Assessment of water quality and water suitability of Al-Dujaila Channel Project-Kut (Southeastern Iraq)

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Abstract. The study area is located in the central part of Iraq in Wasit Governorate. In this study, an attempt was made to eliminate the validity of Al-Dujaila Channel Project water for human consumption by using the National Sanitation Foundation Water Quality index (NSFWQI). Where water quality for human consumption was found to range from poor to medium. The values of sodium percentage ratio for two periods range between 28-34.4, with respect to the RSC value Almost 100% of the samples indication negative values, which indicated that dissolved Ca2+ and Mg2+ concentrations were higher than HCO3- content. However, all samples are safe for irrigation purposes where the RSC values were less than 1 meq/l. According to Killy ratio all the samples are save for irrigation.

Keywords: Al-Dujaila Channel Project, Water Quality Index, Sodium Percentage Ratio, Magnesium Hazard, Residual Sodium Carbonate, Kelly’s Ratio

1. Introduction:

Water is the most vital element among natural resources, and is vital to the survival of all living organism including human, food production and economic development. Today, many cities around the world face a severe shortage of water quantity and quality, and about 40 per cent of the world’s food supply depends on direct irrigation and a wide variety of water-based industrial processes. Environment, economic growth and developments are all highly vulnerable to water - regional and seasonal availability, and surface - groundwater quality. Water quality is usually affected by human activities and decline due to the large expansion of cities, population and industrial growth, climate change and other factors. Water pollution is a serious threat to the safety of both land and its inhabitants.

Mesopotamia is most often a daltian land, created and developed by the Tigris and Euphrates Rivers [1]. The southern part of Mesopotamia depends on the waters of these two rivers permanently, through their own water flows for different uses. River pollution has become a major problem that has become critical due to insufficient protect the quality of surface water as a result of untreated wastewater. The rivers and streams have become the real banks and sinks for these wastes. Waste is often discharged into rivers with little regard for their capacity. The discharge of raw sewage, garbage, and oil spills pose a threat to the destruction of rivers' natural self-purification of polluted materials, while heavily polluted water may travel long distances in days before it is high of purification has achieved [2 and3].

Water pollution threatens food security and worsens both environmental health and public health [4]. However, the specific objectives of the study are as follows:

1. To show differences in water quality along the river for the two seasons (dry and wet) through National Sanitation Foundation Water Quality index (NSFWQI);
2. The validity of its water for different purposes

2.1. Location of Study area

The study area is located in the central part of Iraq in Wasit Governorate, the geographical position lies between latitude (32° 30'-32° 10') N and longitude (45° 50'-46° 27') E, (Fig. 1).

![Figure 1: studied area(S= water sample station)](image)

2.2: Geology of the studied area:

The deposition of the Mesopotamian basin and the surrounding nearby areas can be divided into three main stratigraphic units [5]:

1. Pliocene-Early Pleistocene Units:
   1.1 Bai Hassan Formation
   Which consists of succession of conglomerate, pebbly sandstone, siltstone and mudstone.
   1.2. Dibdibba Formation
   1.3. Mahmudiya Formation

2. Pleistocene Sediments

This period is characterized by stratigraphy from Fluvial to Inter-pluvial and this corresponds to the period characterized by the existence of a global glacial age close to the tectonic activates. This divided into:

2.1. Pleistocene Sediments of the Mesopotamia Fluvial Basin
3. Pleistocene-Holocene Sequence

The sequence comprise of fluvial, deluvio-fluvial evaporatic.

4. Holocene Sequence

The sediments of this period cover most of the basin of Mesopotamia. The upper sequence represents the column of the stratum which is between 15-20 m thicknesses of the quaternary deposits. The sediments of this age are characterized by sequences of fluvial, deltic, lacustrine, and estuarine/marine units.
3. Materials and methods
For the purpose of studying the chemical and physical components of the project water, seven sites were selected for the purpose of water sampling, where acidity, conductivity and dissolved oxygen were measured directly in the field. Water samples For the purpose of determining the concentrations of major ions, they were sent to the General Commission of Groundwater laboratories. The analyses were carried out according to APHA [6] standard methods.

4. Result and discussion
The concentrations of major ions as well as concentrations of phosphate ions can be found in Table 1 and 2, while the biological oxygen demand (BOD) and the number of Fecal Coliform can be verified by (Table 3).

### Table 1: Physical and major chemical cations and anions parameters for Dujaila River during August, 2018.

| No | pH | EC (Ω·m) | TDS (mg/L) | Ca$^{2+}$ | Mg$^{2+}$ | K$^+$ | Na$^+$ | SO$_4^{2-}$ | Cl$^-$ | HCO$_3^-$ | NO$_3^-$ |
|----|----|----------|------------|-----------|-----------|-------|-------|------------|-------|-----------|-----------|
| S.1 | 7.8 | 1000 | 670 | 101 | 22 | 3 | 70 | 212 | 84 | 168 | 3.7 |
| S.2 | 7.9 | 1003 | 685 | 88 | 27 | 3.9 | 81 | 219.9 | 95 | 156 | 5.4 |
| S.3 | 7.7 | 1009 | 690 | 92 | 27 | 3.7 | 80 | 214 | 96 | 170 | 3.5 |
| S.4 | 7.0 | 1008 | 680 | 94 | 25 | 3.6 | 76 | 212 | 90 | 169 | 3 |
| S.5 | 7.0 | 1006 | 675 | 93 | 23 | 3.6 | 74 | 215 | 85 | 171 | 4.6 |
| S.6 | 8.0 | 1005 | 679 | 98 | 20 | 3.8 | 75 | 213 | 83 | 171 | 4 |
| S.7 | 7.0 | 1000 | 695 | 97 | 24 | 3.7 | 79 | 225 | 89 | 167 | 4.8 |
| S.8 | 6.0 | 1008 | 706 | 102 | 27 | 3.9 | 80 | 225 | 93 | 166 | 4.9 |

### Table 2: Physical and major chemical cations and anions parameters for Dujaila River during March, 2018.

| No | pH | EC (Ω·m) | TDS (mg/L) | Ca$^{2+}$ | Mg$^{2+}$ | K$^+$ | Na$^+$ | SO$_4^{2-}$ | Cl$^-$ | HCO$_3^-$ | NO$_3^-$ |
|----|----|----------|------------|-----------|-----------|-------|-------|------------|-------|-----------|-----------|
| S.1 | 670 | 101 | 22 | 3 | 70 | 212 | 84 | 168 | 3.7 |
| S.2 | 682 | 88 | 27 | 3.9 | 81 | 219 | 95 | 156 | 5.4 |
| S.3 | 692 | 92 | 27 | 3.7 | 80 | 214 | 96 | 170 | 3.5 |
| S.4 | 682 | 94 | 25 | 3.6 | 76 | 212 | 90 | 169 | 3 |
| S.5 | 675 | 93 | 23 | 3.6 | 74 | 215 | 85 | 171 | 4.6 |
| S.6 | 676 | 98 | 20 | 3.8 | 75 | 213 | 83 | 172 | 4 |
| S.7 | 695 | 97 | 24 | 3.7 | 79 | 225 | 89 | 167 | 4.7 |
| S.8 | 704 | 102 | 27 | 3.9 | 80 | 225 | 93 | 167 | 4.8 |
| S.9 | 709 | 101 | 27 | 3 | 85 | 228 | 95 | 159 | 4.4 |

### Table 3: Water samples parameters through wet and dry periods

| Parameter | S1 | S2 | S3 | S4 | S5 | S6 | S7 |
|-----------|----|----|----|----|----|----|----|
| Temp. (°C) | 10 | 11 | 10 | 11 | 11 | 15.5 | 11 |
| Turb.(NTU) | 22 | 38 | 40 | 40 | 37 | 35 |
| Do | 10.5 | 7.9 | 7.8 | 9 | 9 | 9.5 | 8 |
| BOD | 1 | 4 | 5 | 2.6 | 3 | 2.8 | 2.6 |
| Fecal Coliform | 2.3×10$^2$ | 2×10$^2$ | 3×10$^2$ | 4×10$^2$ | 2.6×10$^2$ | 2×10$^2$ | 2.6×10$^2$ |
| Temp. (°C) | 30 | 22 | 30 | 29 | 28 | 27 | 27 |
| Turb.(NTU) | 26 | 80 | 115 | 86 | 70 | 65 | 60 |
| Do | 7.29 | 5.1 | 5.1 | 4.1 | 6.5 | 7 | 6.9 |
| BOD | 2.6 | 11 | 13 | 10 | 9 | 8 | 7 |
| Fecal Coliform | 1.35×10$^3$ | 1.3×10$^4$ | 1.4×10$^3$ | 1.5×10$^3$ | 1.1×10$^3$ | 1.2×10$^3$ | 1.5×10$^3$ |

a. National Sanitation Foundation Water Quality index (NSFWQI)
Brown et al. (1972) [7] developed an index to water quality. This manual is based on a combination of physical and chemical parameters. It has therefore developed a simple system for water quality recognition. These efforts have been supported by National Sanitation Foundation (NSFWQI). This work appears to be integrated and comprehensive, and has been discussed in many studies. The experiences of previous scientists have contributed to the identification of important variables related to water quality. Which have been selected in terms of their health influences to public health [8]. The important parameters and its weight chosen for the purpose of building the model were dissolved oxygen (0.17), fecal coliform (0.16), pH (0.11), biological oxygen (0.11), temperature (0.10), phosphate (0.10), nitrates (0.10), turbidity (0.08) and total dissolved solid (Table 4).

Table 4: Weight of WQI parameters

| Factor S1              | Weight |
|------------------------|--------|
| Dissolved Oxygen       | 0.17   |
| Fecal Coliform         | 0.16   |
| pH                     | 0.11   |
| Biological oxygen      | 0.11   |
| Temperature Change     | 0.10   |
| Total Phosphate        | 0.10   |
| Nitrates               | 0.10   |
| Turbidity              | 0.08   |
| Phosphate              | 0.10   |
| Total dissolved solid  | 0.07   |

WQI are range from ≥ 42 through dry period, and ≤ 55 through wet period, where water quality was found to range from poor to medium (Table 5 and 6). It is illustrated through Table 5 and Fig. 2) that the Water Quality Index values for the wet period are higher than the dry period, and this is a natural result. The water temperature increases during the summer and this leads to increased rates of bacterial growth first [9], and lower levels of water during the summer, where high evaporation rates, which lead to the concentration of ions in the river water [10].

Table 5: Water quality index values of wet and dry periods

| Station No. | WQI value | WQI value |
|-------------|-----------|-----------|
| S1          | 55        | 51        |
| S2          | 48        | 43        |
| S3          | 49        | 42        |
| S4          | 49        | 44        |
| S5          | 49        | 44        |
| S6          | 51        | 44        |
| S7          | 52        | 48        |
Figure 2: Water quality indexes values through wet and dry periods

Table 6: water quality range

| Range   | Water Quality |
|---------|---------------|
| 90-100  | Excellent     |
| 70-90   | Good          |
| 50-70   | Medium        |
| 25-50   | Bad           |
| 0-25    | Very bad      |

b. Suitability of river water for irrigation purpose

To achieve the objectives of the current study, it should be include the identification of the water's suitability for irrigation purposes based on the calculation of sodium ratio, magnesium risk, Kelly’s ratio, residual sodium carbonate, permeability index, sodium absorption ratio and salinity risk.

1. The sodium percentage ratio

   Its value can be calculated through the following equation [11]:

   \[
   \text{Sodium Percentage Ratio} = \frac{Na}{Ca+Mg+Na+K} \times 100 \quad \text{(Eq.1)}
   \]

   Table 7: Sodium percent according to (Wilcox, 1965) and current study through wet and dry periods

   | Sodium percent according to (Wilcox, 1995) | Station No. | Current study | Wet period | Dry period |
   |-------------------------------------------|-------------|---------------|------------|------------|
   | <2% (excellent)                            | S1          | 30.5          | 30.5       |            |
   | 2-40% (good)                              | S2          | 34.4          | 34.2       |            |
   | 40-60% (permit)                           | S3          | 33.51         | 32.6       |            |
   | 60-80% (Doubtful)                         | S4          | 32.53         | 32         |            |
   | > 80% (inappropriate)                     | S5          | 32.71         | 28         |            |
   |                                            | S6          | 32.93         | 32.8       |            |
   |                                            | S7          | 33.15         | 33         |            |

As shown in Table 7, the values of sodium percentage ratio for two periods range between 28-34.4, so the canal water is considered good for watering.

2: Magnesium Hazard
The value of magnesium hazard more than 50, water is as harmful and unsuitable [12] for irrigation usage. Magnesium hazard can be calculated using the equation (Eq. 2), while the concentration of ions is in meq/l.

\[
\text{Magnesium Hazard} = \frac{[\text{Mg}^{2+}]}{[\text{Ca}^{2+}] + [\text{Mg}^{2+}]} \times 100
\]  

(Eq. 2)

Al-Dujaila Channel Project water is nearly less than the range of magnesium hazard (< 50 percent). So, it is suitable for irrigation purpose (Table 8).

**Table 8:** Magnesium Hazard ratio for Al-Dujaila Channel Project water.

| Station | Meg. Hazard % (Dry Period) | Magnesium Hazard % (Wet Period) |
|---------|---------------------------|---------------------------------|
| S1      | 25.6                      | 26.4                            |
| S2      | 33.2                      | 33.5                            |
| S3      | 31                        | 32.5                            |
| S4      | 31                        | 30.5                            |
| S5      | 27                        | 28.9                            |
| S6      | 28.2                      | 25.2                            |
| S7      | 28                        | 29                              |

3: Residual Sodium Carbonate

A more of HCO3 in water is too influences the quality of water for irrigation tenacity. Great residual sodium carbonate (RSC) will decay the soil structure and restrict the air and water movement through the soil [13]. The RSC value is suggested as below (Eq. 3), where ionic concentrations are quantified in meq/l.

\[
\text{RSC} = (\text{HCO}_3^-) - (\text{Ca}^{2+} + \text{Mg}^{2+})
\]  

(Eq. 3)

The RSC value in Al-Dujaila Channel Project water samples diverse from -3.65 to -4.98 meq/l during the dry period and -4.02 to -4.74 meq/l through the wet period. U.S. Salinity Laboratory (1954) specified that an RSC value is <1.25 meq/l is considered safe for irrigation; a value between 1.25 and 2.50 meq/l is of moderate quality and a value >2.50 meq/l is unsuitable for irrigation.

Almost 100% of the samples indication negative values, which indicated that dissolved Ca²⁺ and Mg²⁺ concentrations were higher than HCO3- content. However, with respect to the RSC value, all samples are safe for irrigation purposes where the RSC values were less than 1 meq/l (Table 9).

**Table 9:** RSC for Al-Dujaila Channel Project water samples.

| Station | RSC meq/l (Dry Period) | RSC meq/l (Wet Period) |
|---------|------------------------|------------------------|
| S1      | -3.77                  | -4.1                   |
| S2      | -3.97                  | -4.05                  |
| S3      | -3.75                  | -4.02                  |
| S4      | -3.65                  | -3.98                  |
| S5      | -4.98                  | -3.73                  |
| S6      | -3.74                  | -3.74                  |
| S7      | -3.92                  | -4.11                  |

4: Kelly’s Ratio

Kelly’s ratio (KR) can be proposed by Na⁺ concentration against Ca²⁺ and Mg²⁺ concentrations. Kelly’s ratio, that is equivalent to 1 or <1, it shows good quality of water for irrigation, and if the Kelly’s ratio is > 1, the water is not appropriate for agricultural purposes due to the more concentration of Na⁺ in the water [14]. It is itemized as the following equation (Eq. 4) and the concentration of ions is in meq/l:

\[
\text{KR} = \frac{\text{Na}^+}{(\text{Ca}^{2+} + \text{Mg}^{2+})}
\]  

(Eq. 4)

It is detected that practically 100% of the samples were less than 1 for the dry and wet periods, the water is suitable for farming purposes (Table 10).
Table 10: Kelly’s Ratio for Al-Dujaila Channel Project

| Station | KR meq/l (Dry Period) | KR meq/l (Wet Period) |
|---------|------------------------|------------------------|
| S1      | 0.4                    | 0.44                   |
| S2      | 0.53                   | 0.52                   |
| S3      | 0.51                   | 0.49                   |
| S4      | 0.48                   | 0.48                   |
| S5      | 0.49                   | 0.39                   |
| S6      | 0.493                  | 0.49                   |
| S7      | 0.498                  | 0.499                  |

5. Conclusion:
WQI are range from ≥ 42 through dry period, and ≤ 55 through wet period, where water quality was found to range from poor to medium. The values of sodium percentage ratio for two the periods are considered good for watering. The range of magnesium hazard is suitable for irrigation purpose for the two periods. All samples are safe for irrigation purposes with respect to the RSC values, where all the samples are suitable for irrigation purposes.

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