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# Identify the Water Suitability for Irrigation of Different Streams using Water Quality Index

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**Abstract**

Water quality of the main streams in Sharkia governorate were investigated using the water quality index (WQI) technique. A water quality index provides a single number that expresses the overall water quality at a certain location and time based on several water quality parameters. Several essential parameters were investigated such as pH, electrical conductivity (EC), calcium (Ca), magnesium (Mg), Lead (Fe), Cobalt (Co), Nicle (Ni), and Cadmium (Cd) were taken for the calculation of WQI. The results of the water quality index in the summer season at El-Wadi Canal, Abu Elakhdar canal and Bahar El-Baqar drain were 126.6, 74.1, and 186.3 that classified the water suitability for irrigation as poor, good and very poor for irrigation, respectively. While the WQI for the same locations in the winter seasons were 66.3, 41.05, and 107.1 that classified the water suitability for irrigation as good, excellent and poor for irrigation, for El-Wadi Canal, Abu Elakhdar canal and Bahar El-Baqar drain respectively. The impact of various anthropogenic activities was evident on some parameters such as the EC, alkalinity and hardness. It is suggested that monitoring of the drain is necessary for proper management. Application of the WQI is also suggested as a very helpful tool that enables the public and decision-makers to evaluate water quality of lakes Egypt.

**Keywords:** Water quality index; water suitability; Irrigation; Streams; Drain.

**Full length article** **Corresponding Author*, e-mail: salmaazab39@gmail.com

## 1. Introduction

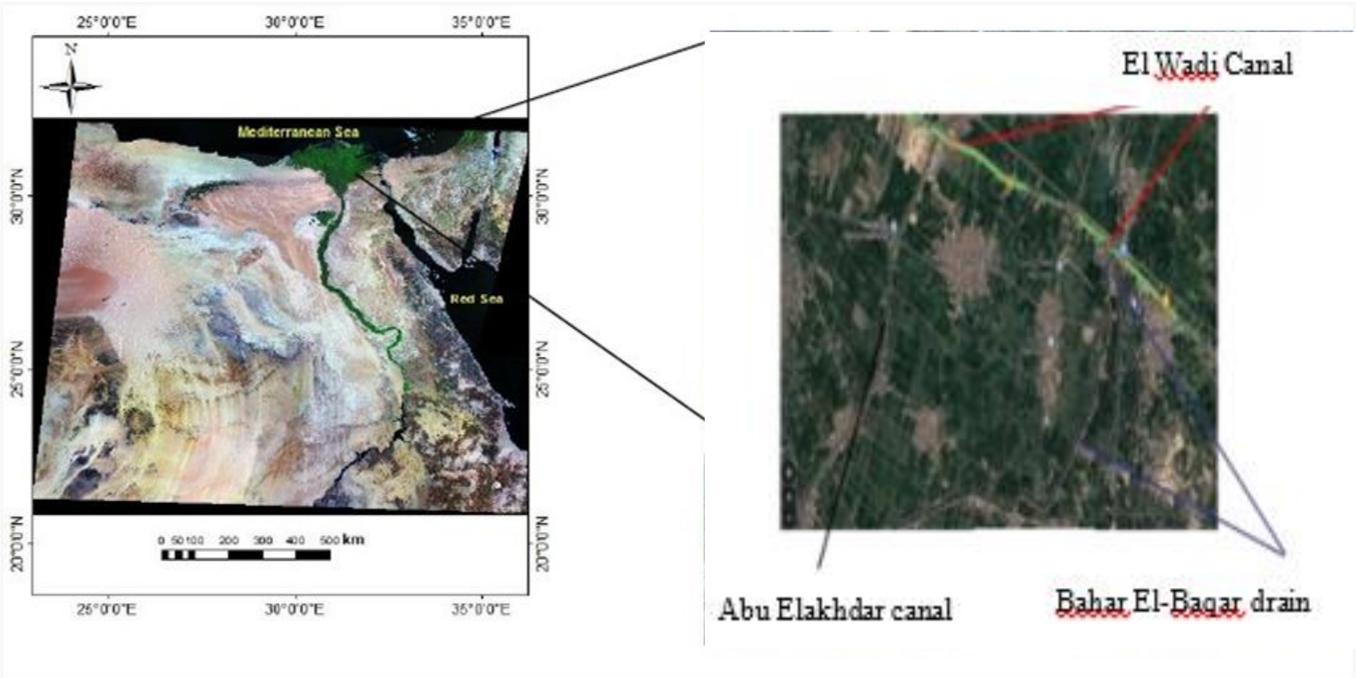
Water is an essential requirement of human and industrial developments and it is one the most delicate part of the environment [1]. Tremendous increase in the demand for freshwater due to rapid growth of population and the accelerated pace of industrialization [2]. Human health is threatened by most of the agricultural development activities particularly in relation to excessive application of fertilizers and unsanitary conditions [3]. The availability of water in shows a great deal with spatial and temporal variability. The increase in population and expansion of economic activities undoubtedly leads to increasing demand for water use for various purposes. Water quality index (WQI) is commonly used tool for the detection and evaluation of water quality and may be defined as a reflection of composite influence of different quality parameters on the overall quality of water [4]. It is based on physical, chemical, and biological factors that are combined into a single value ranges from 0 to 100 and involves 4 processes: (1) parameter selection, (2) transformation of the raw data into common scale, (3) providing weights and (4) aggregation of sub-index values.

Water is the vital natural resource with social and economic values for human beings [5,3]. The optimal quantity and acceptable quality of water is one of the essential needs to survive as mentioned earlier, but the maintenance of an acceptable quality of water is a challenge in the sector of water resources management [6,5]. Accordingly, the water quality of water bodies can be tested through changes in physical, chemical and biological characteristics related to anthropogenic or natural phenomena [7,8]. Therefore, water quality of any specific water body can be tested using physical, chemical and biological parameters also called variables, by collecting samples and obtaining data at specific locations [8,1]. Thus, the suitability of water sources for human consumption has been described in terms of Water Quality Index (WQI), which is one of the most effective ways to describe the quality of water, by reducing the bulk of information into a single value ranging between 0 and 100 [9].

With a growing population and intensified industrial and agricultural activities, large amounts of untreated urban municipal, industrial wastewater, and rural domestic wastes discharge into the river Nile, canals, or agricultural drains which become an easy dumping site for all kinds of wastes. According to [3] the main industrial sectors are oil and soap, starch yeast glucose, pulp and paper, metal industry, plastic and rubber, and textile and dyeing. In the irrigated areas, the level of applied water is generally higher than necessary to prevent salt accumulation in the root zone of the soil. In a system of drainages (~18000km length) the excess water carrying salts and chemical residues is collected and either pumped into irrigation canals for reuse or pumped into the river Nile or the northern lakes or the Mediterranean. Using the water twice or even three times increases the salinity, especially in drains near the lakes bordering the Mediterranean Sea. In Egypt about 0.9 million Ha of irrigated land were damaged by salt, corresponding to about 33% of the total irrigated land [10]. The mixing of drain water with clean water diffuses all kinds of constituents that still have negative environmental and health impacts. Without seasonal flushing floods, the former delta plain surface is now incapable of recycling and or removing agricultural, municipal, and industrial waste generated by Egypt's rapidly expanding population. The necessary expansion of the water supply services is not always fitting to the conjugate development of the sewerage system. This results in an increasing pollution load to canals and drains the Bahr El-Baqar drain system is a typical example [11].

## 2. Material and Methods

The water quality of the Bahr El-Baqar Drain system in Egypt was studied in 2022–2023. The section of the drain system called Bilbeis Drain starts in the eastern zone of Greater Cairo, where all sewage and industrial wastewater, treated or untreated, is dumped into this drain. Near Zagazig, the Bilbeis and Qalubeya Drains flow together to form the Bahr El-Baqar Drain. Along its way from Cairo down to Lake Manzala, there are a lot of discharges, like agricultural run-offs, in the northeastern cultivated areas. Large amounts of untreated urban municipal water are discharged into the drain in larger cities or villages. At 3 different sites along the Abou-Lakhder, El-Wady, and Bahr El-Baqar Drains water samples were taken and analysed for some parameters, salts, heavy metals, and natural (Fig. 1).




The research provides solutions to environmental problems by developing and promoting techniques that help to protect and improve the environment by advancing scientific information to support regulatory and policy decisions, providing technical support, and transferring information to ensure the implementation of environmental regulations and strategies at the national, state and community levels.

Study Area: Bahr El-Baqr drain (BBD) is the largest and most polluted drain [12] of the seven drains discharging in Lake Manzala (5.5 billion $m^3$/day). The drain originates from Cairo, collecting agricultural, industrial, and sewage water for three other governorates before reaching Lake Manzala with a total length of more than 200 km. Wastewater in the drain is composed of particulate, nutrients, heavy metals, hydrocarbons, and residues of toxic compounds such as herbicides and pesticides [13]. Although Bahr El-Baqr is the largest drain in the Eastern Delta, it was excluded from supplying the El-Alam Canal delivering mixed drainage and fresh water to Sinai due to the high level of pollution. This condition results in the loss of large amounts of water that could have been reused for irrigation.

### *2.1. Collection of Water Samples*

All samples were examined according to water and wastewater examination standards [14]. Water samples collected were in clean and sterile polyethylene plastic bottles from the canals. All samples were stored using an ice box and were immediately sent to the laboratory for analysis. All analyses were carried out at the Soil and Water Research Institute, Cairo, Egypt.

Water Samples Analysis: All analyses were done according to Water and Waste Water Examination Standards [15].

Physico-chemical Analysis: All field parameters including pH, Temperature, electric conductivity (EC), and total dissolved solids (TDS) were carried out in the field by utilizing the multi-probe system. Then the water samples were rechecked in the laboratory to ensure data accuracy. As soon as the samples were received in the lab, they were mixed by shaking and examined for different cations and anions as follows: calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), and Cloride (Cl), Carbonate and Dicarbonate, and sulfate (SO4) were examined by the method of [15]APHA (1998). In addition, the certain heavy metals such as Lead (Fe), Cobalt (Co), Nicle (Ni), and Cadmium (Cd) were examined by the method of [15].

### *2.2. Water Quality Index (WQI)*

The water quality index is a 100-point scale that was used to summarize results from a total of eight measurements by using Microsoft Excel Version, 2013 according to National Sanitation Foundation, USA. The used parameters are: DO, BOD, FC, pH, Temp., $PO_4^{3-}$, $NO_3^-$, and turbidity. The WQI makes the reduction of large amounts of data, thus ranking water into one of five categories. The steps for Water quality index (WQI) are:

The quality rating scale for each parameter qi was calculated by using this expression:

qi = (Ci / Si) × 100

A quality rating scale (qi) for each parameter is assigned by dividing its concentration (Ci) in each water sample by its respective standard (Si) and the result multiplied by 100.

Unit weight (Wi) was calculated by a value inversely proportional to the recommended standard (Si) of the corresponding parameter:

Wi = 1 / Si

The overall WQI was calculated by aggregating the quality rating (Qi) with unit weight (Wi) linearly:

i=n

WQI = (Σwi qi)

I=1

Overall WQI = Σ qi wi / Σ wi

**Table 1:** Water quality classification based on WQI value [7,16]

| S.No | WQI | Status | Possible usages |
|---|---|---|---|
| 1 | 0-25 | Excellent | Drinking,Irrigation and Industrial |
| 2 | 25-50 | Good | Domestic, Irrigation and Industrial |
| 3 | 51-75 | Fair | Irrigation and Industrial |
| 4 | 76-100 | Poor | Irrigation |
| 5 | 101-150 | Very poor | Restricted use for Irrigation |
| 6 | Above 150 | Unfit for Drinking | Proper treatment required before use |

## 3. Results and Discussions

Water quality index in the historical and the present study is established from important various physicochemical parameters in different seasons. Season water quality index calculations are depicted in Tables 2, 3, 4, 5, 6 and 7. Among all the physicochemical parameters selected for the water quality index calculation, the importance of Electrical Conductivity (EC) is due to its measure of cations which greatly affects the taste and thus has significant impact on the user acceptance of the water for irrigation [16,17]. It is an indirect measure of total dissolved salts. High conductivity may arise through natural weathering of certain sedimentary rocks or may have an anthropogenic source, e.g. industrial and sewage effluent [18]. The results showed that EC values were slightly higher than the permissible level recommended by the WHO for drinking water. The pH of the aquatic systems is an important indicator of the water quality and the extent pollution in the watershed areas. Results obtained for pH varied between 7.60 and 8.10. However, the pH concentration in the study area is within allowable limits for surface water [18]. However, the values come also in accordance with the known values of Egypt inland waters [19].

**Table 2:** Calculation of the water quality index in the summer season at El-Wadi Canal

| Parameters | Sn | $^{1}/_{sn}$ | $\sum {}^{1}/_{sn}$ | K=$\frac{1}{\sum 1/sn}$ | Wn=$\frac{k}{sn}$ | Vo | Vn | $\frac{Vn}{Sn}$ | Qn=$\frac{Vn}{Sn}\times 100$ | Wn×Qn |
|---|---|---|---|---|---|---|---|---|---|---|
| PH | 8.5 | 0.117647 | 125,349464 | 0.00797769 | 0.0009385 | 7 | 7.70 | 0.9059 | 90.59 | 0.08502 |
| EC | 300 | 0.003333 | 125,349464 | 0.00797769 | 0.00002659 | 0 | 0.93 | 0.0031 | 0.31 | 0.0000082 |
| Ca | 75 | 0.013333 | 125,349464 | 0.00797769 | 0.00010636 | 0 | 3.64 | 0.0485 | 4.85 | 0.000516 |
| Mg | 30 | 0.033333 | 125,349464 | 0.00797769 | 0.0002659 | 0 | 1.56 | 0.052 | 5.2 | 0.00138 |
| Fe | 5.0 | 0.181818 | 125,349464 | 0.00797769 | 0.0015955 | 0 | 1.25 | 0.25 | 25 | 0.03989 |
| Co | 0.05 | 20 | 125,349464 | 0.00797769 | 0.15955 | 0 | 0.046 | 0.92 | 92 | 14.6786 |
| Ni | 0.2 | 5 | 125,349464 | 0.00797769 | 0.039888 | 0 | 0.004 | 0.02 | 2 | 0.07978 |
| Cd | 0.01 | 100 | 125,349464 | 0.00797769 | 0.797769 | 0 | 0.014 | 1.4 | 140 | 111.688 |
| $\sum$ | | | | | 1.00013985 | | | | | 126.573 |
| | | | | | | | | | | |

Wqi= $\frac{\sum wnQn}{\sum Wn}$= $\frac{126.573}{1.00013985}$= 126.6 water classified as Poor for irrigation

**Table 3:** Calculation of the water quality index in the summer season at Abu Elakhdar canal

| Parameters | Sn | $^{1}/_{sn}$ | $\sum {}^{1}/_{sn}$ | K=$\frac{1}{\sum 1/sn}$ | Wn=$\frac{k}{sn}$ | Vo | Vn | $\frac{Vn}{Sn}$ | Qn=$\frac{Vn}{Sn}\times 100$ | Wn×Qn |
|---|---|---|---|---|---|---|---|---|---|---|
| PH | 8.5 | 0.117647 | 125.349464 | 0.00797769 | 0.0009385 | 7 | 7.30 | 0.859 | 85.9 | 0.0806 |
| EC | 300 | 0.003333 | 125.349464 | 0.00797769 | 0.00002659 | 0 | 1.33 | 0.00443 | 0.443 | 0.0000118 |
| Ca | 75 | 0.013333 | 125.349464 | 0.00797769 | 0.00010636 | 0 | 4.55 | 0.06067 | 6.067 | 0.000645 |
| Mg | 30 | 0.033333 | 125.349464 | 0.00797769 | 0.0002659 | 0 | 2.21 | 0.0737 | 7.37 | 0.001959 |
| Fe | 5 | 0.181818 | 125.349464 | 0.00797769 | 0.0015955 | 0 | 1.27 | 0.254 | 25.4 | 0.04053 |
| Co | 0.05 | 20 | 125.349464 | 0.00797769 | 0.15955 | 0 | 0.032 | 0.64 | 64 | 10.2112 |
| Ni | 0.2 | 5 | 125.349464 | 0.00797769 | 0.039888 | 0 | 0.002 | 0.01 | 1 | 0.039888 |
| Cd | 0.01 | 100 | 125.349464 | 0.00797769 | 0.797769 | 0 | 0.008 | 0.8 | 80 | 63.822 |
| $\sum$ | | | | | 1.00013985 | | | | | 74.1968 |
| | | | | | | | | | | |

Wqi= $\frac{\sum wnQn}{\sum Wn}$= $\frac{74.119}{1.00013985}$= 74.109 Water classified as Good for irrigation

**Table 4:** Calculation of the water quality index in the summer season at Bahar El- Baqar drain

| Parameters | Sn | $1/sn$ | $\sum 1/sn$ | K=$\frac{1}{\sum 1/sn}$ | Wn=$\frac{k}{sn}$ | Vo | Vn | $\frac{Vn}{Sn}$ | Qn= $\frac{Vn}{Sn}$×100 | Wn×Qn |
|---|---|---|---|---|---|---|---|---|---|---|
| PH | 8.5 | 0.117647 | 125.349464 | 0.00797769 | 0.0009385 | 7 | 7.40 | 0.871 | 87.1 | 0.0817 |
| EC | 300 | 0.003333 | 125.349464 | 0.00797769 | 0.00002659 | 0 | 0.36 | 0.0012 | 0.12 | 0.0000032 |
| Ca | 75 | 0.013333 | 125.349464 | 0.00797769 | 0.00010636 | 0 | 1.52 | 0.0203 | 2.03 | 0.000216 |
| Mg | 30 | 0.033333 | 125.349464 | 0.00797769 | 0.0002659 | 0 | 1.60 | 0.0533 | 5.33 | 0.00142 |
| Fe | 5 | 0.181818 | 125.349464 | 0.00797769 | 0.0015955 | 0 | 1.64 | 0.328 | 32.8 | 0.0523 |
| Co | 0.05 | 20 | 125.349464 | 0.00797769 | 0.15955 | 0 | 0.058 | 1.16 | 116 | 18.5078 |
| Ni | 0.2 | 5 | 125.349464 | 0.00797769 | 0.039888 | 0 | 0.012 | 0.06 | 6 | 0.2393 |
| Cd | 0.01 | 100 | 125.349464 | 0.00797769 | 0.797769 | 0 | 0.021 | 2.1 | 210 | 167.53 |
| $\sum$ | | | | | 1.00013985 | | | | | 186.413 |
| | | | | | | | | | | |

Wqi= $\frac{\sum wnQn}{\sum Wn}$= $\frac{186.413}{1.00013985}$= 186.3 Water classified as Very Poor for irrigation

**Table 5:** Calculation of the Water quality index in the Winter season at El-Wadi Canal

| Parameters | Sn | $1/sn$ | $\sum 1/sn$ | K=$\frac{1}{\sum 1/sn}$ | Wn=$\frac{k}{sn}$ | Vo | Vn | $\frac{Vn}{Sn}$ | Qn= $\frac{Vn}{Sn}$×100 | Wn×Qn |
|---|---|---|---|---|---|---|---|---|---|---|
| PH | 8.5 | 0.117647 | 125,349464 | 0.00797769 | 0.0009385 | 7 | 7.87 | 0.9259 | 92.59 | 0.087 |
| EC | 300 | 0.003333 | 125,349464 | 0.00797769 | 0.00002659 | 0 | 1.41 | 0.0047 | 0.47 | 0.000012 |
| Ca | 75 | 0.013333 | 125,349464 | 0.00797769 | 0.00010636 | 0 | 2.27 | 0.030 | 3.03 | 0.00032 |
| Mg | 30 | 0.033333 | 125,349464 | 0.00797769 | 0.0002659 | 0 | 5.40 | 0.18 | 18 | 0.0048 |
| Fe | 5.0 | 0.181818 | 125,349464 | 0.00797769 | 0.0015955 | 0 | 2.70 | 0.54 | 54 | 0.09 |
| Co | 0.05 | 20 | 125,349464 | 0.00797769 | 0.15955 | 0 | 0.007 | 0.14 | 14 | 2.23 |
| Ni | 0.2 | 5 | 125,349464 | 0.00797769 | 0.039888 | 0 | 0.004 | 0.02 | 2 | 0.08 |
| Cd | 0.01 | 100 | 125,349464 | 0.00797769 | 0.797769 | 0 | 0.008 | 0.8 | 80 | 65.8 |
| $\sum$ | | | | | 1.00014 | | | | | 66.31 |
| | | | | | | | | | | |

Wqi= $\frac{\sum wnQn}{\sum Wn}$= $\frac{66.31}{1.00014}$= 66.30 water classified as Good for irrigation

**Table 6:** Calculation of the Water quality index in the Winter season at Abu Elakhdar canal

| Parameters | Sn | $^{1}/_{sn}$ | $\sum {^{1}/_{sn}}$ | K=$\frac{1}{\sum 1/sn}$ | Wn=$\frac{k}{sn}$ | Vo | Vn | $\frac{Vn}{Sn}$ | Qn= $\frac{Vn}{Sn}\times100$ | Wn×Qn |
|---|---|---|---|---|---|---|---|---|---|---|
| PH | 8.5 | 0.117647 | 125.349464 | 0.00797769 | 0.0009385 | 7 | 7.85 | 0.9235 | 92.35 | 0.0867 |
| EC | 300 | 0.003333 | 125.349464 | 0.00797769 | 0.00002659 | 0 | 1.12 | 0.0037 | 0.37 | 0.0000099 |
| Ca | 75 | 0.013333 | 125.349464 | 0.00797769 | 0.00010636 | 0 | 1.88 | 0.0251 | 2.51 | 0.00027 |
| Mg | 30 | 0.033333 | 125.349464 | 0.00797769 | 0.0002659 | 0 | 4.95 | 0.165 | 16.5 | 0.0044 |
| Fe | 5 | 0.181818 | 125.349464 | 0.00797769 | 0.0015955 | 0 | 1.44 | 0.288 | 28.8 | 0.0459 |
| Co | 0.05 | 20 | 125.349464 | 0.00797769 | 0.15955 | 0 | 0.003 | 0.06 | 6 | 0.957 |
| Ni | 0.2 | 5 | 125.349464 | 0.00797769 | 0.039888 | 0 | 0.004 | 0.02 | 2 | 0.0798 |
| Cd | 0.01 | 100 | 125.349464 | 0.00797769 | 0.797769 | 0 | 0.005 | 0.5 | 50 | 39.89 |
| $\sum$ | | | | | 1.00014 | | | | | 41.06 |
| | | | | | | | | | | |

Wqi= $\frac{\sum wnQn}{\sum Wn}$= $\frac{41.06}{1.00014}$= 41.05 Water classified as Excellent for irrigation

**Table 7:** Calculation of the Water quality index in the Winter season at Bahar El- Baqar drain

| Parameters | Sn | $^{1}/_{sn}$ | $\sum {^{1}/_{sn}}$ | K=$\frac{1}{\sum 1/sn}$ | Wn=$\frac{k}{sn}$ | Vo | Vn | $\frac{Vn}{Sn}$ | Qn= $\frac{Vn}{Sn}\times100$ | Wn×Qn |
|---|---|---|---|---|---|---|---|---|---|---|
| PH | 8.5 | 0.117647 | 125.349464 | 0.00797769 | 0.0009385 | 7 | 7.95 | 0.9353 | 93.53 | 0.088 |
| EC | 300 | 0.003333 | 125.349464 | 0.00797769 | 0.00002659 | 0 | 2.10 | 0.007 | 0.7 | 0.000019 |
| Ca | 75 | 0.013333 | 125.349464 | 0.00797769 | 0.00010636 | 0 | 5.86 | 0.0781 | 7.81 | 0.00083 |
| Mg | 30 | 0.033333 | 125.349464 | 0.00797769 | 0.0002659 | 0 | 7.63 | 0.2543 | 25.43 | 0.00676 |
| Fe | 5 | 0.181818 | 125.349464 | 0.00797769 | 0.0015955 | 0 | 3.88 | 0.776 | 77.6 | 0.124 |
| Co | 0.05 | 20 | 125.349464 | 0.00797769 | 0.15955 | 0 | 0.060 | 1.2 | 120 | 19.15 |
| Ni | 0.2 | 5 | 125.349464 | 0.00797769 | 0.039888 | 0 | 0.004 | 0.02 | 2 | 0.0798 |
| Cd | 0.01 | 100 | 125.349464 | 0.00797769 | 0.797769 | 0 | 0.011 | 1.1 | 110 | 87.75 |
| $\sum$ | | | | | 1.00014 | | | | | 107.20 |

Wqi= $\frac{\sum wnQn}{\sum Wn}$= $\frac{107.20}{1.00014}$=107.1 water classified as very poor for irrigation

***The water quality index***

The computed overall WQI for the analyzed water streams in the two seasons were presented.

The results of the water quality index in the summer season at El-Wadi Canal was 126.6 which reveals that the water suitability for irrigation is classified as poor (Table 2). While the the water quality index in the summer season at Abu Elakhdar canal was 74.109 (Table 3), and this WQI reveals that the water suitability for irrigation is good. Water quality index in the summer season at Bahar El-Baqar drain high WQI with 186.3 and the the water suitability for irrigation is classified as very poor (table 4) and these results are relevant with the findings of [20,17,21].

The obtained results for the same locations in the winter seasons were obtained. The results of the water quality index in the winter season at El-Wadi canal was 66.3 which reveals that the water suitability for irrigation is classified as good water for irrigation (Table 5). While the the water quality index in the winter season at Abu Elakhdar canal was 41.05 (Table 6), and this WQI reveals that the water suitability for irrigation is excellent. Water quality index in the winter season at Bahar El-Baqar drain high WQI with 107.1 and the the water suitability for irrigation is classified as poor (table 7) and these results are convenient with the findings of [17,22,21].

The high values of WQI have been found mainly in the summer seasons for the whole selected water streams higher than the values of WQI in the same locations in the winter streams. In addition, the WQI values for the Bahar El-Baqar drain is higher than the WQI values for the El-Wadi Canal and Abu Elakhdar canal in both the summer and the winter seasons. This could be attributed to improper disposal of wastes, cottage activities, and large quantity of agricultural and urban run-off, sewage, over application of inorganic fertilizer, improper operation and maintenance of septic system in Bahar El-Baqar drain [18]. During the last decade, Bahar El-Baqar drain has been subjected to a rapid decline in water quality status which is possibly due to the increase in the population and human activities. It is clear that the domestic discharge and agricultural activities in addition to the drought impact are the major threats to Bahar El-Baqar drain water quality and these results are convenient with the findings of [23,22,21].

## 4. Conclusion

The results obtained from the study reveals that Bahar El-Baqar drain is polluted and this could be attributed to anthropogenic activities such as agricultural activities, cottage industries. The WQI of the samples was exceeded 100. Application of Water Quality Index (WQI) in this study has been found useful in assessing the overall quality of water and to get rid of judgment on the quality of the water. This method appears to be more systematic and gives a comparative evaluation of the water quality of sampling stations. It is also helpful for the public to understand the quality of water as well as being a useful tool in many ways in the field of water quality management.

References

[1] I. Hendy, M. Zelenakova, K. Pietrucha-Urbanik, Y. Salama & M. Abu-hashim. (2023). Decentralized Constructed Wetlands for Wastewater Treatment in Rural and Remote Areas of Semi-arid Regions. Water 2023, 15, 2281. https://doi.org/10.3390/w15122281

[2] E. ElBastamy, A . Lubna Ibrahim, A. Ghandour, M. Zelenakova, Z. Vranayova & M, Abu-Hashim. (2021). Efficiency of Natural Clay Mineral Adsorbent Filtration Systems in Wastewater Treatment for Potential Irrigation Purposes. Sustainability, 13(10), 5738; https://doi.org/10.3390/su13105738

[3] L. Ibrahim, M. E El-Sesy, E. ElBastamy ElSayed, M. Zelenakova, M. Hlinkova, E.Sh Mohamed & M. Abu-Hashim. (2022). Simultaneous Removal of Metal Ions from Wastewater by a Greener Approach. Water 14 (24), 4049.

[4] R. K.Horton. (1965). An index number system for rating water quality.j. Water Pollut. Cntrol Fed., 37(3): 300- 305 (6 pages)

[5] M. Zelenakova, P. Purcz, R.D. Pintilii, P. Blistan, P. Hlustik, A. Oravcova & M. Abu-hashim. ( 2018). Spatio-temporal Variations in Water Quality Parameter Trends in River Waters. REV. CHIM. 69, 10, 2940-2974.

[6] J. Das & B.C. Acharya. (2003). Hydrology and assessment of lotic water quality in Cuttack city, India. Water, Air, Soil Pollut., 150: 163-175. DOI: 10.1023/a: 1026193514875.

[7] C.R. Ramakrishnaiah, C. Sadashivaiah & G. Ranganna. (2009). Assessment of water quality index for the groundwater in Tumkur Taluk, Karnataka State. E-Journal of Chemistry, 6: 523-530.

[8] I. Abd-Elaty, M. Zelenakova, S. Straface , Z. Vranayová & M. Abu-hashim. (2019). Integrated Modelling for Groundwater Contamination from Polluted Streams Using New Protection Process Techniques. Water, 11, 2321 34-38 (5 pages)

[9] S. Tyagi, B. Sharma, P. Singh & R. Dobal. (2013). Water quality assessment in terms of water quality index. Am. J. Water Resour., 1(3)

[10] O.C. Okeke, & A.H. Igboanua. (2003). Characteristics and quality assessment of surface water and groundwater recourses of Awka Town, SE Nigeria. W. Resources Journal, 14: 71-77.

[11] K.A. Rahi & T. Halihan. (2010). Changes in the Salinity of the Euphrates River System in Iraq. Regional Environmental Change, 10(1): 27-35.

[12] C. Jones, M. Sultan, E. Yan, A. Milewski, M. Hussein, A. Al-Dousari, S. Al-Kaisy & R. Becker. (2008). Hydrologic Impacts of Engineering Projects on the Tigris-Euphrates System and its Marshlands. Journal of Hydrology, 353(1-2): 59-75.doi.10.1016/j.jhydrol.2008.01.029

[13] S. Sargaonkar & D. Deshpande. (2003). Development of an overall index of pollution for surface water based on a general classification scheme in Indian context. Environ. Monit. Assess., 89: 43-67.

[14] M. T. Shultz. (2001). A Critique of EPA's Index of Watershed Indicators. Journal of Environmental Management, 62(4): 429-442.

[15] APHA. (1998). Standard Methods for the Examination of Water and Wastewater. American Public Health Association, 20th edition, Washington. D.C.

[16] FAO. (2004). Committee on Agriculture. FAO,s Proposed Follow-up to the Report of te Joint WHO/

FAO Expert Consultation on Diet, Nutrition and the prevention of chronic diseases. Available at: http: //www. Fao.org/ DOCREP/ 005/ AC911E/AC911E00.HTM

[17] J. R. Pradeep. (1998). Hydrogeology and Quality of Ground Water around Hirapur, District Sagar (M.P.). Pollution Research, 17(1): 91-94.

[18] W.H.O. (2004). World Health Organization (2004). Guidelines for Drinking- Water Quality. ,Vol 1, 3rd Edition, World Health Organization (WHO), Geneva, pp 1-515.

[19] J. Rozoska. (1980). Euphrates and Tigris Mesopotamian Ecology and Destiny. In: Dr Junk, Ed., Monographiae Biologicae, The Hague-Boston-London, 1980.

[20] R.J. Wilcock, G.B. McBride, J.W. Nagels & G.L. Northcott. (1995). Water Quality in a Polluted Lowland Stream with Chronically Depressed Dissolved Oxygen: Causes and Effects. New Zealand J. Maine and Freshwater Research, 29(2): 277-288.

[21] M. Alam & J.K. Pathak. (2010). Rapid Assessment of Water Quality Index of Ramganga River, Western Uttar Pradesh (India) Using a Computer Program. Nature and Science, 8(11).

[22] H.A. Mohamed. (2005). Physicochemical characteristics of Abu Za'baal Ponds, Egypt. Egyptian J. of Aquatic Research, 31(2): 1-15.

[23] Y. Tepe, A. Türkmen, E. Mutlu & A. Ateú. (2005). Some Physicochemical Characteristics of Yarseli Lake, Hatay, Turkey. Turkish Journal of Fisheries and Aquatic Sciences, 5: 35-42.