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MODELING WATER QUALITY INDEX USING GEOGRAPHIC INFORMATION SYSTEMS AND WEIGHTED ARITHMETIC INDEX IN KIRKUK, IRAQ

MOHAMMED GHAZY HABBEB, MARYAM HASSAN AHMED SULYMAN AND HUDA JAMAL JUMAAH*

Department of Environment and Pollution Engineering, Technical Engineering College-Kirkuk, Northern Technical University, Kirkuk 36001, Iraq

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ABSTRACT

In this study, various water quality parameters have been selected and examined. Weighted Arithmetic Index (WAI) method used to calculate Water Quality Index (WQI). Besides, a statistical model for WQI prediction was proposed to test the correlation between WQI, Acidity (pH), Turbidity (T), Total Dissolved-Solids (TDS), Total Suspended-Solids (TSS), and Electrical-conductivity (Ec). The study was conducted in Kirkuk, north of Iraq. The results of laboratory tests showed that the quality of drinking water that is processed from Kirkuk water project K1 is within the Iraqi specifications, except in one characteristic (Turbidity). The calculated WQI ranged between 67.37-109.92. Water Quality (WQ) was within good and poor water. For the predicted model, an accuracy value was calculated by the regression process. The obtained regression coefficient value R^2 was equal to 0.99. The results demonstrated that the features obtained by regression analysis are able to predicate the WQI with very high accuracy.

KEY WORDS : Water quality, Weighted arithmetic index, Laboratory tests, Linear regression, Analytical model.

INTRODUCTION

The quality of drinking water is critical to public health (Levallois and Villanueva, 2019; Li and Wu, 2019). The term Water Quality is used to identify how appropriate the water is for public consumption and is most used by researchers in publications related to sustainable management. Poor WQ highly affects health, where contaminated water and bad sanitation are causes of the transfer of diseases like cholera, dysentery, and diarrhea (Li and Wu, 2019). There is an urgent need to identify the threat and possible improvement of water services (Allaire 2018). The WHO expects that nearly 10% of the world's population does not have access to good quality drinking water sources where access to good quality potable water remains a critical issue (Levallois and Villanueva, 2019). Also, it has been reported that at least 2 billion people globally use contaminated drinking water (Li and Wu, 2019). Economical activities and population expansion absolutely lead to rising demand for pure water (Rahi and Halihan, 2010). Lately, Iraq water resources specifically have suffered from brilliant strain in terms of water amount because of different motives together with the dams constructed on Tigris and Euphrates from adjacent countries, the incorrect use plan of water, and the worldwide climatic changes (Jones et al., 2008; Rahi and Halihan, 2010). WQ is indeed affected by the supply of the source, therefore, studying water quality is an essential topic to be carried out, that requires comprehensive planning with emphasis on allocation of priorities about the various usages and resource management (Vaux 2001). In the aquatic ecosystem, many factors such as physical, chemical, and biological are used to test water quality (Sargaonkar and Deshpande, 2003). So, a specific problem in monitoring water quality is the complication related to evaluating a different number of tested factors (Boyacioglu, 2006), and high variability due to anthropogenic and natural influences (Simeonov, 2002). There are many techniques to evaluate WQ data that vary according to informational aims, samples type, and sampling area volume (Simeonov, 2002; Boyacioglu and Boyacioglu, 2007). The use of suitable indices is one of the highest operatives means to interconnect information on WQ trends (Dwivedi and Pathak, 2007).

In this study, we evaluated drinking water quality using laboratory tests and WQI calculations based on ArcGIS analysis. Research in this area is extensive, as indicated by the number of methods proposed or developed for classification, modelling and, interpretations of monitoring data.

MATERIALS AND METHODS

The samples have been taken during the period of the study from November 2017 to March 2018. Four reservoirs are located in the study area. Five samples from each location of each tank were selected from 12 regions. Samples were taken from the areas and processed physically at the water laboratory at the Kirkuk Technical College and biologically in the biological laboratory at Kirkuk Water Directorate, and chemists at the laboratories of the Technical Institute of Kirkuk. The residents of the city of Kirkuk depend on the water project of the consolidated K1 in order to obtain water. To calculate the WQI, a set of five WQ parameters was chosen. The equation used for WQI calculating which specify the WAI is;

$$\mathrm{WAI} = \frac{\sum_{i=1}^{i=n} Q_i * W_i}{\sum W_i} \quad .. (1)$$

where; $Q_i = \frac{C_i}{S_i} * 100$ and, $W_i = \frac{1}{S_i}$, Q_i; is the quality rating of water quality parameter, W_i; is the relative weight of each parameter, n; is the number of parameters, C_i; is the measured parameter concentration, and S_i; is the allowed value of each parameter (Kitalika *et al.,* 2018). Figure 1 represents regions distribution based on the water samples.

Multiple linear regression aims to model the correlations among the independent variables and a dependent variable by fitting an equation to used data (Hamed *et al.,* 2021). Using a multiple linear regression model is a useful method to predict an

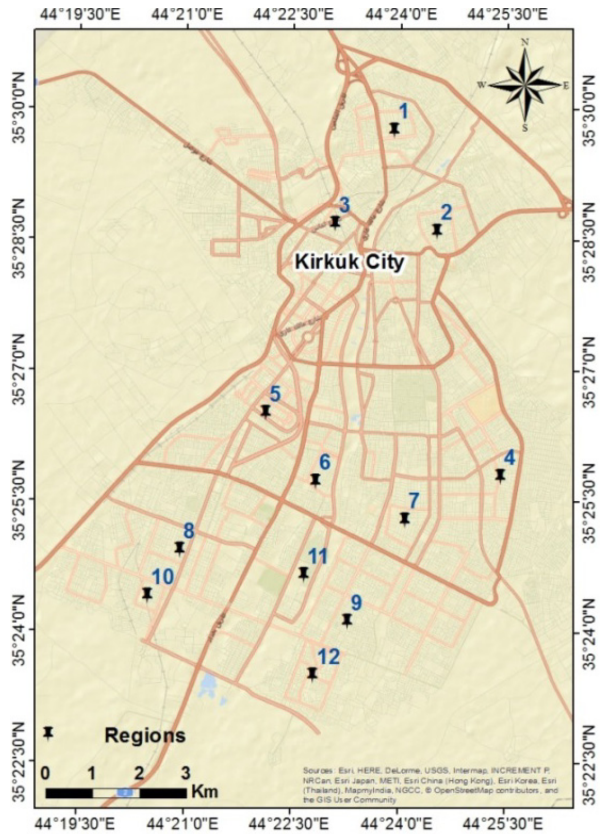

Fig. 1. Regions distribution based on the water samples.

equation to estimate WQI according to the type of parameters used. Here, we used five Water Quality Parameters (WQPs); PH, T, TDS, TSS and, Ec. A Least Square Method has been applied and validated.

The equation that specifies the linear model is (Jumaah *et al.,* 2019);

$$y_i = I + C_1 x_{1i} + \ldots + C_k x_{ki} + e \quad (2)$$

where; y_i is the predicted value, $C_1 \ldots C_k$; are the independent variables coefficients, $x_{1i} \ldots x_{ki}$; are the independent variables, and e; is the error term. Moreover, to measure the accuracy of the productive linear algorithm, the least square model has been demonstrated to fit predicted WQI and calculated WQI from the five water quality parameters. The accuracy has been obtained by regression analysis.

RESULTS AND DISCUSSION

Figure 2 represents the laboratory test results in the reservoir and regions of each parameter used in the study. The pH value of the water in the reservoirs was 7.2. While their values in the regions ranged from (7.5 to 7.9). The PH values in all regions were within the Iraqi standard. Figure 2(a) represents the pH concentration in the reservoirs and regions. The Turbidity T value of the water concentration in the reservoirs ranged from (3.8-4.2 NTU). While their concentrations in the regions ranged from (2.7-6.1 NTU). The Turbidity values in all regions were within the Iraqi standard except in region 1 and region 3 were out the permissible standard as shown in Figure 2(b). The Total Dissolved Solid TDS value of the water concentration in the reservoirs ranged from (262 – 266) ppm. While their concentrations in the regions ranged from (267-282)ppm. The TDS values in all regions were within the Iraqi standard. Figure 2(c) illustrates the value of TDS in reservoirs and regions. The Total Suspended Solids TSS value of the water concentration in the reservoirs ranged from (8-10ppm). While their concentrations in the regions ranged from (16-21) ppm. The TSS values in all regions were within the Iraqi standard. And Figure 2(d) illustrates the value of TSS in reservoirs and regions. The Electrical conductivity Ec value of the water concentration in the reservoirs (355-365) µc. While their concentrations in the regions ranged from (177-193) µc. The Ec values in all regions were within the Iraqi standard.

Moreover, Figure 2(e) represents the value of E_C in reservoirs and regions.

Based on Figure 2, the laboratory test results have shown differences between results in reservoirs and regions. No issue in reservoirs test results. Otherwise, the test results in regions were within standards for the pH, TDS, TSS, and EC while the Turbidity test results were out of standard. Therefore, two regions (Raheem Awa and Almas) WQ was out of standards and resulted in poor water quality.

Based on equation (1), the WQI was calculated. Figure 3 represents ArcGIS-based analysis of WQI. The value of calculated WQI by WAI method was

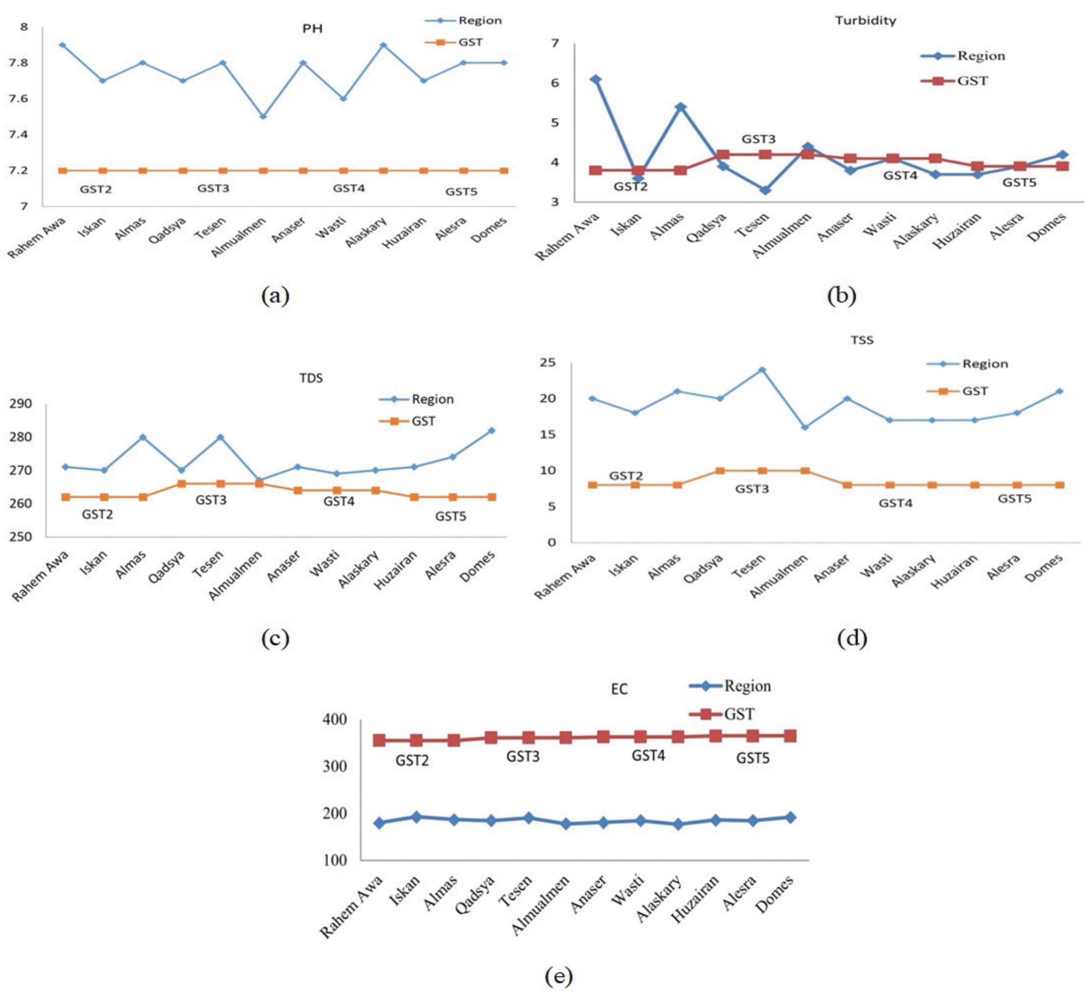

Fig. 2. Laboratory test results in the reservoirs and regions of; (a) PH, (b) T, (c) TDS, (d) TSS, and (e) Ec.

ranged between (67.37 and 110). Furthermore, based on Table 1 the water quality status of WAI (Kitalika *et al.*, 2018), the WQI is classified as Good and Poor. Where region 1(Raheem Awa) and region 3(Almas) are shaded with red color representing the poor water quality in the period of study. All other regions are shaded with green color represents good water quality.

The beast equation obtained to estimate the WQI by linear regression model are specified as follows;

Table 1. The water quality status of WAI (Kitalika *et al.*, 2018)

WAI	WQI status
<50	Excellent
50-100	Good
100-200	Poor
200-300	Bad
>300	Inappropriate for drinking

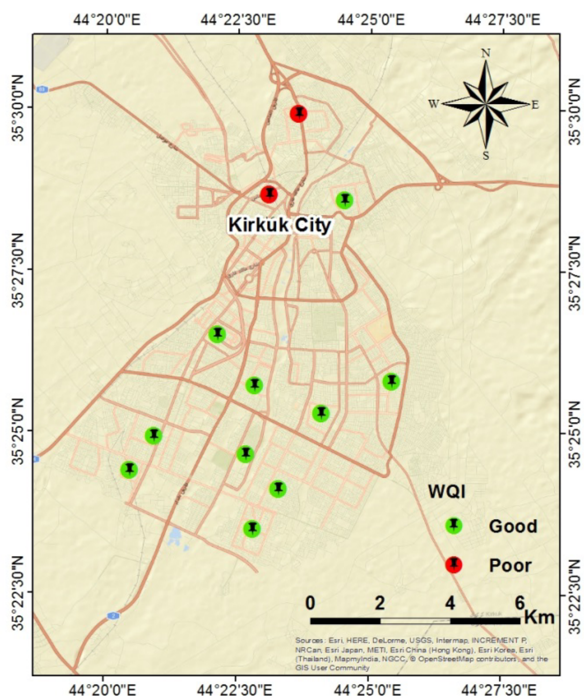

Fig. 3. ArcGIS based map of WQI.

$$WQI = I + C_1 \times pH + C_2 \times T + C_3 \times TDS + e \quad .. (3)$$

$$WQI = -0.0045 + 4.29 \times pH + 12.39 \times T + 0.001 \times TDS + e \quad .. (4)$$

where WQI is the predicted Water Quality Index which represents the dependent variable. While PH, T, and TDS are the independent variables. I; is the intercept, C_1; is the pH coefficient, C_2; is the turbidity coefficient, C_3; is the TDS coefficient, and e; is the error term and its neglected.

There are certain conditions to apply the regression processes. One of the conditions is the probability value (P-Value) of each parameter must be not more than 0.005 else, the parameter will be excluded from the model equation. The predicted values of WQI was ranged from 67.3 to 109.8.

CONCLUSION

This study tried to examine and evaluate the drinking WQ in reservoirs and 12 regions in Kirkuk city. By examining the samples of the reservoirs, they found that all the physical and chemical concentrations were within the standard standards according to the Iraqi specifications and the World Health Organization WHO. Otherwise, the WQ of the region's evaluation results falls in two classes (Good and Poor). However, there was a difference in some concentrations between the regions and reservoirs. This is because the pipes and connecting lines of the areas are dilapidated water, and this changes in some properties, but by examining the water of the regions showed that the differences are few in the concentrations between the reservoirs and regions, but if not addressed these problems there is a high risk of causing pollution of the city water. The results of the biological tests were all positive.

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