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Development of Water Quality Index to Assess Water Quality of Euphrates River within Muthanna Governorate, Iraq

Ameera M. Awad

Department of Civil Engineering, College of Engineering, University of Al- Muthanna, Iraq.

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ABSTRACT

This paper employs widely used Water Quality Index (WQI), which is valuable and unique rating to depict the overall water quality status in a single term and simple (e.g., good or poor) for reporting to authorities management and the public in a consistent manner , that is helpful for the selection of appropriate treatment technique to meet the concerned issues. The water quality of Muthanna Province has been assessed from 2011 to 2014 to express the suitability of water for drinking purposes. Water quality data obtained from two sampling sites. According to the WQI values, the water quality at most of the sites was within an environmentally satisfactory condition during summer, and during the winter. Generally, the results showed that water quality varied from Excellent to Medium range during seasons. The results of the study confirm the suitability of all selected water sources for drinking purposes. Since this is unprecedented attempt to apply WQI on Muthanna , the used WQI proved to be a highly effective tool to assess the water quality of Muthanna in simple way, and its use is strongly recommended.

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Introduction

Water is essential to sustain life, and a satisfactory (adequate, safe and accessible) supply must be available to all. and since, it has become access to safe drinking-water is essential to health, and it is important as a health and development issue at a national, regional and local level. Moreover, improve access to safe drinking water has tangible benefits to health. Therefore, every effort should be made to achieve a drinking-water quality as safe as practicable. since it is a basic human right and a component of effective policy for health protection (WHO, 2004)

Due to the worldwide concern that good quality freshwater may become a scarce resource in the near future. Hence, the evaluation of water quality has become a critical issue, especially in developing countries and countries with transition economies in recent years (Pesce et al ., 2000) .

In general, traditional approaches to assessing river water quality are based on the comparison of experimentally determined parameter values with the existing local normative .In many cases, the use of this methodology allows for a proper identification of contamination sources, and may be essential for checking legal compliance; however, it does not readily give a global vision on the spatial and temporal trends in the overall water quality in a watershed (Debels et al ., 2005) .

Monitoring programs of aquatic systems play a significant role in water quality control since it is necessary to know the contamination degree so as not to fail in the attempt to regulate its impact(Almeida et al., 2007). However, the quality is difficult to evaluate from a large number of samples, each containing concentrations for many parameters (Almeida et al., 2007). Such numerous variables do not normally communicate any meaningful information to the layman, decision maker, policy makers, water managers or the public, who may need water quality information expressed in a concise form for decision making.

In order to overcome this difficulty or decision making problem and communicate water quality information effectively to the public and water managers, an index that summaries the overall physical and chemical quality of water , generally called the Water Quality Index (WQI) has been proposed for management of water bodies . The first WQI was developed in the United States by Horton (1965) and applied in Europe since the 1970s, initially in the United Kingdom. It has also found applicability in Africa and Asia (Darko et al ., 2013) . This methodology was further improved by the US National Sanitation Foundation (NSFI, 2007)

WQI, is regarded as one of the most effective way of monitoring of water quality (Kannan, 1991). It is a mathematical equation used to transform large number of water quality data into single number (Stambuck-Giljanovic, 1999).

In other words, it is represents simple and easy way to summarize large amounts of water quality data into simple terms (e.g., poor, good etc.) for reporting to management and the public in a consistent manner (Bordalo et al ., 2001)

Despite the various water quality indices have been developed and published in the literature, but previous studies on the use of a WQI in Muthanna are inexistent. Where that Euphrates River is a water source for the Province of Muthanna , and considerable amounts of water are extracted for use in irrigation agriculture and for the production of drinking water for the city of samawah . The river also receives the city's urban waste water, which – until recently – was discharged without any previous treatment . For that reason , the aim of this work was to evaluate the water quality in the Euphrates River using the WQI proposed by the National Sanitation Foundation (USA) Which can be used with data on physical and chemical variables routinely collected by Water Directorate .

Tele:

E-mail addresses: ameer.wisam2005@gmail.com

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Water Quality Index

The use of a WQI was initially proposed by Horton (1965) and Brown et al. (1970). Since then, many different methods for the calculation of WQI's have been developed. In general, they all consider similar physical and chemical parameters but differ in the way the parameter values are statistically integrated and interpreted (Zagatto et al., 1998; Stambuck-Giljanovic, 1999)

Several authors have proposed the use of a Water Quality Index (WQI) as a means to derive a numerical expression for the general quality of a surface water (Brown et al., 1970; Ott, 1978; Miller et al., 1986; Bordalo et al., 2001; Cude, 2001; Hallock, 2002).

Water quality index has no unit, with number ranging from 0 to 100;a higher number is indicative of better water quality and lower value shows poor water quality . In other words , WQI is a mathematical instrument used to transform large quantities of water quality data into a single number, which makes information more easily and rapidly understood than a long list of numerical values for a large variety of parameters (Avvannavar, S. M. et al. 2007).

The following four steps are most often associated with the development of any WQI; depending on the sophistication being aimed at , additional steps may be also be taken (Abbasi et al. 2012) :

1-Parameter selection that together reflect the overall quality of the water body with respect to a given end use .

2-Transformation of each parameter, usually having different units of measurement, into a unitless common scale of 0 -100 sub-index values, where 100 represents the maximum quality.

The transformation or standardization is often performed by creating empirical rating curves, i.e., empirically establishing a relationship between expected values and dimensionless sub-index values. The main advantage of a rating curve is that it rapidly transforms the concentration of a parameter into a quality score to represent the water quality for a given use (Darko et al ., 2013) . The sub index values (established from the rating curves) can also be tabulated in tables for more practical use, where scores are read from the rating table.

3-Assignment of weight ages to each selected parameter on the basis of its importance in water quality evaluation

4-Aggregation of sub indices and weight factors of all parameters using aggregation function, to produce a final index score.

Of these , step 1,2 and 4 are essential for all indices . Step 3 is also commonly taken through some indices may be formed without this step as well.

Water quality indices makes it very easy for a lay person to judge whether a water source is usable or not and how one source compares to another , but the development of WQI is by no means an easy task taken (Abbasi et al. 2012) .

Description of Study Area

Al - Muthanna , is one of Governorate Iraq , covers an area of 51740 km^2 . According to census 2011, the total population of the district has reached up to 719100 inhabitants . Euphrates River is the main river of the district and is one of the major water resources of Iraq that is originating from the southeastern of Turkey and it is essential resources for economic activities. In this paper , samples were taken from two major drinking water sources within Muthanna Province namely Al Khader (site N1) and Al Muthanna water project (site N2) , as shown in figure(1). All information are taken from Water Directorate Muthanna , Iraq .

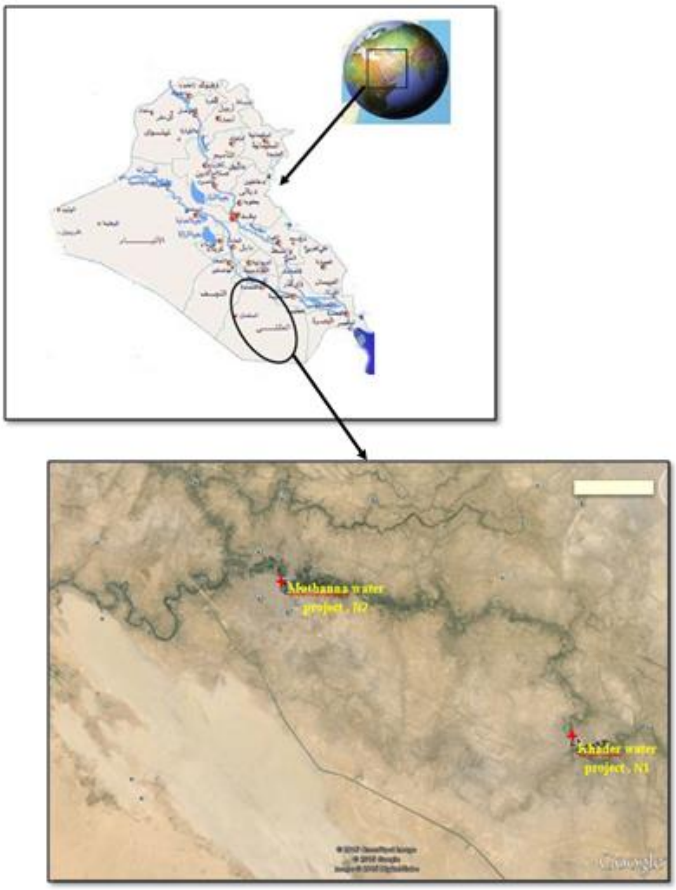

Figure 1. Location of sampling sites at the study area on the Euphrates River

Materials and methods

Data collection

The water samples were collected from two different locations from 2011 to 2014 year on monthly intervals. The samples were analyzed for five parameters which were pH , Turbidity ,Total Suspended Solids (TSS), Temperature and nitrate (NO3) . Water samples were collected into clean plastic bottles from under water surface layer of the River and at depth of 30 cm , On after one meters from the bank of the river , and add a few drops of chloroform for the purpose of storage. Sampling date, place and time were recorded on the sampling bottles before transporting to the Laboratory for analyses.

These locations were selected due to easy accessibility. All field and laboratory determinations were performed according to the Standard Methods for the Examination of Water and Wastewater (APHA, 1998).

Calculating of NSF- Water Quality Index

Brown's et al. (1970) developed a water quality index similar in structure to Horton's index but with much greater rigour in selecting parameter, developing a common scale and assigning weights. This effort was supported by the National Sanitation Foundation (NSF). For this reason, Brown's index is also referred to a NSF-WQ.

The NSF, adopted on the opinions of a panel of 142 persons with expertise in water quality management. On the basis of questionnaires, the NSF, was able to draw up a list of valid parameters which had been rated on a scale of importance. They also established the relation of water quality to values in the form of rating curves. In developing rating curves, the experts were asked to attribute values for variation in the level of water quality caused by different levels of each of the selected parameters.

Table 1. Weighting factors of water quality parameters

Parameter	Weight Factor
DO (Mg/L)	0.17
FAECAL COLIFORM	0.16
BOD (Mg/L)	0.11
pH value	0.11
NITRATE	0.1
PHOSPHATE (Mg/L)	0.1
TEMPERATURE (^oC)	0.1
TURBIDITY (NTU)	0.08
TOTAL SUSPENDED SOLIDS (Mg/L)	0.07

Table 2. Water Quality Ranges

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

So, the Euphrates River water quality was assessed using Brown's weighted arithmetic index. Each individual water quality parameter was transformed into a unitless sub-index (Qi) value using Q-value the charts described by Ott (1978). Next, the sub-index for each parameter was multiplied by its weight (Wi), as shown in Table 1.

For the calculation of the NSF – WQI or Brown's , the following standard equation was used to calculate the overall WQI :

$$WQI = \sum_{i=1}^{n} (w_i \times q_i) \quad \text{.......................... (1)}$$

Where ,

WQI= water quality index

n= the total number of parameters

qi= the sub-index for i^{th} water quality parameter

wi = is the relative weight of the i^{th} parameter such that

$$\sum_{i=1}^{n} w_i = 1 \quad \text{..............................(2)}$$

To convert the numerical values of the WQI into an easily understood format, word descriptors associated with a specific range of WQI values were used, as illustrated in Table 2.

Although the WQI is designed to include nine parameters, it can still be calculated if data for some parameters are missing (Srivastava and Kumar, 2013). In our study, some of the parameters have been excluded from the WQI, because sometimes it is difficult to get the concentration of all nine quality parameters, and then the weights of the missing parameters in the WQI were distributed to other parameters based on the weight of each parameter in the index.

Results and Discussion of Wqi Analysis

The WQI developed was applied to two selected sampling sites (N1 and N2) , to evaluate the water quality of Euphrates river for public uses , using five water quality parameters . The changes in the WQI over time at each two sites are shown in Figures (2) and (3). The WQIs of water collected at region N1 ranged from 61 to 88. The lowest WQI found at this station corresponded to a medium level recorded in summer 2014, whereas the highest value, recorded in summer 2013, was considered Good . While , the results of water quality values are changing slightly during 2011 and 2012 .

In contrast to site N1, the WQI values that recorded at site N2 were higher in summer than in winter. Where the results showed that water quality varied from Excellent to Medium range. There was no large different in water quality between summer season and winter season , exception at winter 2012. The WQI values of samples taken at station N2 were among the highest in Muthanna.

In general, water Quality Index (WQI) reveals the 'Good' and 'Excellent' water quality during seasons . The results of the study confirm the suitability of all selected water sources for drinking purposes. But, regular monitoring is required to determine the pollution load with follow up treatment of water to improve the water quality, which is being used for drinking purpose.

Recommendations and Conclusions

The complexity of water quality data is principle obstacle to understanding and evaluating the environmental situations for any ecosystems. Accordingly, several environmental indices were developed in different fields to communicate environmental status of certain ecosystem to fill the gap between scientific data and people

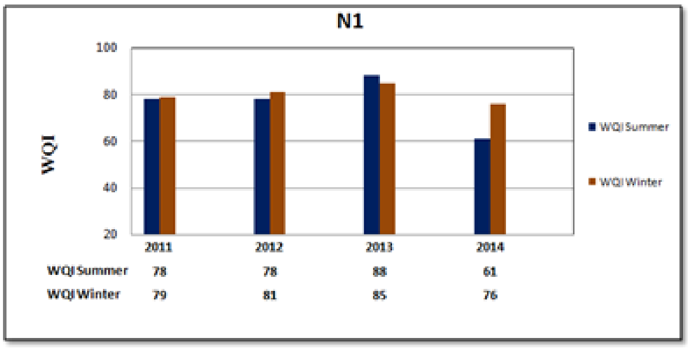

Figure 2. Changes in WQI over time at N1 site

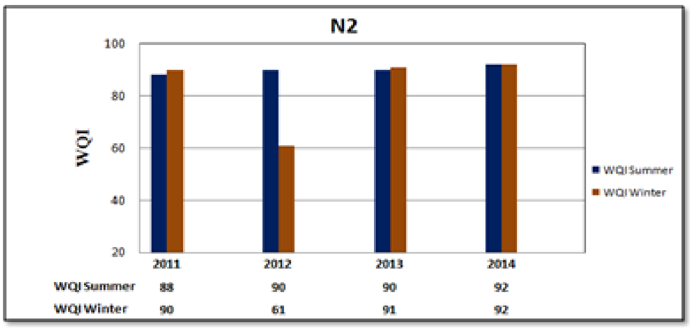

Figure 3. Changes in WQI over time at N2 site

The application of WQI in waters of Muthanna Province indicates effectiveness and simplicity of the index without losing significant information. Using this method to monitor, assess, and report water quality allows decision makers and the public to easily understand the condition of the water quality in Muthanna Province and promotes environmental awareness in the society.

An analysis of the water quality in the Governorate by means of a WQI showed a good general water quality in most of the regions and throughout every year. Therefore , due to its simplicity and effectiveness, our present research recommends using WQI used in this research to communicate and assess the water quality of Muthanna governorate.

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