Water Quality Index of Euphrates River Near Al- Musayyab Power Plant

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Abstract
This research deals with analyzing samples of water from the Euphrates River before and after (50m, 200m, 500m, and 1000m from the outflow) the power plant of AL-Musayyab. A Water Quality Index (WQI) analysis was performed, which is a helpful tool for rapid estimation of the quality of any water resource. Water quality of the river was classified into good, poor, very poor, and unsuitable for drinking, based on physico-chemical parameters such as pH, total hardness (TH), and concentrations of the major ions of calcium (Ca\(^{2+}\)), sodium (Na\(^{+}\)), magnesium (Mg\(^{2+}\)), potassium (K\(^{+}\)), nitrate (NO\(_3\)-), sulphate (SO\(_4\)\(^{-2}\)), phosphate (PO\(_4\)\(^{-3}\)), and Chloride (Cl\(^{-}\)), which indicate the extent of pollution. The study shows the deterioration of water quality, with the main candidate causes being the direct discharge of the power plant into the river and high anthropogenic activities.

Keywords: Water Quality Index, Pollution, River Euphrates, Industrial Waste Contaminated River.

Introduction
Water is considered as one of the most significant resource that supports ecosystems, playing vital roles in various uses such as drinking and industry [1]. In the last decades, the quality of natural water surfaces and ground water has been changed due to urbanization, industrial activities, etc., which usually cause pollution that has serious impacts on the physical and chemical properties of water. As a result, the aquatic ecosystem interactions, such as the delicate food web, can be seriously altered. In addition, the polluted water is well known to have extremely deleterious impacts on the health of the residing communities consuming this water for various purposes [1]. A variety of physical, chemical

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and biological criteria can be used to determine the water quality of any specified origin. In case that the measured values of these parameters are exceeding the defined limits, the consumed water is undoubtedly harmful to human health [2]. Therefore, water source suitability for human consumption has been depicted in terms of WQI, which is known as one of the most efficient approaches to rank water quality into categories, such as good, poor, unsuitable for drinking, and others. These terms are publically used because they are easy to understand. Horton was the first scientist who introduced the WQI at 1965, then several researchers employed it for evaluating the quality of diverse water resources [3]. It is worth mentioning that the quality of water samples is widely evaluated by the WQI around the world, including that of rivers and other surface waters [4, 5] as well as groundwater and aquifers [6, 7]. In Iraq, several studies were conducted in 2012 to assess the quality of surface water. Shaymaa and Ayad [8] conducted a study to determine the water quality of the river Euphrates. Abbas and Ali [9] determined the water quality of Diyala River and demonstrated that it represented a contamination source due to its highly contaminated water. Ahmad WQI of Qalyasan Stream in the city of Sulaimania / Kurdistan, Iraq was also estimated, whereas another study was reported in relation to Tigris River's raw and processed water quality inside Baghdad [11]. Water quality assessment of Rawanduz River and Gali Ali Beg stream were also investigated [12]. The present study aims to evaluate changes in water quality of Euphrates River before and after Al-Musayyab thermal power plant using WQI, based on physical-chemical parameters, as a tool to determine water suitability for drinking purposes.

**Study area**

The study area is located at the Euphrates river near Al-Musayyab power plant, in the northern border of Babylon Governorate, Central Iraq, within the Mesopotamian basin of the unstable shelf [13] between 32°50'50" N 44°16'12" E. The study area is characterized by flat topography and is covered by the Quaternary deposits of the flooding periods of Tigris and Euphrates Rivers. No rock units are exposed in the area, while sedimentary rocks are covered by very thick layers of recent sediments that are up to 600 m thick [14]. Agriculture farms and villages with moderately-sized populations are distributed in the surrounding areas of the power plant.

**Materials and methods**

Water samples were collected from four sampling stations before and after the plant (Figure-1). Wide-mouthed plastic bottles of one-liter size were used for collecting the samples and preserved until the parameters were analyzed in the laboratory. Water samples were analyzed for the following Physico-chemical parameters: pH, TH, and concentrations (Mg²⁺), (Ca²⁺), (K⁺), (Na⁺), (PO₄³⁻), (NO₃), (Cl⁻) and (SO₄) (APHA 1998) [15].

![Figure 1- Study area and water sampling stations](image-url)
In this study, the estimation of water quality index was based on ten significant physicochemical factors. The WQI was calculated and the quality of water was determined by means of the standards of drinking water adopted by the World Health Organization (WHO) [16], which are listed in Table-1.

Table 1- Standards for different parameters used [16]

| Parameter | Standard |
|-----------|----------|
| PH        | 7.5      |
| T.H       | 500      |
| Ca<sup>2+</sup> | 100    |
| Mg<sup>2+</sup> | 125    |
| Na<sup>+</sup> | 200    |
| K<sup>+</sup> | 12      |
| NO<sub>3</sub> | 50      |
| PO<sub>4</sub> | 0.4     |
| SO<sub>4</sub> | 250     |
| Cl        | 250      |

Water quality index determination WQI was calculated by using the Weighted Arithmetic Index method [17, 18], as expressed in the following equation:

\[ Q_i = \frac{C_i}{S_i} \times 100 \]  

(1)

Qi = Quality rating of its parameter for a total of n water quality parameters.  
Ci = Actual value of the water quality parameter obtained from the analysis.  
Si = Suggested standard of the water quality parameter.

Then the relative (unit) weight (Wi) was intended by a value contrariwise proportional to the recommended standard (Si) for the consistent parameter using the next expression:

\[ Wi = \frac{1}{S_i} \]  

(2)

where Wi = Relative (unit) weight for the parameter.  
Si = Standard allowable value for the parameters.

Finally, the overall WQI was calculated by combining the quality rating with the unit weight by using the following equation:

\[ WQI = \frac{\sum Qi i Wi}{\sum Wi} \]  

(3)

where Qi = Quality rating.  
Wi = Relative (unit) weight.

Table 2- Water quality classification based on WQI values [19]

| WQI Value | Water Quality           |
|-----------|-------------------------|
| <50       | Excellent               |
| 50 - 100  | Good water              |
| 100-200   | Poor water              |
| 200-300   | Very Poor water         |
| >300      | Water unstable for drinking |
Results

The results of the physico-chemical characterization of Euphrates river conducted in 17th November 2018 are briefed in Table-3. The results of the calculation of water quality index of sampling stations are shown in Tables- 4, 5, 6, and 7.

**Table 3**-Concentrations of the different parameters used in calculating the water quality index.

| parameters | PH  | T.H ppm | Ca ppm | Mg ppm | Na ppm | K ppm | NO$_3$ ppm | PO$_4$ ppm | SO$_4$ ppm | Cl ppm |
|------------|-----|---------|--------|--------|--------|-------|------------|------------|------------|--------|
| Station1   | 8   | 452     | 96.192 | 47.488 | 4.864  | 1.633 | 14.531     | 1.037      | 204.086    | 175.944 |
| Station2   | 7.8 | 650     | 168.336| 89.568 | 10.59  | 1.32  | 53.344     | 2.879      | 460        | 314.722 |
| Station3   | 8   | 720     | 184.208| 97.388 | 4.86   | 1.475 | 9.844      | 0.451      | 583.09     | 279.912 |
| Station4   | 8   | 518     | 140.24 | 59.568 | 4.86   | 1.63  | 11.719     | 0.819      | 133.326    | 335.894 |

**Table 4**-Calculation of water quality index of sampling station 1

| Water quality parameters | C$_i$ | S$_i$ | W$_i$ | q$_i$ | W$_i$q$_i$ |
|--------------------------|-------|------|-------|------|------------|
| PH                       | 8     | 7.5  | 0.133 | 106.667 | 14.222 |
| T.H                      | 452   | 500  | 0.002 | 90.400  | 0.181  |
| Ca$^{+2}$                | 96.192| 100  | 0.010 | 96.192  | 0.962  |
| Mg$^{+2}$                | 47.488| 125  | 0.008 | 37.990  | 0.304  |
| Na$^+$                   | 4.864 | 200  | 0.005 | 2.432   | 0.012  |
| K$^+$                    | 1.633 | 12   | 0.083 | 13.611  | 1.134  |
| NO$_3$$^{-2}$            | 14.531| 50   | 0.020 | 29.063  | 0.581  |
| PO$_4$$^{-2}$            | 1.037 | 0.4  | 2.500 | 259.213 | 648.032|
| SO$_4$$^{-2}$            | 204.086| 250 | 0.004 | 81.634  | 0.327  |
| Cl$^-$                   | 175.944| 250 | 0.004 | 70.378  | 0.282  |

\[\Sigma W_i=2.77\quad \Sigma W_iq_i=666.036\]

Water Quality Index (WQI) = $\Sigma W_iq_i/\Sigma W_i=240.47$

**Table 5**-Calculation of water quality index of sampling station 2

| Water quality parameters | C$_i$ | S$_i$ | W$_i$ | q$_i$ | W$_i$q$_i$ |
|--------------------------|-------|------|-------|------|------------|
| PH                       | 7.8   | 7.5  | 0.1333| 104  | 13.8667    |
| T.H                      | 650   | 500  | 0.0020| 130  | 0.2600     |
| Ca$^{+2}$                | 168.336| 100 | 0.0100| 168.34 | 1.6834    |
| Mg$^{+2}$                | 89.568| 125  | 0.0080| 71.66 | 0.5732     |
| Na$^+$                   | 10.59 | 200  | 0.0050| 5.3   | 0.0265     |
| K$^+$                    | 1.32  | 12   | 0.0833| 10.98 | 0.9144     |
| NO$_3$$^{-2}$            | 53.344| 50   | 0.0200| 106.69| 2.1338     |
| PO$_4$$^{-2}$            | 2.879 | 0.4  | 2.5000| 719.85| 1799.6231  |
| SO$_4$$^{-2}$            | 460   | 250  | 0.0040| 184   | 0.7360     |
| Cl$^-$                   | 314.722| 250 | 0.0040| 125.8888| 0.5036    |

\[\Sigma W_i=2.77\quad \Sigma W_iq_i=1820.3205\]

Water Quality Index (WQI) = $\Sigma W_iq_i/\Sigma W_i=657.23$
### Table 6 - Calculation of water quality index of sampling station 3

| Water quality parameters | C_i | S_i | W_i  | q_i   | W_iq_i |
|--------------------------|-----|-----|------|-------|--------|
| PH                       | 8   | 7.5 | 0.1333 | 106.6667 | 14.2222 |
| T.H                      | 720 | 500 | 0.0020 | 144   | 0.2880 |
| Ca^{2+}                  | 184.208 | 100 | 0.0100 | 184.208 | 1.8421 |
| Mg^{2+}                  | 97.388 | 125 | 0.0080 | 77.9104 | 0.6233 |
| Na^{+}                   | 4.86 | 200 | 0.0050 | 2.4320 | 0.0122 |
| K^{+}                    | 1.475 | 12  | 0.0833 | 12.2917 | 1.0243 |
| NO₃⁻                    | 9.844 | 50  | 0.0200 | 19.6875 | 0.3938 |
| PO₄⁻²                   | 0.451 | 0.4 | 2.5000 | 112.6466 | 281.6164 |
| SO₄²⁻                   | 583.09 | 250 | 0.0040 | 233.2360 | 0.9329 |
| Cl⁻                     | 279.912 | 250 | 0.0040 | 111.9648 | 0.4479 |

$$\Sigma W_i = 2.77$$  $$\Sigma W_iq_i = 301.4030$$  

**Water Quality Index (WQI) = \( \frac{\Sigma W_iq_i}{\Sigma W_i} \) = 108.82**

### Table 7 - Calculation of water quality index of sampling station 4

| Water quality parameters | C_i | S_i | W_i  | q_i   | W_iq_i |
|--------------------------|-----|-----|------|-------|--------|
| PH                       | 8.0000 | 7.5 | 0.1333 | 106.6667 | 14.2222 |
| T.H                      | 518 | 500 | 0.0020 | 103.6 | 0.2072 |
| Ca^{2+}                  | 140.24 | 100 | 0.0100 | 140.24 | 1.4024 |
| Mg^{2+}                  | 59.568 | 125 | 0.0080 | 47.6544 | 0.3812 |
| Na^{+}                   | 4.86 | 200 | 0.0050 | 2.4320 | 0.0122 |
| K^{+}                    | 1.63 | 12  | 0.0833 | 13.6111 | 1.1343 |
| NO₃⁻                    | 11.719 | 50  | 0.0200 | 23.4375 | 0.4688 |
| PO₄⁻²                   | 0.39 | 0.4 | 2.5000 | 97.5000 | 243.7500 |
| SO₄²⁻                   | 133.326 | 250 | 0.0040 | 53.3304 | 0.2133 |
| Cl⁻                     | 335.894 | 250 | 0.0040 | 134.3576 | 0.5374 |

$$\Sigma W_i = 2.77$$  $$\Sigma W_iq_i = 262.32$$  

**Water Quality Index (WQI) = \( \frac{\Sigma W_iq_i}{\Sigma W_i} \) = 94.715**

Table-8 indicates the location and classification of water collection stations according to their own quality levels, which reveals that water quality of the selection stations ranges from "very poor to good water", based on their location before or after the power plant.

### Table 8 - Descriptions of the water sampling stations and classification of their water quality for samples collected in November 2018.

| station coordinates | Mean WQI | Description           |
|---------------------|----------|-----------------------|
| E   | N   |                |
| Station (1)        | 44°16'12" | 32°50'50" | 240.47 | Very poor water |
| Station(2)         | 44°16'13" | 32°50'23" | 657.23 | Water unsuitable for drinking |
| Station(3)         | 44°16'12" | 32°50'20" | 108.82 | Poor water |
| Station (4)        | 44°16'14" | 32°49'59" | 94.715 | Good water |

3006
Discussion

According to the above WQI values at various sampling stations, there was an increasing trend in these values at the plant’s downstream, indicating an increase in contamination load in the river. Pollution load increases in a river due to effluent discharges by the plants established along its course. Among all the physicochemical parameters selected for water quality index calculation, pH is a factor that regulates the appropriateness of water for many uses and the level of contamination in the watershed areas. In this study, pH values ranged from 7.8 to 8.2, falling within the acceptable surface water limits and indicating that water samples are almost neutral to sub alkaline.

Water is described as hard when it contains high levels of dissolved minerals, specifically calcium and magnesium. Hard water is not a health risk, but a nuisance because of mineral buildup on fixtures and poor soap and detergent performance [20]. The results reported by water surveys conducted in this study showed that total hardness levels were frequently higher than the minimum allowable level suggested by the WHO for drinking water" [21].

High levels of calcium and magnesium cations contribute to the elevated hardness of water. However, levels of sodium and potassium cations were within the permissible levels. Nitrate”ion can cause methemoglobinemia in infants less than six months old if it is found in water "[22]."The mean nitrate concentration of the samples was found to be more than the allowable levels “of 50 mg /L.

High phosphate levels may imply toxicity and are largely responsible for eutrophic circumstances. Domestic wastewater with run-off detergents, industrial effluents, and fertilizers contributes to high phosphate levels in surface water [23]. The mean level of phosphate in the studied sites was higher than that specified by the limits.

Sulphate naturally exists in surface waters as SO$_2^2$. Atmospheric precipitation and industrial discharges can also add significant amounts of sulphate to surface waters. The mean concentration of sulphate was within the tolerable limits of WHO for drinking water.

Chloride is an essential parameter for evaluating the quality of water. High concentrations of chloride indicate a higher degree of organic contamination that can occur near sewages, irrigation drains and waste outlets [22]. The mean chloride concentration was found to be at the acceptable value of 250 mg /L.

Conclusions

Over time, water quality conditions can be identified and compared by WQI. This rapid evaluation tool can be used as an environmental indicator in a variety of ways, improve awareness of general issues of water quality, evaluate the effectiveness of water quality management activities, and illustrate the need for protection practices and their effectiveness. In this study, the implementation of WQI was found to be very useful to evaluate the overall water quality along four stations upstream and downstream a power plant established at Euphrates river within Babylon Governorate.

This study concludes that, for drinking purposes, the water quality is not appropriate. The results suggested that Euphrates river's water quality is mostly very poor, ranging from very bad upstream water to unsuitable for human consumption in the downstream, indicating the effects of pollution resulting from waste materials discharged from urban activities and industrial activities.

Several recommendations could be extracted based on the results of the present study. It must be made sure that efficient water treatment measures are followed in the operating units before being established at the rivers and other parts of the environment. Analysis of heavy elements in water is necessary to determine the level of pollution generated by power plants. Water quality assessment should be conducted periodically to identify pollutants and to reduce the risk of environmental pollution.

References

1. Khanna D.R., R. Bhutiani, Bharti Tyagi, Prashant Kumar Tyagi and MukeshRuhela, 2013. Determination Of Water Quality Index For The Evaluation Of Surface Water Quality For Drinking Purpose. International Journal of Science and Engineering, 1(1): 09-14.
2. Guidelines for Drinking-water Quality. 2012. Fourth Edition, World Health Organization ISBN 978 92 4 154815 1. 2012.
3. Mohammad Alam and J.K. Pathak, 2011. Rapid Assessment of Water Quality Index of Ramganga River, Western Uttar Pradesh (India) Using a Computer Programme”, Nature and Science, 8(11).
4. Babak Jafari Salim, Gholamreza Nabil Bidhendi And Amir Salami, 2009. “Water Quality Assessment Of Gheshtlagh River Using Water Quality Indices”, Environmental Sciences, 6(4): 19-28.

5. PradyusaSamantray, Basanta K. Mishra, Chitta R. Panda and Swoyam P. Rout, 2009. “Assessment of Water Quality Index in Mahanadi and Atharabanki Rivers and Taldanda Canal in Paradip Area, India”, J Hum Ecol, 26(3): 153-161.

6. Vaishnav M.M. and Dewangan S. 2011. “Assessment of Water Quality Status in Reference to Statistical Parameters in Different Aquifers of Balco Industrial Area, Korba, C.G. INDIA”, Research Journal of Hemical Sciences, 1(9): 67-72.

7. Paul Supantha and Mishra Unesh, 2011. “Assessment Of Underground Water Quality In North Eastern Region Of India: A Case Study of Agartala City”, International Journal Of Environmental Science, 2(2): 850-862.

8. Shaymaa A.M. Alhashimi and Ayad Sleibi Mustafa, 2012. “Prediction Of Water Quality Index For Euphrates River, Iraq”, International Journal of the Environment and water, 1(2): 114-128

9. Dalal Ahmed Abbas, Kamal K. Ali 2020. (Water Quality of Grundwater and Diyala River in Jisr Diyala Area Within Baghdad City-Iraq). Iraqi Journal of Science, 61(3): 584-590.

10. Ahmad I. Khwakaram, Salih N. Majid and Nzar Y. Hama, 2012. “Determination Of Water Quality Index (Wqi) For Qalyasan Stream In Sulaimani City/ Kurdistan Region Of Iraq”. International journal of plant, animal and environmental sciences. 2(4).

11. Abdul Hameed M. Jawad Alobaidy, Bahram K. Maulood and Abass J. Kadhem, 2010. “Evaluating Raw And Treated Water Quality Of Tigris River Within Baghdad By Index Analysis”, J. Water Resource And Protection, 2: 629-635.

12. Nihal Suhail Hanna , Yahya Ahmed Shekha and Luay Abdul-Qader Ali, 2019.( Water quality assessment of Rawanduz River and Gali Ali Beg stream by applied CCME WQI with survey aquatic insects (Ephemeroptera), Iraqi Journal of Science, 2019, 60(12): 2550-2560.

13. Jassim, S.Z. and Goff, G.C. 2006. Geology of Iraq. Published by Dolin, Prague and Moravian Museum, Brno. pp: 354.

14. Oil Exploration Company, 2007. Primary reservoir study for east Baghdad oil field, Zubair reservoir. (Internal Project).

15. APHA(American Public Health Association), AWWA (American Water Works Association ) and WPCF(Water Pollution Control Federation) .1998. Standard methods for Examination of water and waste water.20th Edn.

16. WHO (World Health Organization). 2011. Guidelines for Drinking water Quality, Selenium in Drinking-water, Geneva.

17. Khudair, B.H. 2013. "Assessment of water quality index and water Suitability of Tigris River for drinking water within Baghdad city, Iraq".Journal of Engineering, 19(6): 764(2013).

18. Kumer, A. and Dua, A. 2009. "Water quality index for assessment of water quality of river Ravi .India". Journal of Environmental Sciences, 8(1): 49.

19. Bhaven N. Tandel, Dr. JEM Macwan and Chirag Soni, 2011. "Assessment of Water Quality Index (WQI) of small lake in South Gujarat region, India", International Conference on Ecological, Environmental and Biological Sciences, 235-237, Integrated Society for Engineering and Management.

20. Brian Oram, PG. 2014. Hard Water Hardness Calcium Magnesium Water Corrosion Mineral Scale, https://water-research.net/index.php/water-treatment/tools/hard-water-hardness.

21. WHO (World Health Organization), 2004. “Guidelines for Drinking Water Quality,” 3rd Edition, Geneva.

22. Egereonu, U.U. and Nwachukwu, U. L. 2005. "Evaluation of the surface and groundwater resources of Efuru River Catchment, Mbano, South Eastern, Nigeria” J. Assoc.Adv.Model.Simulat.Tech. Enterpr, 66: 53-71.

23. Munawar, M. 1970. "Limnological studies on fresh water ponds of Hyderabad" India-II, J. Hydrobiologia. 35: 127-162.