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# Evaluation water quality of Diyala River in Iraq using Bhargava method

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**Abstract**. Diyala River is a tributary of Tigris River, it is one of the important rivers in Iraq. It covers a total distance of 445 km (275 miles). 32600 km$^2$ is the area that drains by Diyala River between Iraqi-Iranian borders. This research aims to evaluate the water quality index WQI of Diyala River, where three stations were chosen along the river. These stations are D12 at Jalawlaa City at the beginning of Diyala River, the second station is D15 at Baaquba City at the mid distance of the river, and the third station is D17 which is the last station before the confluence of Diyala River with Tigris River at Baghdad city. Bhargava method was used in order to evaluate the water quality index for both irrigation and drinking uses. The results indicated that Diyala river water quality at its beginning was excellent for irrigation and good for drinking, while at the mid distance of the river, it was good for irrigation but heavily polluted and unsafe for drinking. Water quality of the river at the third site was acceptable for irrigation but again severely polluted and unsafe for drinking.

## 1 Introduction

Diyala River is one of the important water resources and one of the main tributaries of Tigris River in Iraq. It covers a total distance of 445 km Diyala weir controls the river floods and irrigates the area northeast of Baghdad. Diyala city depends mainly on Diyala River for water supply for domestic, municipal, agriculture and other purposes. **[1]**. Many towns are located on the river banks. Wastes from agricultural and industrial activities in these towns are drained straightway to the river. The river covers an area of 32600 km$^2$ . The river catchment is widely varied through the entire catchments area from semi-arid plain north of Baghdad to mountainous area of western Iran [2]. The catchments of this river are divided into four parts; the first part is above Derbendikhan, the second part is Upper Diyala, the third part is Middle Diyala and the fourth part is down Diyala, each of these parts has different characteristics and different contribution to the main river flow. From the geological point of view, river catchments have different geological units. Down Diyala is covered mainly by recent alluvium and lies within the unfolded zone **[3].** Derbendikhan and Hemrin are two dams constructed on the river, (360 and 188 km upstream the confluence with the Tigris River south Baghdad respectively. In addition to the two dams, the Diyala wier was constructed on the river (11 km downstream from Hemrin Dam) and it distributes the outflow of Hemrin reservoir to the Lower Diyala River and the irrigation canals (Al-Khalis canal and Sadr Al-Mushtarak). **[4].**

A research on Evaluation of Water Quality of Diyala River For Irrigation Purposes , comprised suitability evaluation of water quality of Diyala River for irrigation. The researcher depends on four stations along Diyala River which are Jalawlah station (DI2) before Jalawlah Bridge, Saadiyah station (DI3) before inter to Hamren Dam, Muqdadia station (DI4) after Diyala Dam, and Baqubah station (DI5) at Iron Bridge, besides wand river station in Khanaqin (DIW) Before Dam. The parameters studied were pH, electric conductivity (EC), TDS, $Na^+$, $K^+$, $Ca^{+2}$, $Mg^{+2}$, $HCO^{-3}$, $CO_3^{-2}$, $SO_4^{-2}$, $Cl^-$, and $NO_3$. The study were done during January to December 2010, the study showed that water samples of DIW and DI5 fall in the class of high salinity with low sodium water, which can be used for irrigation on almost all types of soil, while water samples of other stations fall in the class of medium salinity with low sodium water, which can be suitable to salt tolerant plants with probability developed permeability. The results of this study revealed that the quality of Diyala River water can be classified as suitable for irrigation with few exceptions[1].

Suspended and Solute Loads on the Lower Diyala River is a research done on Suspended sediment and solute loads associated with the Lower Diyala River were evaluated for the period from June 1984 to May 1985. During the studied period the mean discharge reached 128 cumecs and the maximum and minimum were 505 and 1.72 cumecs respectively. The annual suspended load reached 64589 tonnes. The rate of transport was not uniform throughout the studied period, where most of the load (51.02 percent of the suspended load and 54.68 percent of the solute load) was transported during the Winter [4].

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**A** research dealing with the Heavy Metals in Diyala River**,** aimed to investigate the status of Diyala River water quality in Iraq with respect to the concentrations of its heavy metals by preparing the heavy metal pollution index. The locations selected were along of Diyala River, from Kalar district to the meeting with Tigris River. The study indicates that Diyala River is polluted with heavy metals. The study showed the impact of anthropogenic sources on the pollution load of the river water. [5]

A research on Spectral Analysis of Some Selected Hydrochemical Parameters of Diyala River In Iraq , has Some hydrochemical variables of Diyala River to analyze their periodicities quantify and qualify surface water and investigate the behavior of these variables.

The results appeared the variation of the factors affecting the water quality of the river in both hydrological and meteorological conditions also the impact of human activities through the area of the river basin **[3].**

Bhargava in 1983 studied WQI to evaluate the water quality for several activities in Ganga River in India and Saigon River in Vietnam using the sensitivity function method. The method transfers the values of variables according to a standard specification (0 – 1) scale. The WQI was used to classify rivers into five groups of different water activities depending on the variables which affected the WQI.

Bhargava 1983 studied the potable Water Quality Index(PWQI ) using the sensitivity function which were represented as a curve showing that the ratio of pollutant concentration to the maximum permissible concentration level had the range of (0 – 1). He divided the variables into four groups as: biological, heavy metals, physical and organic and non- organic variables. He suggested that, for potable water supply, the WQI should be greater than 90.

Bhargava Method is one of the modern methods which is used in many countries, and it is easy for dealing with parameters for different uses by sensitivity functions curves which take the value between zero to one. The results are accumulated using the geometric mean.

## 2 Area of study

Diyala River is one of the main water resources of Iraq and one of the most important tributaries of Tigris River in Iraq. The river passes through Diyala province northeast of Baghdad as shown in Figure 1. It covers a total distance of 445 km (275 miles). The catchment of Diyala River is located between Latitude (33° 13′00" N-35° 50′ 00" N) and Longitude (44° 30′ 00" E- 44° 50′ 00" E),

Many towns are situated on its banks, agricultural and industrial wastes are discharged in to Diyala river. The river drains 32600 km$^2$ of the area between Iraqi-Iranian borders . North of Baghdad the catchment is varied from semi-arid plain while mountainous area at western Iran **[2]**.

## 3 Methods and calculations

In this research, Diyala River was studied for the period 2011-2016.Three stations were chosen in order to evaluate the Water Quality Index of Diyala River. The first station was D12 which is at Jalawlaa City at the beginning of the river after the Iraqi-Iranian borders. The second station was D15 at Baquba City in the middle of the river, while the third station was D17 south of Baghdad City before the confluence of Diyala River with Tigris River. The data were collected from the Operation Department [6].

For calculating the Water Quality Index (WQI), Bhargava method was used to evaluate Diyala River for irrigation and drinking uses.

The sensitivity functions can be calculated by the impact of the parameter value on water quality as in Figs 2, 3.

The sensitivity functions curves are used to evaluate the quality of river water. For instance, when the concentration of sulfate ($SO_4^{-2}$) is 400 ppm, the s nsitivity function will be very low which makes water worse for drinking use, while the same concentration value can give sensitivity function equal to 0.6 for irrigation use which means it is acceptable 60%. **[7]**

The relative parameters for irrigation use are: TDS, pH, $SO_4^{-2}$, SAR, EC, and $Cl^{-1}$, while the relative parameters of drinking use are TDS, T.H, $Cl^{-1}$, $SO_4^{-2}$, BOD, pH, and $Ca^{+2}$. Finally; the relative parameters for industrial use are EC, T.H, and Tu.

This index is suitable for classifying rivers into five classes as shown inTable 1 and to determine the WQI for each use of different water uses depending on the variables which affect that use by geometric mean formula.

The geometric mean formula is shown below:

$$WQI = \left[\pi_{i=1}^{n} fi\left(P_i\right)\right]^{1/n} \quad *100 \qquad \ldots\ldots\ldots\ldots 1$$

Where:

$f_i$ ($P_i$) is the sensitivity function for each variable including the effect of variable weight concentration which is related to a certain activity and varies from (0 – 1]. **[7]**

## 4 Results and discussion

After applying the Bhargava Method for the period from 2011 to 2016, the results indicated that the first station D12 which is at Jalawlaa city after the Iraqi-Iranian borders has an excellent water quality for irrigation and good water quality for drinking as shown in Table 2 and Table3. The second station D15 which is at mid distance of Diyala River in Baquba city, the results indicated that the river has good water quality for irrigation but severely polluted water for drinking as shown in Table 4 and Table 5. D17 the last station , located at Baghdad city before the meeting of Diyala River with Tigris River, the Tables 6 and 7 indicated that the river has acceptable water quality for irrigation but severely polluted water for drinking.

Figures 4,5,6 show that the river is suitable for irrigation but unsuitable for drinking except for station D12 in Jalawlaa City. Figure 7 shows that the variation of WQI with respect to time for the three stations for irrigation uses, it is clear that the best station is D12 then D15 and D17 Figure 8 showes the variation of WQI with respect to time for the three stations for drinking uses, it is clear that only station D12 is suitable for drinking uses, and that is because of the high values of BOD concentration that was discharged to Diyala River from the mid distance of river at Baquba city until its end at Baghdad city. The zero values for the WQI shown in Tables 5 and 7 refer to the parameters concentrations were out of the range suggested by Bhargava. In other words the parameters concentration exceeded the permissible limits that were used in this method.

## 5 Conclusions

From this research we can conclude that:
1- The first station at Jalawlaa city after the Iraqi-Iranian borders has excellent water quality for irrigation and good water quality for drinking, because it is the nearest point to the river origin and few population beside it.
2-The second station at the mid distance of Diyala River in Baquba city, has good water quality for irrigation but severely polluted water for drinking, this city considered as Diyala province center and many agricultural and industrial wastes discharged directly to the river.
3-The last station located at Baghdad city before the meeting of Diyala River with Tigris River, the river has acceptable water quality for irrigation but severely polluted water for drinking, we can conclude that the river is heavy polluted with various wastes and high concentration of BOD values affected on river water quality.
4-The heavy population and uncontrolled discharging wastes to the river affected the river water quality.

## 6 References

**1**. Hamza, Nahida H, Evaluation Of Water Quality Of Diyala River For Irrigation Purposes, Diyala Journal of Engineering Sciences, Vol. 05, No. 02, pp. 82-98 , December 2012, Iraq.(2012)

**2.** Al-Ansari, N. and Al-Jabbari, M, Hemrin reservoir, geological and hydrological investigation, J. of Water Res., Special Publ. No. 2, Sector 2, (1987).

**3.** Aqeel et al., S, Qusay A. Al-Suhail, Spectral Analysis of Some Selected Hydrochemical Parameters of Diyala River In Iraq , Fourteenth International Water Technology Conference, IWTC14 2010 Cairo, Egypt, (2010)

**4.** Al-Ansari, et al., Suspended and Solute Loads on the Lower Diyala River , Lulea University of Technology, (2014)https://www.researchgate.net/publication/253518411.

**5.** Abdullah, Enaam, Evaluation of Surface Water Quality Indices for Heavy Metals of Diyala River-Iraq, Journal of Natural Sciences Research,ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online), Vol.3, No.8, Iraq.(2013)

**6.** Documented data, Operation department, Water Resources Ministry, Baghdad, Iraq.(2016)

**7.** Bhargava, D. S., Use of a water quality index for river classification and zoning of the Ganga River. *Environmental Pollution*, B6, 51–67.(1983)

**Table 1.** Bhargava classification for Water quality

| A. *Class* | B. *WQI Value* | C. *Water Quality* |
|---|---|---|
| I | 100 – 90 | Excellent |
| II | 89 – 65 | Good |
| III | 64 – 35 | Acceptable |
| V | 34 – 11 | Polluted |
| IV | Less than 10 | Severe Polluted |


Fig. 1. Diyala River map

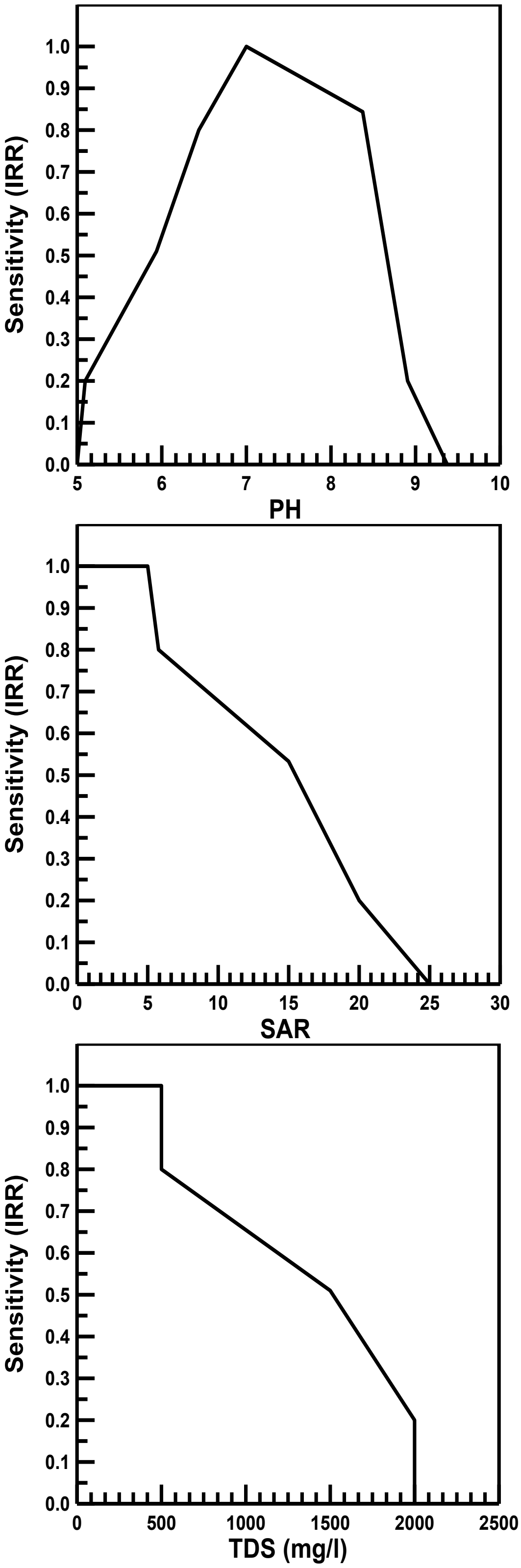


**Figure 2** Sensitivity functions curves according to Bhargava for irrigation use

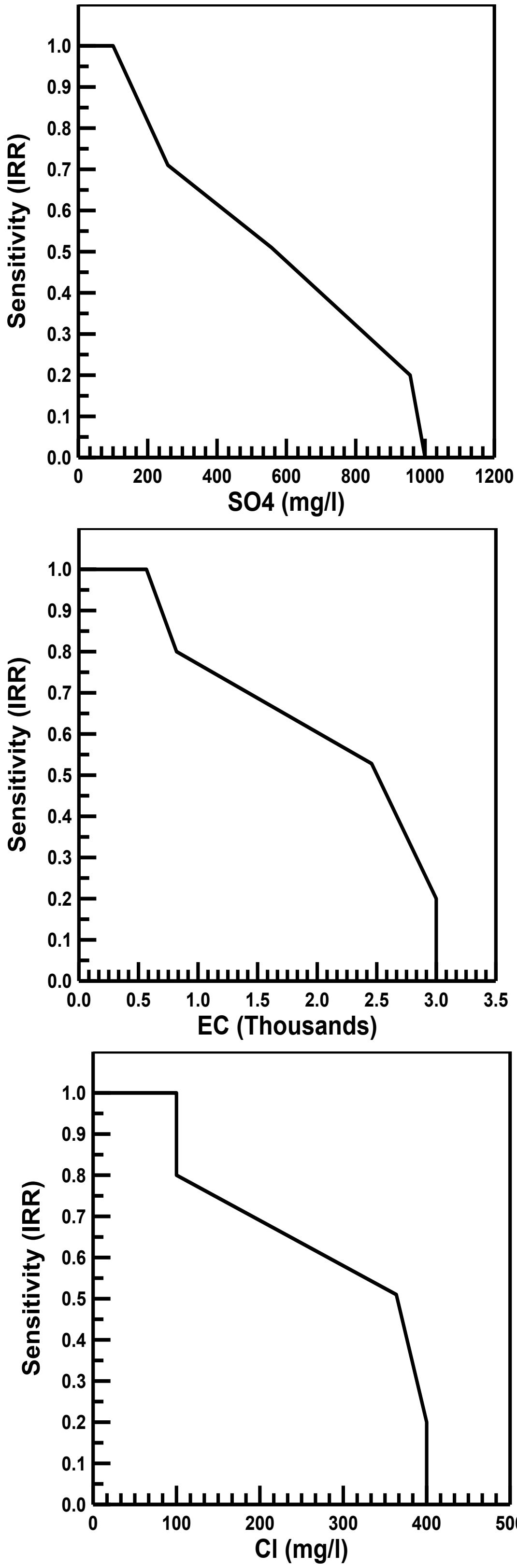


**Figure 2** Sensitivity functions curves according to Bhargava for irrigation use continued

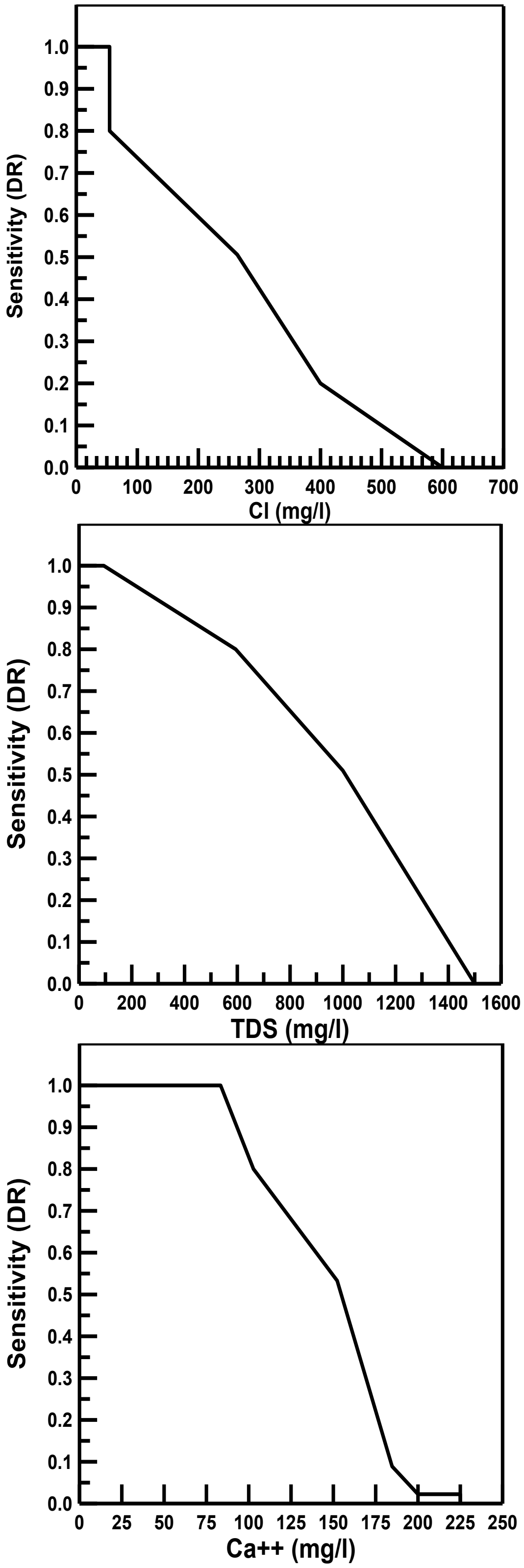


Figure 3 Sensitivity functions curves according to Bhargava for drinking use

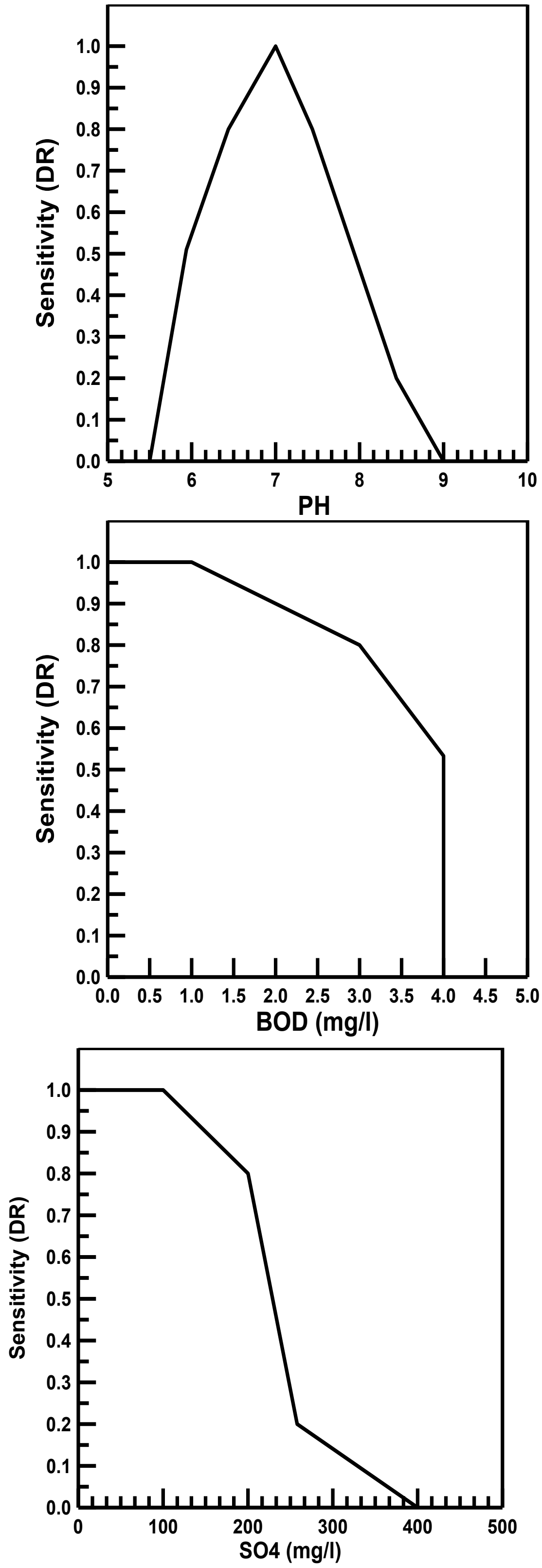


Figure 3 Sensitivity functions curves according to Bhargava for drinking use continued

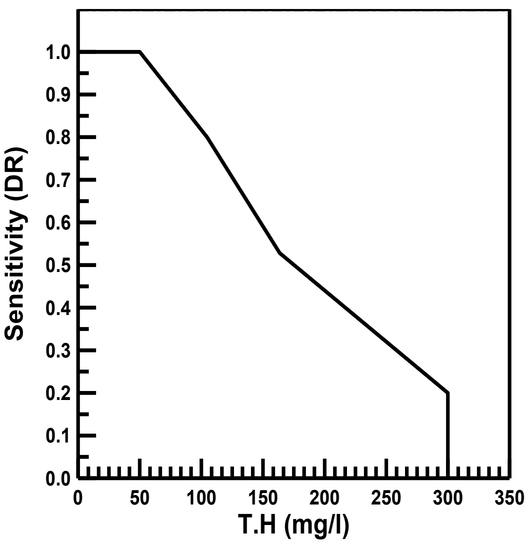


Figure 3 Sensitivity functions curves according to Bhargava for drinking use continued

**Table 2** The relative sensitivity functions for the parameters of irrigation uses for station D12

| Year | SAR | EC | TDS | Cl | pH | SO4 | WQI | Class |
|---|---|---|---|---|---|---|---|---|
| 2011 | 1 | 1 | 1 | 1 | 0.95 | 1 | 99.15 | 1 |
| 2012 | 1 | 1 | 1 | 1 | 0.94 | 1 | 98.98 | 1 |
| 2013 | 1 | 1 | 1 | 1 | 0.9 | 1 | 98.27 | 1 |
| 2014 | 1 | 0.95 | 1 | 1 | 0.9 | 0.9 | 95.74 | 1 |
| 2015 | 1 | 1 | 1 | 0.761 | 1 | 1 | 95.55 | 1 |
| 2016 | 1 | 1 | 1 | 1 | 1 | 0.733 | 94.95 | 1 |

**Table 3** The relative sensitivity functions for the parameters of drinking uses for station D12

| Year | Ph | TH | TDS | Ca | Cl | SO4 | BOD | WQI | Class |
|---|---|---|---|---|---|---|---|---|---|
| 2011 | 0.89 | 0.24 | 0.9 | 1 | 1 | 0.85 | 0.53 | 70.48 | 2 |
| 2012 | 0.75 | 0.4 | 0.9 | 1 | 1 | 1 | 0.55 | 76.13 | 2 |
| 2013 | 0.75 | 0.4 | 0.9 | 1 | 1 | 0.95 | 0.54 | 75.38 | 2 |
| 2014 | 0.7 | 0.3 | 0.94 | 1 | 1 | 0.9 | 0.56 | 71.89 | 2 |
| 2015 | 0.79 | 0.3 | 0.9 | 1 | 1 | 0.9 | 0.55 | 72.66 | 2 |
| 2016 | 0.88 | 0.23 | 0.9 | 1 | 1 | 0.9 | 0.54 | 70.87 | 2 |

**Table 4** The relative sensitivity functions for the parameters of irrigation uses for station D15

| Year | SAR | EC | TDS | Cl | pH | SO4 | WQI | Clas s |
|---|---|---|---|---|---|---|---|---|
| 2011 | 1 | 0.7 | 0.75 | 0.8 | 0.94 | 0.9 | 84.17 | 2 |
| 2012 | 1 | 0.68 | 0.69 | 0.7 | 0.94 | 0.69 | 77.29 | 2 |
| 2013 | 0.79 | 0.73 | 0.69 | 0.69 | 0.95 | 0.68 | 74.79 | 2 |
| 2014 | 0.78 | 0.7 | 0.68 | 0.72 | 0.94 | 0.67 | 74.32 | 2 |
| 2015 | 0.65 | 0.65 | 0.65 | 0.69 | 0.95 | 0.6 | 69.02 | 2 |
| 2016 | 0.65 | 0.59 | 0 | 0.61 | 0.94 | 0.59 | 68.97 | 2 |

**Table 5** The relative sensitivity functions for the parameters of drinking uses for station D15

| Year | pH | TH | TDS | Ca | Cl | SO4 | BOD | WQI | Class |
|---|---|---|---|---|---|---|---|---|---|
| 2011 | 0.7 | 0 | 0.71 | 0.58 | 0.79 | 0.88 | 0 | 0 | 5 |
| 2012 | 0.7 | 0 | 0.55 | 0.49 | 0.78 | 0.2 | 0 | 0 | 5 |
| 2013 | 0.75 | 0 | 0.54 | 0.49 | 0.6 | 0.09 | 0 | 0 | 5 |
| 2014 | 0.7 | 0 | 0.56 | 0.49 | 0.78 | 0.09 | 0 | 0 | 5 |
| 2015 | 0.75 | 0 | 0.35 | 0.45 | 0.78 | 0 | 0 | 0 | 5 |
| 2016 | 0.75 | 0 | 0 | 0.1 | 0.5 | 0 | 0 | 0 | 5 |

**Table 6** The relative sensitivity functions for the parameters of irrigation uses for station D17

| Year | SAR | EC | TDS | Cl | pH | SO4 | WQI | Class |
|---|---|---|---|---|---|---|---|---|
| 2011 | 0.25 | 0.28 | 0.24 | 0.55 | 0.95 | 0.45 | 39.68 | 3 |
| 2012 | 0.25 | 0.29 | 0.25 | 0.54 | 0.95 | 0.39 | 39.21 | 3 |
| 2013 | 0.46 | 0.29 | 0.3 | 0.54 | 0.94 | 0.44 | 45.57 | 3 |
| 2014 | 0.45 | 0.5 | 0.6 | 0.56 | 0.95 | 0.43 | 56.03 | 3 |
| 2015 | 0.2 | 0.56 | 0.62 | 0.63 | 0.94 | 0.43 | 51.05 | 3 |
| 2016 | 0.55 | 0.6 | 0.64 | 0.71 | 0.9 | 0.45 | 62.71 | 3 |

**Table 7** The relative sensitivity functions for the parameters of drinking uses for station D17

| Year | pH | TH | TDS | Ca | Cl | SO4 | BOD | WQI | Class |
|---|---|---|---|---|---|---|---|---|---|
| 2011 | 0.8 | 0 | 0 | 0.58 | 0.33 | 0 | 0 | 0 | 5 |
| 2012 | 0.8 | 0 | 0 | 0.34 | 0.31 | 0 | 0 | 0 | 5 |
| 2013 | 0.75 | 0 | 0 | 0.36 | 0.31 | 0 | 0 | 0 | 5 |
| 2014 | 0.8 | 0 | 0 | 0.44 | 0.41 | 0 | 0 | 0 | 5 |
| 2015 | 0.75 | 0 | 0 | 0.05 | 0.15 | 0 | 0 | 0 | 5 |
| 2016 | 0.65 | 0 | 0.24 | 0.58 | 0.63 | 0 | 0 | 0 | 5 |

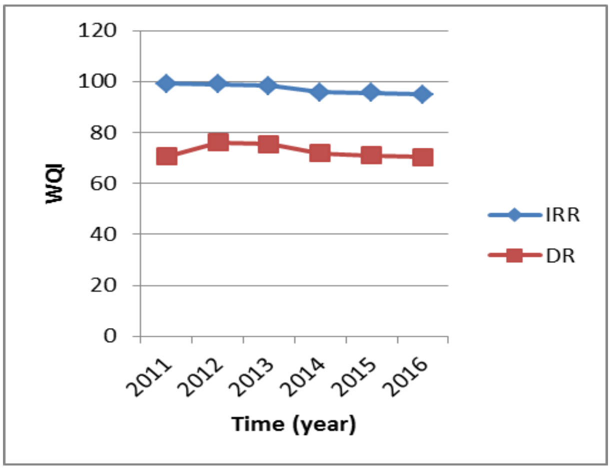


**Figure 4** Variation of WQI with respect to time for both irrigation and drinking uses for station D12

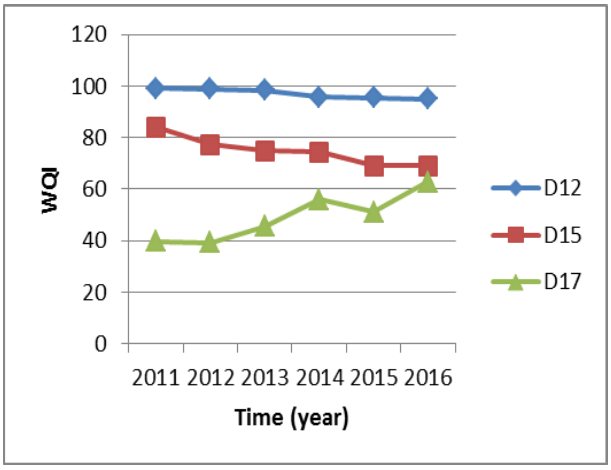


**Figure 7** Variation of WQI with respect to time for irrigation uses for the three stations

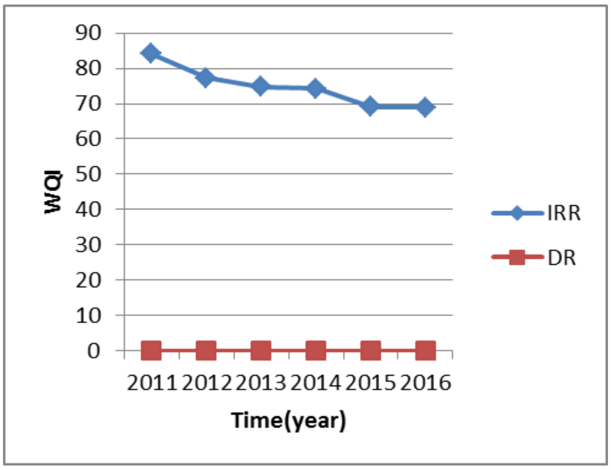


**Figure 5** Variation of WQI with respect to time for both irrigation and drinking uses for station D15

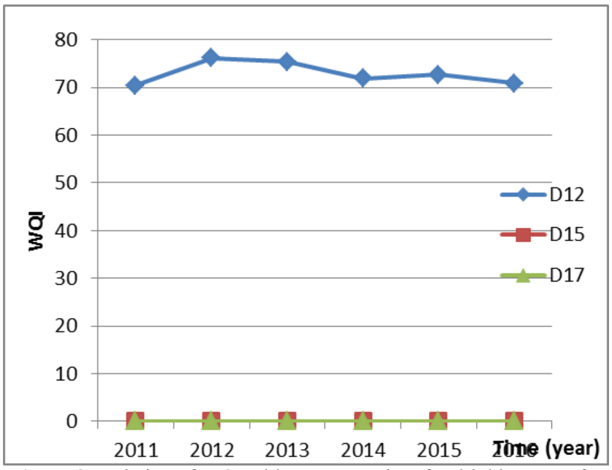


**Figure 8** Variation of WQI with respect to time for drinking uses for the three stations

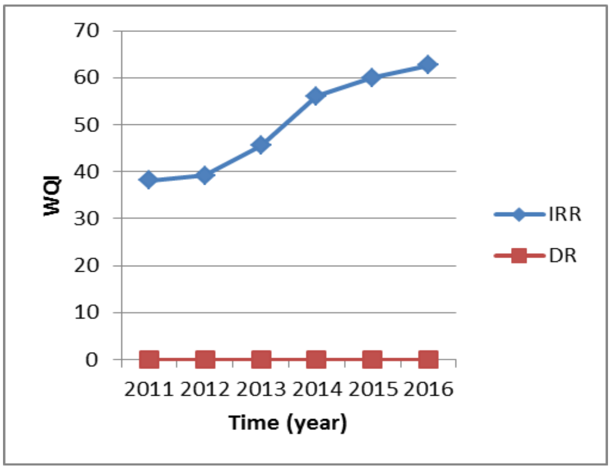


**Figure 6** Variation of WQI with respect to time for both irrigation and drinking uses for station D17