

## Monitoring Water Quality Parameters of Khirisan River in Iraq

Yaser Ibrahim Jasem<sup>1,\*</sup>, Qassem H. Jalut<sup>1</sup>, Salah N. Farhan<sup>2</sup>, Muataz H. Ismael<sup>2</sup>

<sup>1</sup> Department of Civil Engineering, College of Engineering, University of Diyala, Iraq

<sup>2</sup> Department of Chemical Engineering, College of Engineering, University of Diyala, Iraq

### ARTICLE INFO

#### Article history:

Received 21 March 2020

Received in revised form 30 May 2020

Accepted 1 June 2020

Available online 18 November 2020

### ABSTRACT

In this work, a set of physical, chemical and biological parameters were analysed for Khirisan river from the period extending from December 2017 up to November 2018. The samples were selected from three different sites, agricultural, commercial and residential area to assess the water quality of the river for drinking and irrigation purposes. The study showed that a number of diversity factors were recognized which have a direct effect on the quality of Khirisan river. This includes the catchment feeding area of the river, untreated domestic sewage from the restaurants, cafeterias and government buildings which are adjacent to the river. Water quality of Khirisan river, according to the Iraqi and international standards, satisfies the limits of the rules of the drinking purposes for all studied parameters except the values of calcium ions and total hardness value for some rainy months as well as to organic load. The mean values of BOD5 and COD for the three sites were 7.7 and 36 mg/l. In terms of irrigation purposes, the water quality of the river can be considered low to medium damage in terms of salinity and sodium hazards. In terms of chloride risk, there are no toxicity problems to the roots and leaves of the plants. Therefore, it requires a continual intensive water quality monitoring program to reduce its impact.

#### Keywords:

Khirisan river; water quality; drinking purposes; irrigation purposes

## 1. Introduction

Rivers around the world serve as the recipient of large amounts of waste produced as a result of agricultural, human and industrial activities. Agriculture is the most important source of pollution due to the runoff of the fertilized land. The lack of fresh water worldwide, which is attributed to human misuse, is a form of pollution [1]. Increasing water pollution not only leads to deterioration of water quality but also threatens human health, the balance of aquatic ecosystems, economic development and social prosperity [2,3].

The human activities that affect the quality of the river water in the discharge of Khirisan river are agriculture and domestic sewage. The sources of pollution in the sewage basin are the use of fertilizers and pesticides mainly in the land along the river path, in addition to the direct discharge of

\* Corresponding author.

E-mail address: [yaser.ij13@gmail.com](mailto:yaser.ij13@gmail.com)

<https://doi.org/10.37934/arfmts.78.1.2334>

untreated sewage from restaurants and cafeterias on the banks of the river (market area) in a river as well as solid waste [4].

The environmental monitoring parameters are one of the most critical priorities in assessing the ecological state of water resources and in the policy of environmental protection. The main objectives are to understand and assess the availability and quality of water, to control and reduce the occurrence of pollution-related problems, as well as to provide suitable water quality for different water uses such as water supply, irrigation water, and others [5].

The quantity of water is assessed by measuring the runoff or discharge of specific sections of surface water [6]. The quality of the surface water and groundwater is determined in terms of physical, chemical and biological parameters. The main problem in water quality control is the large number of measured variables [7]. Evaluation of physicochemical and bacteriological parameters in water bodies like lakes, rivers and others is widely used to state the suitability of water for different purposes [8,9].

The quality parameters can be reduced to the most effective ones by studying the patterns and variations of the observed quality parameters at the monitoring stations [10]. Reducing the amount of data can also be achieved by using multivariate statistical analyses [11]. The box and whisker statistical method was applied to the field collecting samples to identify the important quality parameters that can be used as indicators of pollution in rivers (Cisadane River as case study) [12].

In this work, the monthly values of water runoff and the water quality parameters including physical, chemical and some of the biological ones were collected in addition to some of the major cations and anions were analyzed in order to assess the use of the rivers' water in urban water supply and irrigation according to water quality standards.

## 2. Study Area

Khirisan river is one of the most important sources of freshwater to Baquba city in the middle of Iraq. It's the first water source used for drinking and irrigation purposes. It has a length of about 59.5 km with a design flow rate of 22 m<sup>3</sup>/sec approximately constant throughout the year. Raw water of Khirisan river has been a source of supply to fifteen water-treatment plants along its course and about 415000 km<sup>2</sup> of agriculture area. Three sites were selected for sample collection. Site 1 (Al-Wathba), which is near to the intake of Chbenat water treatment plant, site 2 (Al-Balda) and site 3 (Al-Jahza), which is near to the intake of Al- Jahza water-treatment plant as shown in Figure 1. Site 1 which is located in the unpadded part of the river and other sites are located in the padded part of the river.

The areas which precede site 1 are rural villages and agricultural regions where herbicides and fertilizers are widely used. While the space between site 1 and sites 2 is a commercial market area as well as many restaurants and cafeterias along the river. The area between Site 2 and Site 3 represents residential areas and some governmental buildings.

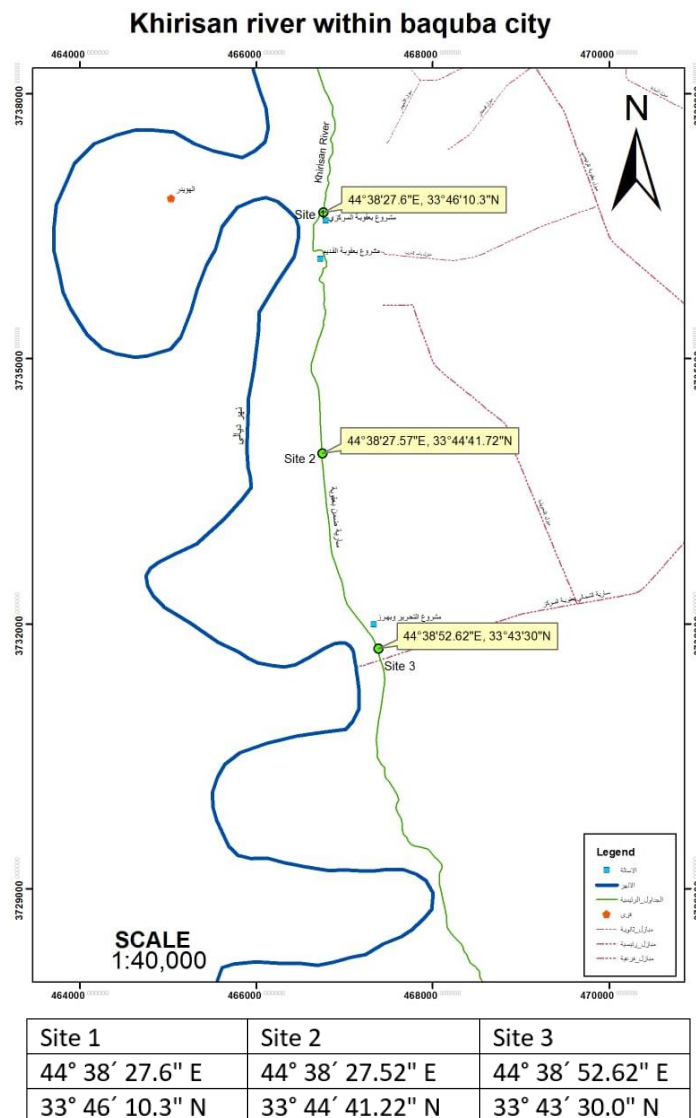
## 3. Sampling Methods, Measurement and Standards

Samples collection was carried out monthly from Dec. 2017 to Nov. 2018. At each sample location, two samples were collected with the average taken. Quality parameters include physicochemical parameters such as temperature, total suspended solid (TSS), pH, electrical conductivity (EC), total dissolved solids (TDS), total alkalinity as CaCO<sub>3</sub> (TA), total hardness as CaCO<sub>3</sub> (TH), chloride ion (Cl<sup>-</sup>), sodium (Na), calcium (Ca), magnesium (Mg) and nitrate as nitrogen (NO<sub>3</sub>-N) were analyzed. In addition to biological parameters such as biochemical oxygen demand (BOD) and chemical oxygen

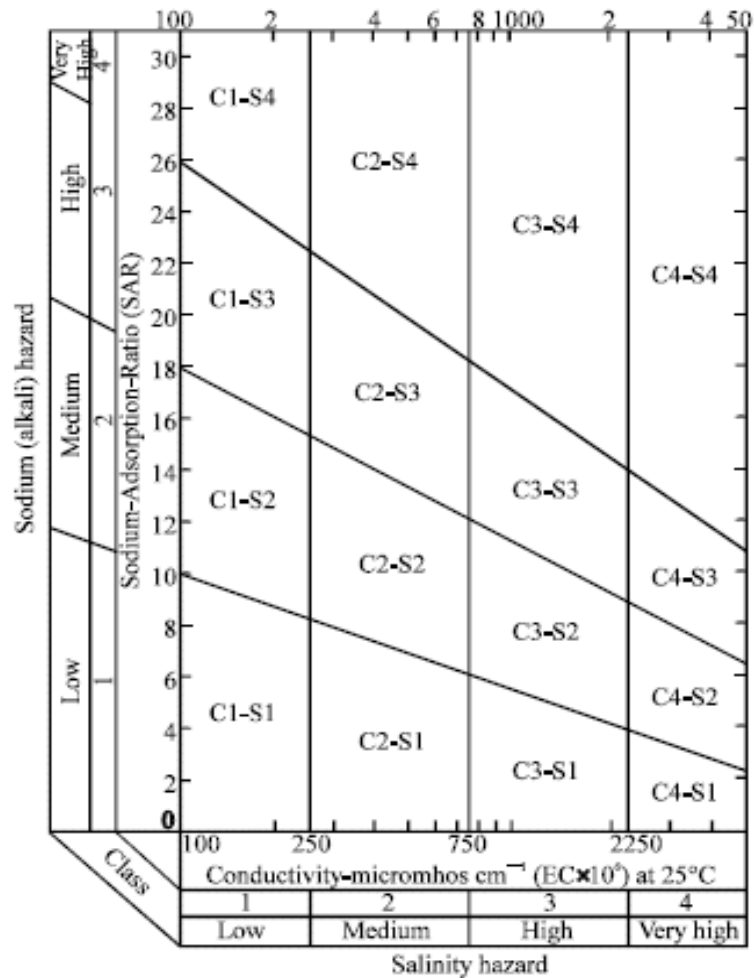
demand (COD) were analyzed. Some heavy metals such as lead (pb), iron (Fe) and zinc (Zn) were also analyzed for the first four months only.

Temperature was tested using a thermometer. The pH was measured using pH meter- Hanna instrument. Standard methods, were adopted for TSS analysis. TA, TH, Na, Ca, Mg and NO<sub>3</sub>-N were measured by laboratories in the College of Engineering, Diyala University using Photometer 7100, Wagtech, England [13]. Also, in same laboratories above, BOD and COD were measured using (Palintest Instructions). TDS, EC and Cl were measured using (Ion Selective 7320, WTW). Pb, Fe and Zn were measured using (ASC 7000).

The results of the analyses performed on Khirisan river were compared with Iraqi Standard NO. 417 for the year 2009 issued by the central Agency for standardization and the requirements of the US Environmental Protection Agency (USEPA) and its updates for 2018 [14,15]. For irrigation purposes, the values of the parameters which were adopted from this study and were compared to several categories, including the American Salinity Laboratory (Figure 2), Taylor and Ashcroft [16] and the rating of Todd [17] and Fipps [18]. Finally, the classification of American Society of Civil Engineers (ASCE) [19], lists irrigation water into four categories depending on the EC, SAR and ESP, along with Food and Agriculture Organization of the United Nations (FAO) regulations [20].



**Fig. 1.** Map of study sites for Khirisan river



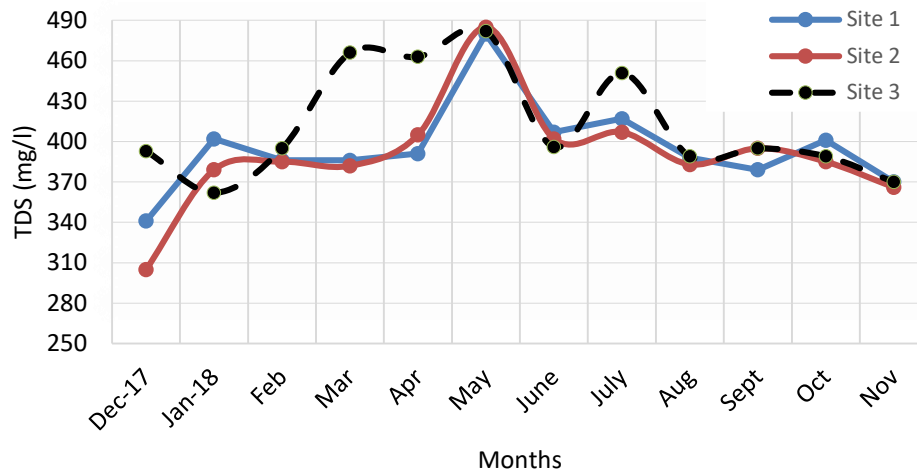
**Fig. 2.** U.S. Salinity Laboratory scheme for the classification of irrigation water

## 4. Results and Discussion

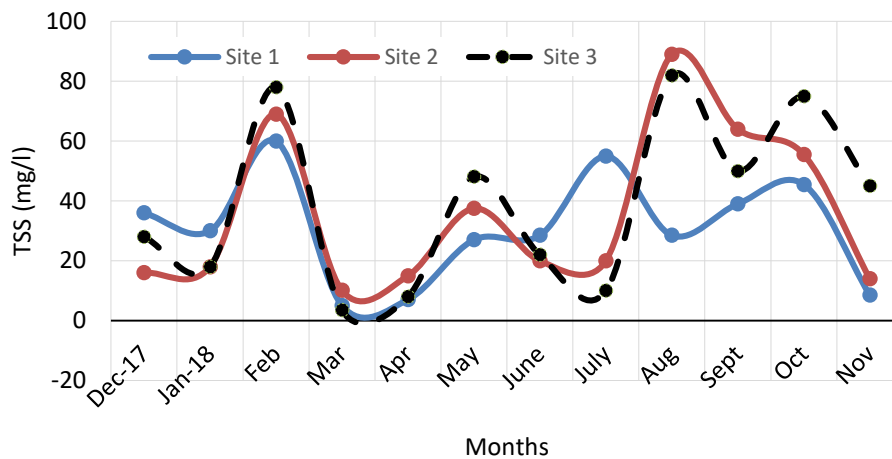
### 4.1 Suitability for Drinking Purposes

All pH values fall within the boundaries of the Iraqi and USEPA standards (6.5-8.5) except their value for October in the first site (8.75), where it has somewhat exceeded this standard as mentioned in Table 1. In general, the river water is relatively alkaline. Figure 3 and Figure 4 represent the values of TDS and TSS as a function of time. It's clear that the highest values of TDS were observed in dry seasons, especially in the downstream of river. This may be attributed to the increasing human activities, geologic formation that the river passes through and the high evaporation rate [21].

All values of TSS for site (1) are within the limits of the Iraqi standard (60 mg/l). It may be due to the presence of herbs and aquatic plants, whereas the river is not padded in this location, and the adsorption of the suspended materials was occurring. As for sites 2 and 3, some values exceed the limits of the standard; the highest values were shown in February and August 78 and 89 mg/l, respectively. This may be due to the river receiving quantities of water contaminated with washing and human activities from restaurants and cafeteria's [22]. Based on the average values of the TSS for three site 35.24 mg/l, the water quality which is located within the limits of the Iraqi standard, and has no limits within the USEPA standard.



**Fig. 3.** Values of TDS as a function of time of three adopted sites



**Fig. 4.** Values of TSS as a function of time of three adopted sites

**Table 1**

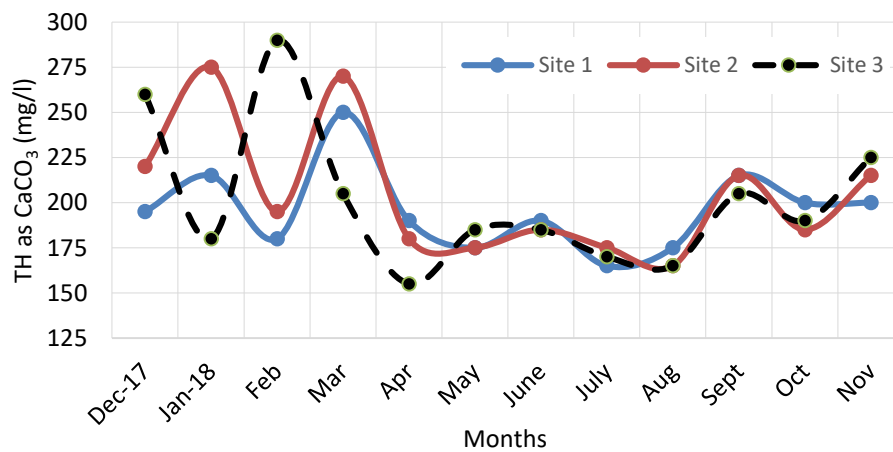
Max., min., mean and standard deviation (SD) values of pH, EC and TDS for three sites

| Parameters     | pH      |        |        | EC ( $\mu\text{S/cm}$ ) |        |        | TDS (mg/l) |        |        |
|----------------|---------|--------|--------|-------------------------|--------|--------|------------|--------|--------|
|                | Site 1  | Site 2 | Site 3 | Site 1                  | Site 2 | Site 3 | Site 1     | Site 2 | Site 3 |
| Locations      | Site 1  | Site 2 | Site 3 | Site 1                  | Site 2 | Site 3 | Site 1     | Site 2 | Site 3 |
| Max.           | 8.25    | 8.36   | 8.3    | 824                     | 831    | 872    | 480        | 485    | 482    |
| Mean           | 7.754   | 7.83   | 7.752  | 732.5                   | 710.67 | 761    | 398.67     | 389.91 | 412.58 |
| Min.           | 7.04    | 7.33   | 7.33   | 653                     | 610    | 450    | 341        | 305    | 362    |
| SD             | 0.485   | 0.260  | 0.281  | 64.21                   | 60.14  | 112.4  | 32.969     | 40.218 | 40.955 |
| Iraqi Standard | 6.5-8.5 |        |        | 1000                    |        |        | 1000       |        |        |
| USEPA Standard | 6.5-8.5 |        |        | 1000                    |        |        | 500        |        |        |

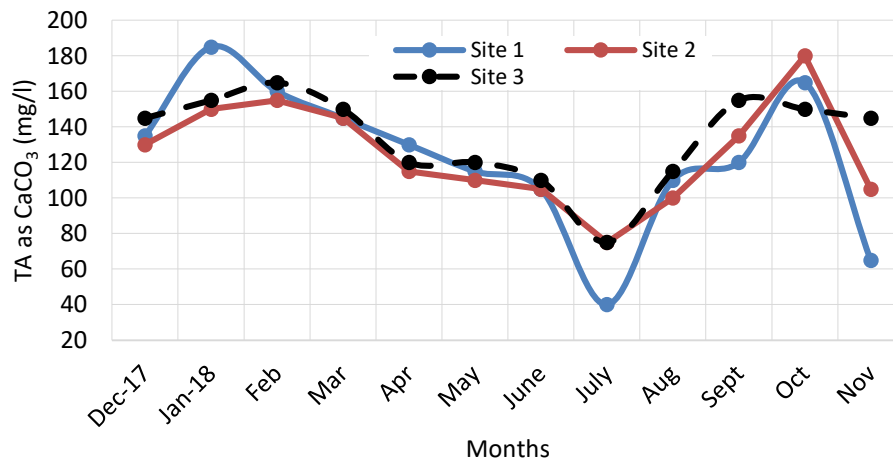
Figure 5 represents the Total Hardness (TH) as  $\text{CaCO}_3$  for the selected sites. These values ranged between 155 and 290 mg/l with average value of 200.5 mg/l for the three sites. It has seen that the TH at a highly fluctuation and maximum values in the rainy season, especially from January to mid-March. In contrast, this fluctuation disappears in dry seasons with lower concentration values. These observations may be due to the exposure of the Diyala river basin feeder of the Khirisan river to a high erosion of soil during rainy seasons and the increase of concentrations of calcium and

magnesium ions which causes causing hardness and these concentrations are reduced in the summer months. As displayed in Figure 5, all values are well below the limits of the Iraqi standard (500mg/l) and most of them are within the permissible limits according to the USEPA standard (250 mg/l).

Figure 6 shows the values of TA as CaCO<sub>3</sub> during the evaluation period. It is clear that the higher values of TA shown in wet seasons. Alkalinity in freshwater systems is derived from several sources: weathering of rocks and soil, exchange of reactions in soils, biological uptake and reduction of strong acid anions, evaporation and precipitation of minerals. In most systems, weathering is typically the dominant source of alkalinity for inland waters. This fact may explain the higher values of alkalinity for wet seasons as illustrated in Figure 6 [23]. There are no limits for TA in the Iraqi and USEPA standard.



**Fig. 5.** Values of TH as a function of time of three adopted sites



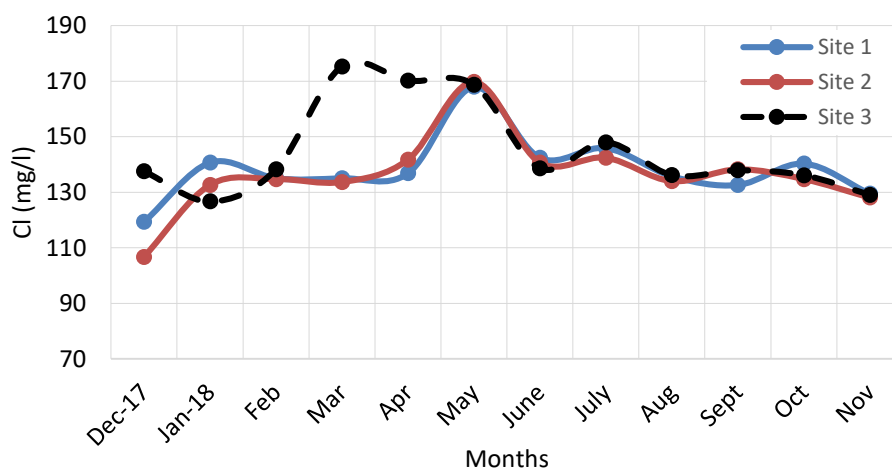
**Fig. 6.** Values of TA as a function of time of three adopted sites

Figure 7 represents the time variations of the chloride values during the year for the three sites. The chloride concentration recorded the highest in dry seasons for all sites and some of recorded values for site 3 in May and April. This could be as a result of untreated domestic waste and uncontrolled human activities from restaurants and cafeterias [24]. All chloride values of the three sites within the permissible limits of the Iraqi and USEPA standard, are estimated at 250 mg/l.

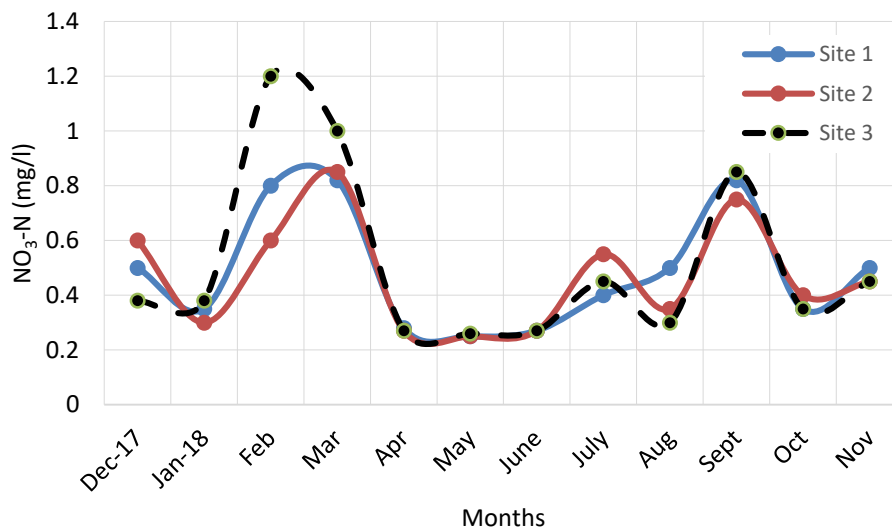
Figure 8 illustrates the values of nitrates as a function of time. It's shown that the higher value was recorded for February, 1.2mg/l at site 3. This finding may be due to the discharge of untreated domestic waste from some governmental buildings located near the water bodies. All other recorded

values of nitrate during the year for the three sites were below 1.0 mg/l. This fact is due to the uptake processes of microbial activity especially through dry seasons [25]. All nitrate values of the three sites within the limits of the Iraqi and USEPA standard are estimated at (10 mg/l), with no pollution due to nitrate.

Figure 9 and Table 2 illustrate the BOD<sub>5</sub> and COD values for the studied sites. The maximum values of BOD<sub>5</sub> and COD were 10.5 and 48.5 mg/l, recorded at the beginning and mid of dry seasons. The high level of BOD can be attributed to the discharge of organic wastes such as refuse, human and animal waste and detergents ejected directly into the water body which subsequently resulted into the uptake of oxygen through oxidation of these wastes [24,26]. The average values of BOD<sub>5</sub> and COD were 7.7 and 36 mg/l for the three sites. Depending on these values, the water quality does not satisfy the permissible limits of the Iraqi standard. This indicates that the occurrence of pollution is due to organic load.

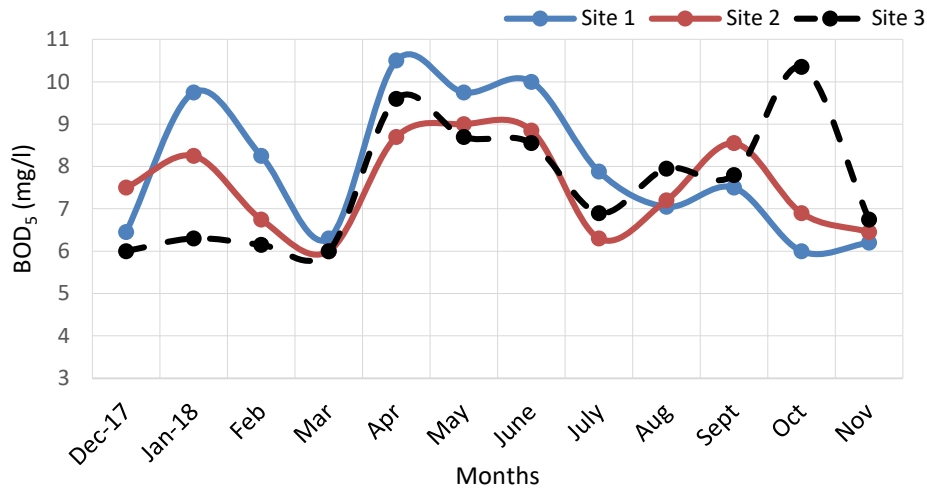


**Fig. 7.** Chloride value as a function of time of three adopted sites



**Fig. 8.** Nitrate value as a function of time of three adopted sites





**Fig. 9.** Value of BOD<sub>5</sub> as a function of time of three adopted sites

Table 3 shows the maximum, minimum, average and standard deviation (SD) of pb, Fe and Zn for the three sites. This table shows that all values for the three ions are within the limits of Iraqi Standard. All this ion values within the USEPA standard except for lead at first site, is almost zero with average value of (0.00025) mg/l. This indicates that there are no threats to health due to the tested heavy metals. Table 4 shows the maximum, minimum, average and standard deviation (SD) of sodium, calcium and magnesium for the three sites. It's clear from this table that both the sodium and magnesium ions are within the limits of Iraqi Standard. As for calcium ions, their value exceeds the limits of Iraqi Standard (50) mg/l. This may be due to the geological formation of land surrounding the river with a Limestone [27].

**Table 2**

Max., min., mean and SD values of EC and TSS for three sites

| Parameters     | BOD <sub>5</sub> (mg/l) |        |        | COD (mg/l) |        |        |
|----------------|-------------------------|--------|--------|------------|--------|--------|
|                | Site 1                  | Site 2 | Site 3 | Site 1     | Site 2 | Site 3 |
| Locations      | Site 1                  | Site 2 | Site 3 | Site 1     | Site 2 | Site 3 |
| Max.           | 10.5                    | 9      | 10.35  | 48.5       | 41.3   | 48.3   |
| Mean           | 7.97                    | 7.54   | 7.58   | 37.66      | 35.13  | 35.39  |
| Min.           | 6                       | 6      | 6      | 28.4       | 28     | 28     |
| SD             | 1.6549                  | 1.0857 | 1.4758 | 7.2054     | 4.8664 | 6.8559 |
| Iraqi Standard | <5                      |        |        | -          |        |        |
| USEPA Standard | -                       |        |        | -          |        |        |

**Table 3**

Max., min., mean and SD values of pb, Fe and Zn for three sites

| Parameters     | Pb (mg/l)   |        |        | Fe (mg/l) |         |        | Zn (mg/l) |        |        |
|----------------|-------------|--------|--------|-----------|---------|--------|-----------|--------|--------|
|                | Site 1      | Site 2 | Site 3 | Site 1    | Site 2  | Site 3 | Site 1    | Site 2 | Site 3 |
| Locations      | Site 1      | Site 2 | Site 3 | Site 1    | Site 2  | Site 3 | Site 1    | Site 2 | Site 3 |
| Max.           | 0.001       | 0      | 0      | 0.0121    | 0.0052  | 0.0069 | 0.0463    | 0.0354 | 2.258  |
| Mean           | 0.00025     | 0      | 0      | 0.00777   | 0.00415 | 0.0024 | 0.03055   | 0.0242 | 0.7838 |
| Min.           | 0           | 0      | 0      | 0         | 0.001   | 0      | 0.0203    | 0.011  | 0.0033 |
| SD             | 0.0005      | 0      | 0      | 0.0057    | 0.0021  | 0.0030 | 0.0117    | 0.0106 | 1.0042 |
| Iraqi Standard | 0.01        |        |        | 0.3       |         |        | 3         |        |        |
| USEPA Standard | Zero at tab |        |        | 0.3       |         |        | 5         |        |        |



**Table 4**  
 Max., min., mean and SD values of Na, Ca and Mg for three sites

| Parameters     | Na (mg/l) |        |        | Ca (mg/l) |        |        | Mg (mg/l) |        |        |
|----------------|-----------|--------|--------|-----------|--------|--------|-----------|--------|--------|
|                | Site 1    | Site 2 | Site 3 | Site 1    | Site 2 | Site 3 | Site 1    | Site 2 | Site 3 |
| Max.           | 140.35    | 134.75 | 136.15 | 115       | 115    | 175    | 31        | 28     | 41     |
| Mean           | 84.16     | 82.84  | 85.07  | 77.58     | 82.58  | 91.42  | 22.91     | 23.75  | 26.08  |
| Min.           | 68.2      | 61     | 72.4   | 52        | 62     | 56     | 11        | 18     | 21     |
| SD             | 3.736     | 3.439  | 3.714  | 17.53     | 15.927 | 17.349 | 5.401     | 3.018  | 6.156  |
| Iraqi standard | 200       |        |        | 50        |        |        | 50        |        |        |
| USEPA standard | 20        |        |        | -         |        |        | -         |        |        |

#### 4.2 Suitability for Irrigation Purposes

The parameters which define the water quality used for irrigation are the total concentration of salts in water, which could be measured by the TDS expressed in mg/l and the EC expressed in  $\mu\text{S}/\text{cm}$  at 25 °C. The Sodium Adsorption Ratio (SAR) and Exchangeable Sodium Percentage (ESP) which is calculated as

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

$$\text{ESP} = 100 * \frac{[-0.0126+0.01475*SAR]}{[1+(0.0126+0.01475*SAR)]} \quad (2)$$

##### 4.2.1 Risk of salinity

Table 1 shows that the average values of EC and TDS for the three sites were 734.7 $\mu\text{S}/\text{cm}$  and 400.34 mg/l, respectively. When comparing these results with the classification of US Salinity Laboratory, we note that the water quality of the Khirisan river falls within the class C2, medium salinity (EC, 250-750  $\mu\text{S}/\text{cm}$ ; TDS 160-480 mg/l). While, when comparing with the Tyler and Ashcroft classification, the water quality is classified as class A, little damage (EC<750; TDS<480). While when compared to the Todd and Fipps classification, the water quality is classified in a good class (EC, 250-750  $\mu\text{S}/\text{cm}$ ; TDS, 175-525 mg/l). Based on the foregoing, the water quality may be classified as a little to medium damage to the soil and plant.

##### 4.2.2 Risk of sodium

The sodium adsorption ratio (SAR) values ranged from 7.73 to 22.33 with average of 11.65 and the average value of EC was 734.7 $\mu\text{S}/\text{cm}$ , (Table 1 and Table 5). When these results are compared with the US Salinity Laboratory, we note that the water quality falls within the class medium- C2-S2 (SAR, 8-15 and EC, 250-750  $\mu\text{S}/\text{cm}$ ). While according to the Fipps classification, its falls under the category of medium damage (SAR 10-18). Finally, with the adoption the average values of EPS, 13.63 as mentioned in Table 5 and the average values of EC 734.7  $\mu\text{S}/\text{cm}$ , we find that the water quality falls within the class normal, no adverse effect on the growth and yield of crops, according to the ASCE. Depending on all the above classifications the water quality may be classified as a fair to medium damage as a sodium risk.

### 4.2.3 Risk of chloride

Table 5 shows the maximum, minimum, mean and SD values of chloride ions for the three sites. As noted in this table, the average values of chloride ions for the three sites were 138.48, 136.47 and 145.22 mg/l, respectively. When comparing the above values with the FAO regulations, we note that each of the two sites 1 and 2 falls within the first category (<142 mg/l, there are no problems). The average values of chloride ion for the third site was slightly higher than the value of the first category (145.22 mg/l), which put them within the second category (142-355 mg/l, and gradually increases the problem with the continued use of water). These results are due to the fact that the water quality of the river is deterioration towards the downstream. However, when comparing the average values of chloride ion for the three sites (140.05 mg/l) with the FAO regulations, we place the water quality within the first category, not causing toxicity problems to the roots of plants or their leaves.

**Table 5**

Max., min., mean and SD values of EC and TSS for three sites

| Parameters | SAR    |        |        | ESP    |        |        | Cl (mg/l) |        |        |
|------------|--------|--------|--------|--------|--------|--------|-----------|--------|--------|
|            | Site 1 | Site 2 | Site 3 | Site 1 | Site 2 | Site 3 | Site 1    | Site 2 | Site 3 |
| Locations  | Site 1 | Site 2 | Site 3 | Site 1 | Site 2 | Site 3 | Site 1    | Site 2 | Site 3 |
| Max.       | 22.331 | 18.423 | 20.41  | 24.058 | 20.58  | 22.38  | 145.95    | 169.75 | 327.6  |
| Mean       | 12.039 | 11.408 | 11.5   | 14.030 | 13.399 | 13.453 | 138.48    | 136.47 | 145.22 |
| Min.       | 9.281  | 8.714  | 7.73   | 11.055 | 10.389 | 9.4    | 119.35    | 106.75 | 71.15  |
| SD         | 3.38   | 2.42   | 3.23   | 3.34   | 2.52   | 6.79   | 11.54     | 14.07  | 16.67  |

## 5. Conclusions

Throughout this study, the researcher comes up with the following indications.

- i. Water quality of Khirisan river satisfies the Iraqi and international standards concerning drinking purposes for all studied parameters except the values of calcium ions and total hardness for some rainy months as well as to organic load.
- ii. High level of organic load was investigated which was attributed to the discharge of organic wastes such as refuse, human and animal waste and detergents ejected directly into the water body.
- iii. The average values of BOD<sub>5</sub> and COD were 7.7 and 36 mg/l for the three sites.
- iv. The uncontrolled discharge sewage from the adjacent restaurants, cafeterias and government buildings affects the water quality of Khirisan river.
- v. The water quality of Khirisan river is classified as a little to medium damage to the soil and plant according to the river salinity risk.
- vi. The water quality is classified as a fair to medium damage as a sodium risk.
- vii. The water quality within the first category as a chloride risk, does not cause toxicity problems to the roots and leaves of plants.
- viii. To improve water quality of Khirisan river requires a continual intensive water quality monitoring program.

## Acknowledgements

The researchers gratefully acknowledge the support provided by the local authority of Diyala Governorate and the Environment Administration of Diyala Province.

## References

- [1] Goudi, Andrew. *The Human Impact on the Natural Environment*. The MIT Press; Fifth edition edition, 2000.
- [2] Milovanovic, Mimoza. "Water quality assessment and determination of pollution sources along the Axios/Vardar River, Southeastern Europe." *Desalination* 213, no. 1-3 (2007): 159-173. <https://doi.org/10.1016/j.desal.2006.06.022>
- [3] Jalut, Qassem H. "Evaluation of water quality parameters of water supply stations in Babylon Governorate." *Journal of Babylon University* 3, no. 5 (1998).
- [4] Latiffi, Nur Atikah Ahmad, Radin Maya Saphira Radin Mohamed, Vicky Airama Shanmugan, Najeeha Mohd Apandi, Ramlah Mohd Tajuddin, and Amir Hashim Mohd Kassim. "Characteristics of Water Quality from Meat Processing Wastewater." *Journal of Advanced Research in Applied Sciences and Engineering Technology* 17, no. 1 (2019): 78-84.
- [5] Loukas, Athanasios. "Surface water quantity and quality assessment in Pinios River, Thessaly, Greece." *Desalination* 250, no. 1 (2010): 266-273. <https://doi.org/10.1016/j.desal.2009.09.043>
- [6] Psilovikos, A. R. "Trend Analysis of RE MO. S. Water Quality Electronic Data in Agiasma Lagoon-River Nestos Delta for the Years 2000-2002." In *Proceedings of the First Conference on Environmental Management, Engineering, Planning and Economics (CEMEPE)*, vol. 1, pp. 715-720. 2007.
- [7] Boyacioglu, Hülya. "Surface water quality assessment using factor analysis." *Water Sa* 32, no. 3 (2006): 389-393. <https://doi.org/10.4314/wsa.v32i3.5264>
- [8] Rawal, I., H. Joshi, and B. L. Chaudhary. "Water Quality Assessment Using Physicochemical and Bacteriological Parameters of Fateh Sagar Lake, Udaipur, India." *Water Resources* 45, no. 3 (2018): 427-435. <https://doi.org/10.1134/S0097807818030120>
- [9] Newton Moses, Sulaiman Mohammed, Haruna Saidu, Ahmed Ibrahim Galadima, Danladi Mohammed Umar, Kotos Abubakar, Mathias Kefas, and Cleophas Billah. "Determination of physicochemical parameters and riparian land effect on Kwadon stream." *Journal of Advanced Research Design* 36, no. 1 (2017): 13-24.
- [10] Mohamed, Ibrahim, Faridah Othman, Adriana IN Ibrahim, M. E. Alaa-Eldin, and Rossita M. Yunus. "Assessment of water quality parameters using multivariate analysis for Klang River basin, Malaysia." *Environmental Monitoring and Assessment* 187, no. 1 (2015): 4182. <https://doi.org/10.1007/s10661-014-4182-y>
- [11] Hafsi, R., L. Ouerdachi, A. E. O. Kriker, and H. Boutaghane. "Assessment of urbanization/impervious effects on water quality in the urban river Annaba (Eastern Algeria) using physicochemical parameters." *Water Science and Technology* 74, no. 9 (2016): 2051-2059. <https://doi.org/10.2166/wst.2016.350>
- [12] Purwati, Sri Unon, Nastiti Sih Lestari, and Eva Lindasari Nasution. "Water quality assessment of Cisadane River using pollution indicator parameters." In *IOP Conference Series: Earth and Environmental Science*, vol. 407, no. 1, p. 012009. IOP Publishing, 2019. <https://doi.org/10.1088/1755-1315/407/1/012009>
- [13] American Public Health Association, American Water Works Association, Water Pollution Control Federation, and Water Environment Federation. *Standard methods for the examination of water and wastewater. 21st edition*. American Public Health Association., 2005.
- [14] The Ministry of Planning and Development Cooperation / Central Agency for Standardization and Quality Control. *Iraqi Standard For Drinking Water No. 417*. 2009.
- [15] USEPA, United State Environmental Protection Agency. "Edition of Drinking Water Standards and Health Advisories Tables." U.S.A. (2018).
- [16] Taylor, S. T., and G. L. Ashcroft. "Physical Edaphology: the Physics of Irrigated and Nonirrigated Soils WH Freeman (San Francisco, CA)." *Physical Edaphology: The physics of irrigated and nonirrigated soils*. WH Freeman, San Francisco, CA. (1972).
- [17] Todd, D. K. *Groundwater Hydrology: Second Edition*. John Wiley and Sons Inc., N. Y., 1980.
- [18] Fipps, Guy. "Irrigation water quality standards and salinity management strategies." *Texas FARMER Collection* (2003).
- [19] Wu, Laosheng, Christopher Amrhein, and James D. Oster. "Salinity assessment of irrigation water using WATSUIT." In *Agricultural Salinity Assessment and Management*, pp. 787-800. 2012. <https://doi.org/10.1061/9780784411698.ch25>
- [20] Ayers, Robert S., and Dennis W. Westcot. *Water quality for agriculture. Vol. 29*. Rome: Food and Agriculture Organization of the United Nations, 1985.
- [21] Tiwari, Seema. "Water quality parameters - A review." *International Journal of Engineering Science Invention Research and Development* 1, no. 9 (2015): 319 - 324.
- [22] Roy, K., S. Akter, and M. Islam. "Assessment of Supplied Water Quality of Rajshahi Wasa (RWASA) in Bangladesh." In *Proceedings of the 4th International Conference on Civil Engineering for Sustainable Development (ICCESD 2018)*, KUET, Khulna, Bangladesh. 2018.

- 
- [23] Muralikrishna, Iyyanki V., and Valli Manickam. *Environmental Management: CHAPTER EIGHTEEN*. Elsevier Inc., 2017.
- [24] Fashae, Olutoyin Adeola, Hannah Abiola Ayorinde, Adeyemi Oludapo Olusola, and Rotimi Oluseyi Obateru. "Landuse and surface water quality in an emerging urban city." *Applied Water Science* 9, no. 2 (2019): 25. <https://doi.org/10.1007/s13201-019-0903-2>
- [25] Al-Ani, R. R., A. M. J. Al Obaidy, and F. M. Hassan. "Multivariate Analysis for Evaluation the Water Quality of Tigris River Within Baghdad City in Iraq." *The Iraqi Journal of Agricultural Science* 50, no. 1 (2019): 331-342.
- [26] Begum, Abida, and Harikrishnarai. "Study on the Quality of Water in Some Streams of Cauvery River." *Journal of Chemistry* 5, no. 2: 377-384. <https://doi.org/10.1155/2008/234563>
- [27] Mallick, Javed. "Hydrogeochemical characteristics and assessment of water quality in the Al-Saad Lake, Abha Saudi Arabia." *Applied Water Science* 7, no. 6 (2017): 2869-2882. <https://doi.org/10.1007/s13201-017-0553-1>