012). Over 70% of the population depends solely on shallow groundwater, as well as surface water of poor microbial quality for drinking and other domestic purposes (Wirmvem et al., 2013).

Quality of water is equally important to its quantity owing to the suitability of water for various purposes. Water quality analysis is an important issue in groundwater studies. Variation of groundwater quality in an area is a function of physical and chemical parameters that are greatly influenced by geological formations and anthropogenic activities (Belkhiri et al. 2010). Measuring some of chemical quality parameters is so difficult and expensive in laboratory and often there is a relationship between water quality parameters. By estimating these relationships as a mathematical equation we can estimate the values of parameters that are difficult to measuring and save money and time. Total Dissolved Solid (TDS) is

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one of these parameters which is in a relationship versus Electrical Conductivity (EC). So TDS could be estimate by estimated equation easily. Regression methods help us to determining of these equations.

Quality of Irrigation water

Alkalinity Hazard: The sodium/alkali hazard is typically expressed as the sodium adsorption ratio (SAR). This index quantifies the proportion of sodium (Na) to calcium (Ca) and to magnesium (Mg) ions in a sample. Sodium hazard of irrigation water can be well estimated by determining the SAR. The sodium adsorption ratio (SAR) values for each water sample were calculated by using the following equation (Richard, 1954) than express in below in Equation (1).

Sodium Adsorption Ratio (SAR): SAR is a mathematical relationship, set out in Equation (1), the concentration of sodium in relation to Calcium and Magnesium to known effects on soil dispersibility. SAR and the electrical conductivity of irrigation water can be assessed for the potential to cause dispersion in a soil. Sandy soils are not affected by the sodium (because of the low clay content), but the plants growing on them may be affected. The Sodium Adsorption Ratio (SAR) was calculated by the following equation given by Richards (1954) as:

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}} \qquad \text{Equation (1)}$$

Where, the concentrations are reported in equation l.

Salinity Hazard: Electrical conductivity is a good measurement of salinity hazard to crop as it reflects the TDS in surface water. According to Wilcox classification (Wilcox, 1948), the water surface in the study area is ranging between excellent and good for irrigation uses. The primary effect of high EC reduces the osmotic activity of plants and thus interferes with the absorption of water and nutrients from the soil.

1) Total Dissolved Solids (TDS): Total Dissolved Solids (TDS) are solids in water that can pass through a filter. TDS is a measure of the amount of material dissolved in water. This material can include carbonate, bicarbonate, chloride, sulphate, phosphate, nitrate, calcium, magnesium, sodium, organic ions, and other ions. A certain level of these ions in water is necessary for aquatic life. Changes in TDS concentrations can be harmful because the density of the water determines the flow of water into and out of an organism's cells. TDS is used to estimate the quality of drinking water, because it represents the amount of ions in the water. Water with high TDS often has a bad taste and/or high water hardness, and could result in a laxative effect.

2) Electrical Conductivity (EC): Electrical conductivity is a measure of how well a material accommodates the movement of an electric charge. It is the ratio of the current density to the electric field strength. Its SI derived unit is the Siemens per meter**.** Since the electrical conductivity is a measure to the capacity of water to conduct electrical current, it is directly related to the concentration of salts dissolved in water, and therefore to the Total Dissolved Solids (TDS). Salts dissolve into positively charged ions and negatively charged ions, which conduct electricity. Since it is difficult to measure TDS in the field, The Electrical Conductivity of the water is used as a criterion.

The relationship between water chemical quality parameters such as Electrical Conductivity, Total Dissolved Solutes, Sodium Adsorption Ratio and Total Hardness versus water flow of Haraz River using regression analysis in SPSS software was analysed. The results of this study showed that in most cases, showing the relationship between water chemical quality parameters and flow rate using a logarithmic regression model was statistically significant (Vafakhah et al., 2009).

The study of changes of the water quality parameters Influenced by flow changes of Gorganrood river, expressed that, by changing the river flow, the concentration of dissolved substances in water are has changes during periods of high water and low water, so the water quality parameters should be examined separately (Karami Moghaddam, 2006). He collect the required parameters for the analysis of changes of Anions and Cations in GorganRoud River route from the stations of Qzaqly, Gonbad and Gorgan dam, then draw Collins and Schuler diagrams and the results obtained are as follows: there is a close relationship between increasing of flow rate and decreasing of EC in Gonbad station and increase flow rate leads to decrease Na and Cl in Qazaqly station and cause of decreasing of all of chemical elements especially Sulphates in Gorgan station.

For investigating the causes of salinity of Ajichay River and how to optimal utilization of water using flow rate and water quality data from 30 recent years, calculated the mean of flow rate and mean of annual salinity of the Ajichay River. It is suggested that for optimal utilization of Ajichay River its water be used for cultivation, storage and injecting into underground water resources, in that Seasons River has wet regime (April and May) and good quality (Gorji et al., 1994).

In a study entitled "The Effects of water withdrawals on water quality of downstream of Mamlou dam by QUAL2E" has been proved that before and after the construction of dams, the water quality changes before entering of Parchin complex wastewater was not tangible, but assuming even that the Parchin complex wastewater refined to the extent of surface water quality standards, it makes the river water quality varies greatly. This is due to the flow rate of wastewater that enters to the river is more than flow rate of river in the entrance section. Also the construction of dams and withdrawal of water, enhance its effects (Torabiyan, 2004).

In a study that took place to order to investigate the effects of upstream activities on water quality of Aravandrud and Karun River, stated the Aravandrud and Karun river water quality depends on flow rate and due to a very noticeable reduction in flow in recent years, water quality was affected (Ghandehadri, 2006).

Obiefuna and Orazulike (2010) carried study in Yola area of Northeast Nigeria which indicated that the groundwater of the area is largely suitable for irrigation purposes. One of the objectives of the present work is to discuss the major ion chemistry of water of Karun. In this case the methods proposed by Wilcox classification have been used to study critically the hydro-chemical characteristics of water of Karun.

Study Area

Karun River Watershed with an area equivalent to 65230 square kilometres with 22000 Milliard m^3 and 860 kilometres is one of the largest catchments in the Iran. This river originates from Zagros Mountains and after passing through the mountains near the Gotvand city enters to the Khuzestan plain (Figure 1). Karun River in the north of Ahvaz is divided to two branches that are connected to each other in South of Ahvaz. In this maze way, Karun river provides water needed for drinking, agriculture and industry, dozens of cities and villages, thousands of hectares of agriculture, hydroelectric power generation, fish farming and several projects and provides industrial plants. In this study to evaluate the Water quality of Karun River, water quality parameters were earned from Khuzestan Water and Power authority. Ahvaz Hydrometric Station with code 309-21 on the Karun River and geographical coordinates: 48° 41' 28" E and 31° 20' 25" N is located in Ahvaz.

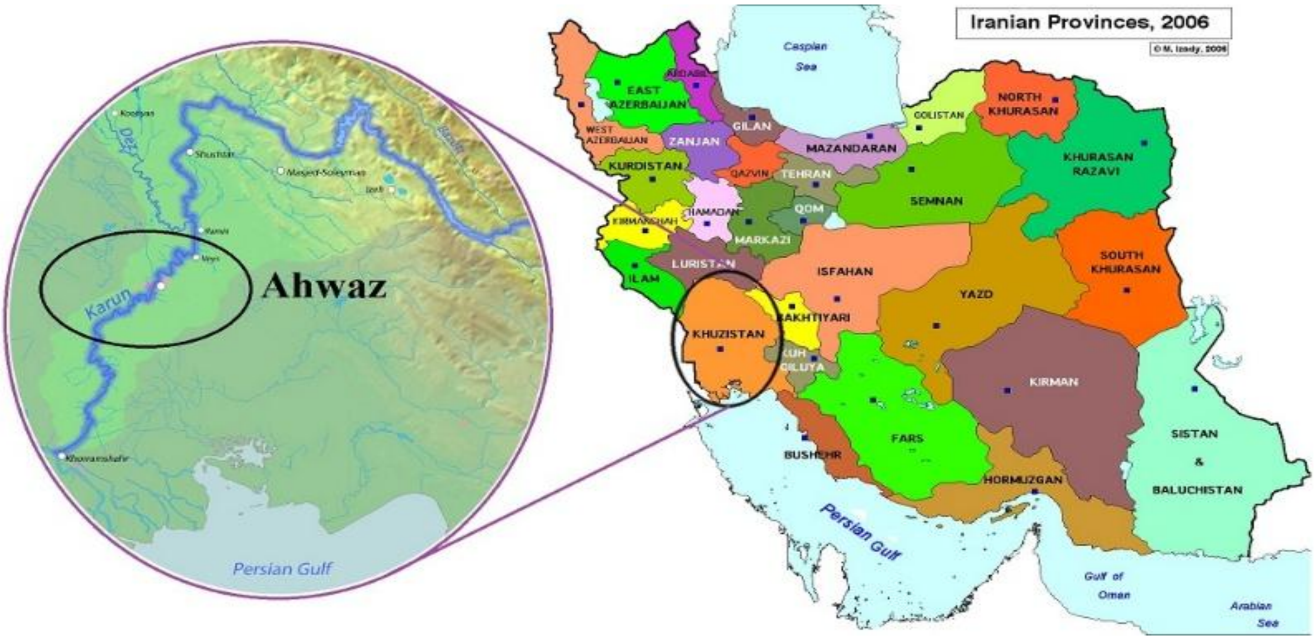

Figure 1. The Ahvaz and Karun River Location in Khuzestan, Iran

MATERIAL AND METHODS

In a manner, the water quality data from October 1971 to September 2012 were classified in three separate discharge classes, less than 400 CMS, between 400 and 800 CMS and more than 800 CMS. Graphs between EC (the dependent variable) and TDS (independent variable) plotted and to fitting the best regression model the Linear pattern is used. To judgment on efficiency of the obtained regression equation, the results of the SPSS 18.0 are used (the ANOVA for regression and values of Sig. and Adjusted R Square). It should be noticed, to obtain regression equations should be ensured that correlation coefficient between two variables are statistically significant or not. The SPSS software using Sum of Squared Residuals as default and stop calculation when the difference between the two end-stage were 1E-8. If on ANOVA for regression Sig. was less than 0.05 the regression models was fitted properly. After obtaining the regression equation based on river flow classifications, the independent variable (EC: Electrical Conductivity) put into the equation and estimate the values of TDS.

To verifying the ability of obtained linear regression equation to estimate reliable values of TDS the One-Sample t-test is used. One-Sample t-test between the amounts of residuals (the difference between the estimated values and actual values) and zero is done. This test is based on a uniform distribution of residues around zero, so that the algebraic sum of all negative values of residuals and sum of all positive values should be equal. If this test were statistically significant, obtained regression equation estimates the acceptable values (Helsel and Hirsch, 2002; Stiff and Petrol, 1951).

RESULTS AND DISCUSSION

The classification of water samples from the study area with respect to SAR is represented in Table (1) for classified flow rates, the SAR value of all the samples are found to be less than 10 and are classified as excellent for irrigation in farms with coarse grained soil texture. When the SAR and electrical conductivity of water are known, the classification of water for irrigation can be determined by graphically plotting these values on the US salinity (USSL) diagram (Figure 2). Respectively about 64.5%, 91.8% and 78.7% of the samples are grouped within C3S1 (Table 3 and Figure 2).

For the purpose of diagnosis and classification, the total concentration of soluble salts (salinity hazard) in irrigation water can be expressed in terms of Electrical Conductivity. Classification of water based on salinity hazard is presented in Table 2. It is found from the EC value, only 14, 1 and 1 samples of water with discharges less than 400 CMS (a), between 400 and 800 CMS (b) and more than 800 CMS (c) were found to be unsuitable for irrigation purposes.

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Table 1. Sodium hazard classes based on USSL classification

Sodium Hazard Class	SAR in Equivalents Per mole	Remark on Quality	Flow Rate		
(Alkalinity)			Less than 400	Between 400-800	Upper than 800
S1	10<	Excellent	89 (64.5%)	148 (92.5%)	105 (97.2%)
S2	10-18	Good	49 (35.5%)	12 (7.5%)	3 (2.8%)
S3	18-26	Doubtful	-	-	-
S4	>26	Unsuitable	-	-	-

Table 2. Salinity hazard based on USSL classification

Salinity Hazard Class	EC in (micro-mhos/cm)	Remark on Quality	Flow Rate		
			Less than 400	Less than 400	Less than 400
C1	100-250	Excellent	-	-	-
C2	250-750	Good	-	1 (0.7%)	20 (18.5%)
C3	750-2250	Doubtful	124 (89.9%)	158 (98.6%)	87 (80.5%)
C4	2250<	Unsuitable	14 (10.1%)	1 (0.7%)	1 (1%)

Table 3. Water Quality Classification based on USSL classification

Class	Flow Rate		
	Less than 400	Between 400-800	Upper than 800
C2S1	-	1 (0.7%)	20 (18.5%)
C3S1	89 (64.5%)	147 (91.8%)	85 (78.7%)
C3S2	35 (25.4%)	11 (6.8%)	2 (1.9%)
C4S1	-	-	-
C4S2	14 (10.1%)	1 (0.7%)	1 (0.9%)

There is a significant relationship between sodium adsorption ratio (SAR) values for irrigation water and the extent to which sodium is absorbed by the soils. If water used for irrigation is high in sodium and low in calcium, the cation exchange complex may become saturated with sodium, which can destroy the soil structure owing to dispersion of clay particles (Singh, 2002). The S\odium Adsorption Ratio of water of Karun river obtained in the present study are generally less than 10 and fall under the category of C3S1 indicating low alkali hazards and Doubtful salinity hazards and generally excellent irrigation water in all range of Flow Rates (US Salinity Laboratory Staff, 1954). In figure 2, the USSL diagram presents in three classes of discharge.

The most important characteristics of irrigation water in determining its quality are:

1) Total concentration of soluble salts;

2) Relative proportion of sodium to calcium and magnesium, which affect the availability of the water to the crop.

In figure 2 (c) most samples fall in low sodium class (S1) (Table 3). This implies that no alkali hazard is anticipated to the crops. If the SAR value is greater than 6–9, the irrigation water will cause permeability problems on shrinking and swelling of clayey soils types (Saleh et al., 1999). Most samples of the three classified flow rates fall in the field of C3S1, indicating high salinity and low sodium hazard. These samples will be suitable for plants having good salt tolerance and can be used for irrigation on almost all types of soils with little danger of exchangeable (Karanth, 1989; Mohan et al., 2000).

A Scatter diagram can present all the base aspects of existence or non-existence between two variables. It should be noticed, that judgment based on correlation coefficient between two variables will not be right judgment. The diagrams of Total Dissolved Solids versus Electrical Conductivity of Karun River were shown separately in Figure 3.

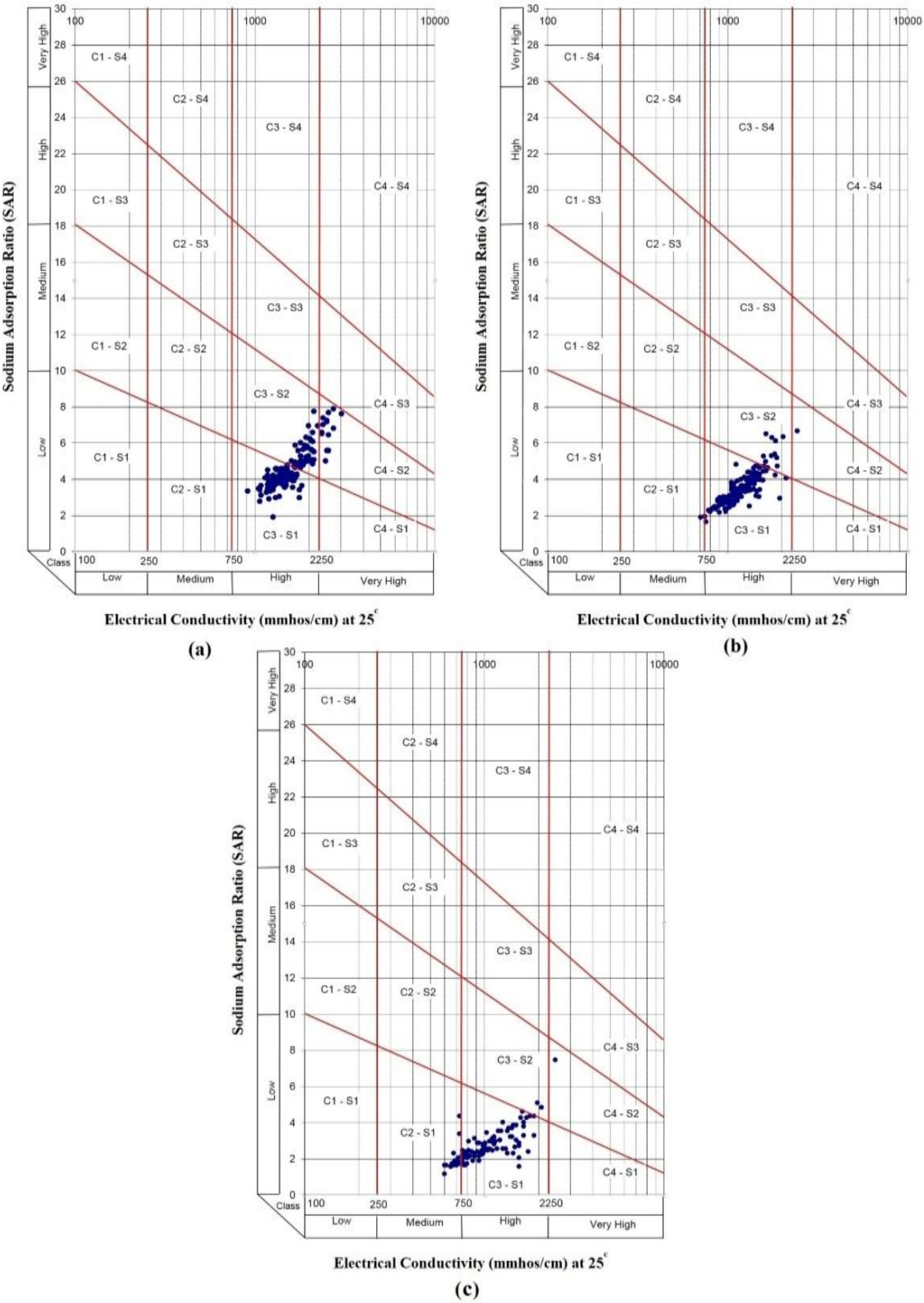


Figure 2. USSL classification of water for Discharges less than 400 CMS (a), between 400 and 800 CMS (b) and more than 800 CMS (c) (Wilcox, 1950

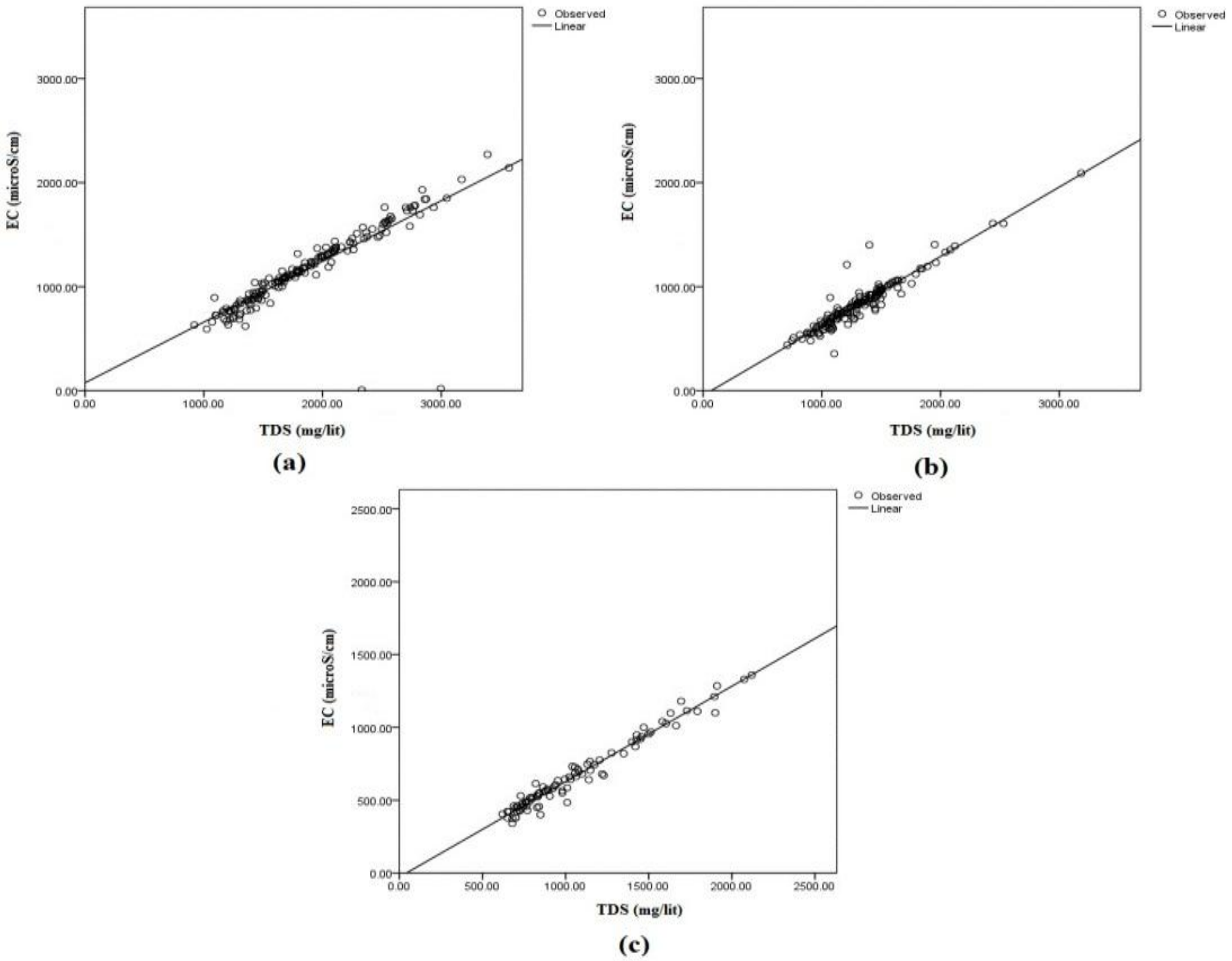


Figure 3. The Scatter diagram and linear regression line of TDS vs. EC for classified discharges

The results of model summary, correlation coefficients for classified discharges were presented in Table 4 and the results of ANOVA, for classified discharges were presented in Table 5.

Using the results of SPSS software, the linear regression equation for classified discharges less than 400 CMS achieved is $TDS = 0.584(EC) + 75.393$, for discharges between 400 and 800 CMS equation is $TDS = 0.668(EC) - 45.976$ and for discharges more than 800 CMS is $TDS = 0.655(EC) - 28.388$. The coefficient of linear regression equation presented in the Table 6.

In tables 4 the probability of significance in the ANOVA test was 0.00. This value represents the significance of the regression test and correctness of the linear model fit between TDS and EC. After ensuring about the meaningfulness of linear regression one has to test regression components separately. Tables 6 indicate the regression coefficients and partial correlation coefficients or beta weights. Validation test for each of obtained coefficients is presented in the last column of the mentioned table. For all 3 classes of discharge, the probability of significance of the slope of regression line is proven to be lower than 0.05 and the probability of significance of the intercept is higher than 0.05; this indicates the necessity to apply the slope component in regression equations and not to apply to the intercept. That illustrates the necessity to consider the slope parameter in linear regression and to dismiss the intercept in those equations. Thus, the obtained equations will change to TDS=0.584(EC) for the discharges lower than 400 CMS, TDS=0.668(EC) for discharges between 400 to 800 CMS and TDS=0.655(EC) for discharges higher than 800 CMS. After ensuring about the integrity of the obtained equation, different values of EC will be considered on them and for each value of EC, an element of TDS in estimated. According to basis of the regression, these values differ from their actual values. In other words, the estimated points and actual data won't coincide on each other in the scatter plot. This difference between predicted variable and actual values is known as residual or error. These comparisons and tests are designed for examining the linear relation, so amount of errors and residuals are not considered here. For the purpose of checking these errors, residual values are plotted onto the obtained values. If the residuals have uniform distribution around the zero, regression equations has been successful at estimation the desired parameter (TDS). In other words if the average of residuals have no significant difference with zero, regression equations will predict the TDS values according to a specific EC. Due to the very small average error and very strong probability (significantly more than 0.05) that are provided in tables 7, high precision of obtained regression equations for TDS using values of EC can be expressed. In figures 4 it is observable that residuals have been distributed around the zero uniformly, however this claim must be proven by mathematical tests. The residuals test results with zero using t-test have been shown in table 7.

Table 4. The summary of regression model for classified discharges (1971-2012)

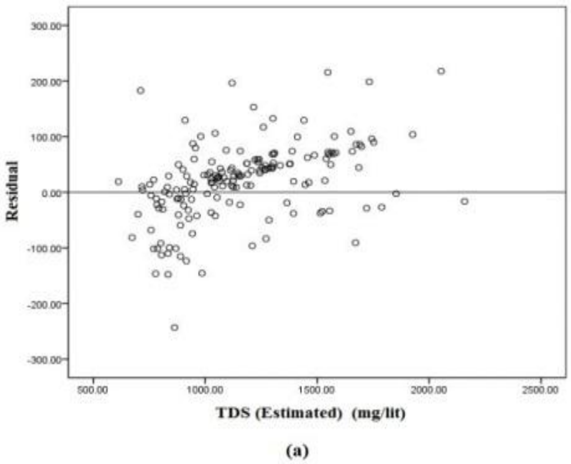
Discharge class	R	R Square	Adjusted R Square	Std. Error of the Estimate
Less than 400 CMS	0.852	0.726	0.725	191.499
400-800 CMS	0.943	0.889	0.888	79.614
More than 400 CMS	0.983	0.965	0.965	46.327

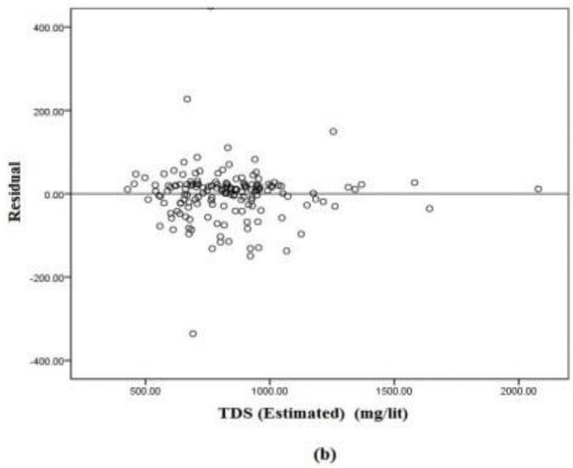
Table 5. The results of ANOVA for classified discharges (1971-2012)

Discharge class	Parameters	Sum of Squares	df	Mean Square	F	Sig.
Less than 400 CMS	Regression	1.63×10^7	1	1. 1.63×10^7	445.508	0.0001
	Residual	6.16×10^6	168	36672.011	-	-
	Total	2.25×10^7	169	-	-	-
400-800 CMS	Regression	7.86×10^6	1	7.86×10^6	1239.896	0.0001
	Residual	9.82×10^5	155	6338.435	-	-
	Total	8.84×10^6	156	-	-	-
More than 400 CMS	Regression	5.39×10^6	1	5.39×10^6	2510.870	0.0001
	Residual	1.93×10^5	90	2146.173	-	-
	Total	5.58×10^6	91	-	-	-

Table 6. The coefficient of linear regression equation

Discharge class	Coefficient	Un-standardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
Less than 400 CMS	EC	.584	.028	0.852	21.107	0.000
	(Constant)	75.393	53.758	-	1.402	0.163
400-800 CMS	EC	.668	.019	0.943	35.212	0.000
	(Constant)	-45.976	25.787	-	-1.783	0.077
More than 400 CMS	EC	.655	.013	0.983	50.109	0.000
	(Constant)	-28.388	14.745	-	-1.925	0.057





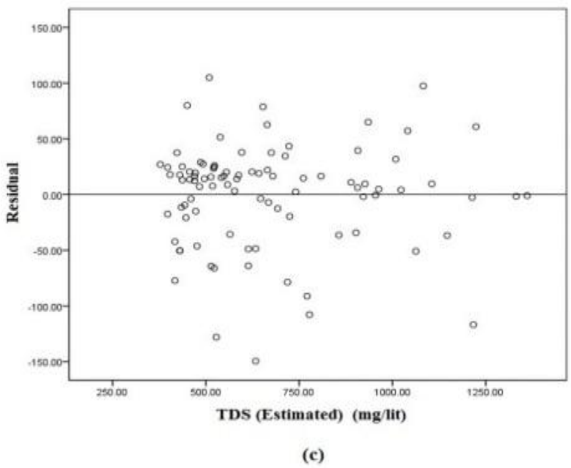


Figure 4. The Scatter diagram of estimated TDS vs. Residuals for classified discharges

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Table 7. Results of One-Sample t-test

Discharge class	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Less than 400 CMS	.011	169	.991	.15784	-28.7505	29.0662
400-800 CMS	.180	156	.857	1.14198	-11.3686	13.6526
More than 800 CMS	.005	91	.996	.02244	-9.5187	9.5636

In this table, negligible value of the t-test statistic has caused the probability of equality of the residual average with zero to reach to a certain point. The reason for this absolute equality is:

a) High degree of freedom of the samples, which caused the match between the distribution of the data and the normal distribution.

b) Correct estimate of TDS by obtained linear regression equations.

CONCLUSION

Estimation of a relationship between regression equation the electrical conductivity and total dissolved solids with the use of total annual data is unreasonable; since the electrical conductivity depends on total dissolved solids values and the other hand the total dissolved solids itself is a function of river discharge which varies throughout the year. For this reason, in this study the desired regression equation has been estimated for three classes. Results of the statistical tests suggest the TDS=0.584(EC) for the discharges lower than 400 cubic meters per second, the TDS=0.668(EC) for discharges between 400 and 800 cubic meters per second and the TDS=0.655(EC) for discharges over 800 cubic meters per second. The mentioned equations have been proven by analysis of variance for regression and the residuals from each one have been compared with zero value based on the One-Sample t-test. The results showed that the residuals have the average value of zero. This illustrates the correctness of the proposed equations for the relationship between EC and TDS of the Karun River in three discharge classes. In addition, irrigation indices of the sampled water also fall within the permissible level indicating low sodic waters. The water will cause high salinity hazards and have a fairly severe effect on the soil properties, but are suitable for irrigation purpose which requires special careful application.

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