GIS-based analysis of water quality deterioration of the water treatment plants' effluents in Basrah province

Cite as: AIP Conference Proceedings **2386**, 040004 (2022); https://doi.org/10.1063/5.0066809
Published Online: 11 January 2022

Zahraa Hussain Ali Mahdi and Ahmed Naseh Ahmed Hamdan

GIS-Based Analysis of Water Quality Deterioration of the Water Treatment Plants' Effluents in Basrah Province

Zahraa Hussain Ali Mahdi [a)] and Ahmed Naseh Ahmed Hamdan [b)]

Dept. of Civil Engineering, Engineering College, University of Basrah, Basrah, Iraq

Corresponding author: [a)] eng.civil187@gmail.com
[b)] ahmed.hamdan@uobasrah.edu.iq

Abstract. Because of several factors that led to the deterioration of water quality in Basrah southern Iraqi, which still the problem of degradation still exists up today; therefore a geographic information system (GIS)-based technique with the Water Quality Index was used to evaluate the quality of water effluent from the main water treatment plants in t Basrah. In this study, twelve physicochemical parameters (pH, Ca^{+2}, Mg^{+2}, TH, K^{+}, Na^{+}, SO_4^{-2}, Cl^{-}, EC, TDS, Turbidity, and Alkalinity) were used by analyzing their data and using the water quality index for eight stations selected over a period (2011-2019). The results revealed that the decline in water quality of most stations was due to the intrusion of salinity from the Arabian Gulf and water pollution that drainage into the Shatt Al-Arab River from some branches, as well as the poor performance of the treatment plants.

INTRODUCTION

The term water quality has been used in reference to the quality of water needed for human consumption (i.e. for drinking, agricultural and industrial purposes). For all marine species or habitats, this word is entirely natural [1]. The quality of river water is declining and day by day water contamination has been the key explanation for deterioration in recent years [2]. In order to assess the status of river contamination, constant monitoring of water quality is very critical and, along with many other indices, the Water Quality Index (WQI) refers to a collection of water quality parameters on a common format and transforms them into a single number in conjunction with the system or model of computation chosen [3]. It is necessary to research the water quality and concentration of several variables in order to understand the Iraqi water quality for drinking or other planned use, through using Water Quality Indices (WQIs) and Geographic Information System (GIS) methodologies that can provide an appropriate assessment and also indicating contamination, saving time needed, and water quality management [4]. In some of the environmental subjects in Iraq and other countries in recent decades, several researchers have used water quality index applications and GIS, such as surface water quality, groundwater quality, and sanitation…etc. Using water quality indices, Noori et al. [4] calculated the water quality of the Euphrates River and generated colored WQI maps based on GIS software based on the current categorization of river water to show the river pollution areas in five water treatment plants (Al-Kifl, Al-Kufa, Al-Shannafiya, Al-Manathera, and Al-Shamiya) for 2015 and 2016. Several water quality parameters are used in the analysis: pH, temperature, DO, BOD, PO_4^{-3}, NO_3^{-}, Ca^{+2}, Mg^{+2}, TH, K^{+}, Na^{+}, SO_4^{-2}, Cl^{-}, TDS, EC, and Alkalinity. In the study area, the consistency of the river is graded as fair to highly polluted according to various methods. The results of the WQI classification on the creation of layers and spatial distribution maps of these indices and the display of the river pollution region are associated with the 'ArcGIS' software. Karakuş [5] analyzed the Kızılırmak River water quality and presented the Kızılırmak River water quality maps using the GIS software in the provincial borders of Sivas. For the wet and dry seasons of the year 2015, surface water measurements from 28 monitoring stations were examined. For each station, he calculated the hydro-chemical characteristics of surface water quality and assessed the water quality index. The quality of water of the Kızılırmak River did not meet the drinking water requirements for the study region. For drinking purposes, Muralitharan and Palanivel [6] used GIS in the state of Tamil Nadu to determine and classify the groundwater quality through the Water Quality Index (WQI) process. In

3rd International Scientific Conference of Alkafeel University (ISCKU 2021)
AIP Conf. Proc. 2386, 040004-1–040004-7; https://doi.org/10.1063/5.0066809
Published by AIP Publishing. 978-0-7354-4150-7/$30.00

order to imagine the spatial pattern of groundwater quality in the study area, GIS and WQI methods were applied. A total of 32 geochemical groundwater samples pre- (July-2012) and post monsoon (January-2013) were obtained and analyzed for large anions and cations. Results showed a higher WQI, suggesting the compromised existence of the content of groundwater and the majority of chemical parameters of groundwater were higher than post-monsoon during pre-monsoon.

Honarbakhsh et al.[7] used a geographic information systems (GIS)-based approach with the Groundwater Quality Indicator (GWQI) to assess groundwater quality in Marvdasht in the semi-arid region of Iran, using groundwater quality data collected over a period (2010-2015) for parameters (pH, EC, TDS, TH, HCO^{3-}, $SO4^{-2}$, Cl^{-}, Ca^{+2}, Mg^{+2}, K^{+} and Na^{+}). The results indicated that groundwater content was essentially desirable for drinking. The GWQI map indicates that groundwater was of higher quality in the northern sections of the sample area, but only 2% was greater than that of the low quality class.

The main objectives of this research were: (1) to analyze the physicochemical parameters in order to ascertain the safety of water and health risk in the Shatt Al-Arab River (SAR), (2) to assess their drinking suitability in compliance with Iraqi drinking requirements (3) characterize its spatial and temporal variations on the study area.

MATERIALS AND METHODS

Study Area

The key source of water, in the Basrah Governorate, is the Shatt Al-Arab River (SAR). Another source that was added to the governorate is the Sweet Water Canal (SWC) which was dug as a short-term solution for improved water quality in the late 1990s [8]. SAR in Basrah governorate is 200 kilometers long, 400 meters width in the beginning then expand to reach over 2 kilometers width in the estuary, and a depth ranged between 8-15 meters based on the tide. [9]. The SWC length is about 238 Km and fed from Bada'a, near Shatra, north of An Nasiriya.

Data Collection

The 12 physicochemical parameters chosen in this analysis included pH, Turbidity, Calcium(Ca^{+2}), Magnesium (Mg^{+2}), Total Hardness (TH), Potassium (K^{+}), Sodium (Na^{+}), Sulphates (SO_4^{-2}), Chloride (Cl^{-}), Electrical Conductivity (EC), Total Dissolved Solids (TDS), and Alkalinity. Some parameters such as pH, TDS, Turbidity, and EC were measured directly in the field. Others like Calcium, Magnesium, Total Hardness, Potassium, Sodium, Chloride, Sulfate, and Alkalinity were measured in the laboratory. They were determined in the laboratory within 24 hours of sampling by adopting standard methods of Golterman and Clymo (1969) and APHA (1998) [10]. The samples were taken frequently once, two, or three times per month through the periods extended from January 2011 to December 2019. The measurements were done by the staff of the central laboratory in the Basrah Water Directorate [11], the water samples were collected from each of the stations and placed in polyethylene bottles for the laboratory investigations.

Chemical Material and Method Used

Table (1) includes the methods and chemical materials that have been used in the test of the chemical parameters.

TABLE .1 Methods and Chemical materials used

Chemical Parameter	Method used	Materials used in the test
Ca	EDTA complex metric titration method	Sodium hydroxide (NaOH) and MIROXIDE talltale
TH	EDTA complex metric titration method	Ammonia and Aerochrome dye
Mg	$Mg\left(\frac{mg}{l}\right) = TH - (Ca * 2.5) * 0.244$	
K and Na	photometer model CL378	
SO_4	Spectrophotometric using the barium sulfate turbidity method	Red methyl, hydrochloric acid, Silver nitrate and Barium chloride
Cl^{-}	Silver nitrate titration method	potassium chromate reagent, Silver nitrate
Alkalinity	Burette	Phenol-Naphthalene, Orange Methyl and Thiosulfate

Which should be noted that the standard additions method of calibration was used to effectively compensate for any sample interferences (other than background absorption) provided a working signal is obtained in the sample matrix. In this method, aliquots of increasing analyte concentration are added to equal volumes of the sample. A sample of zero addition is also prepared and all final volumes are equalized. The absorbances are determined and plotted on the vertical axis of a graph and the concentrations of the analyte additions are plotted on the horizontal axis. The resulting line is extrapolated to intercept the abscissa on the left. The point of interception determines the concentration of analyte in the sample[11].

Physical Material

Table (2) includes the method that have been used in the test of the physical parameters.

TABLE 2. Methods and Chemical materials used

Chemical Parameter	Method used
PH	pH meter
TDS	Beaker and filter papers test
EC	Lab WIW meter type Cond 7110
Tur.	Turbidity meter type HACH 2100N

Main Water treatment Plants

For this analysis, eight water treatment plants were selected in Basrah, namely Al-Bradhiah plant (ST1), Al-Jubailah plant (ST2), Garmmat Ali 1 plant (ST3), Al-Shaebah plant (ST4), Al-Labanie plant (ST5), Al-Abbas plant (ST6), Mhejran plant (ST7) and Maheilah plant (ST8), which were selected for the duration 2011-2019 at various locations in Basrah Governorate, as seen in (Table3). Many of these plants are old, conventional plants or plants using multiple package units (MPU). The coordinates of the WTPs under analysis are shown in (Fig.1).

TABLE 3. The stations and their details

Stations	Locations		Type	Water source [1]	Year of installation
	Latitude	Longitude			
ST 1	30° 30' 9.33" N	47° 51' 19.96" E	Conventional	SWC & SAR	1958
ST 2	30° 33' 0.77" N	47° 48' 46.62" E	Conventional	SWC & SAR	1937
ST 3	30° 34' 19.15" N	47° 44' 45.01" E	MPU	SWC & GAR	1986
ST 4	30° 25' 27.09" N	47° 40' 11.34" E	Conventional	SWC	1938
ST 5	30° 27' 50.97" N	47° 59' 7.19" E	MPU	SAR	1970
ST 6	30° 31' 33.09" N	47° 42' 35.83" E	MPU	SWC	1997
ST 7	30° 28' 6.51" N	47° 52' 44.40" E	Conventional	SAR	1991
ST 8	30° 27' 30.20" N	47° 55' 25.21" E	Conventional	SAR	1985

[1]SAR: Shat Al-Arab River, SWC: Sweet Water Canal, GAR: Garmmat Ali River.

[1]Where needed, raw water from the SWC may be supplied [12].

FIGURE 1. Locations of the stations in Basrah City.

Water Quality Index

A weight assignment for each parameter (wi), relative weight measurement (Wi) and consistency rating scale (qi) are needed to calculate WQI. The estimated weights were assigned in accordance with the relative importance of the variables of drinking water quality. The highest weight of 5 was given to parameters which have the main impact on water quality. The calculated Wi parameter values are presented in Table 4.

$$W_i = \frac{W_i}{\sum_{i=1}^{n} W_i} \quad (1)$$

For of parameter, qi was measured using determined parameter concentration (ci) and potable water quality (Si) values based on IQ's guidelines. The qi was computed with eq. (2)

$$q_i = \frac{C_i}{S_i} \times 100 \quad (2)$$

Finally, WQI was computed using computed qi and Wi [13] as shown in eq. (3)

$$WQI = \sum_{i=1}^{n} W_i \times q_i \quad (3)$$

TABLE 4. Water quality parameters and their relative weights.

Parameter	Iraqi guideline standard*	Weight (wi) [14]	Relative weight (Wi)
PH	8.5 - 6.5	3	0.0698
Turbidity	5	5	0.1163
Ca^{+2}	50	3	0.0698
Mg^{+2}	50	3	0.0698
TH	500	2	0.0465
K^{+}	12	2	0.0465
Na^{+}	200	4	0.0930
SO_4^{-2}	250	4	0.0930
Cl^{-}	250	5	0.1163
TDS	1000	5	0.1163
EC	2000	4	0.0930
Alkalinity	120	3	0.0698

*all parameters in mg/L, except EC in µm/cm and Turbidity in NTU. PH has no unit.

In order to identify type of water of the collected samples (Table 5), the results of WQIs were compared with the ranges of WQI [15].

TABLE 5. Table 1 Range of WQI and water type.

Range	Water type
<50	Excellent water
50–100	Good water
100–200	Poor water
200–300	Very poor water
>300	Unsuitable or Unfit

RESULTS AND DISCUSSIONS

As Previously mentioned twelve physicochemical parameters were chosen for the WQI measurement, based on both the relevance of the parameters and the availability of data.

Applying the equations (1-3) on the results of water quality parameters of the eight stations, annual WQIs of the Treated water for temporal variation have been presented in Fig.2, also the temporal and spatial variation have been presented in Fig.3 using GIS software.

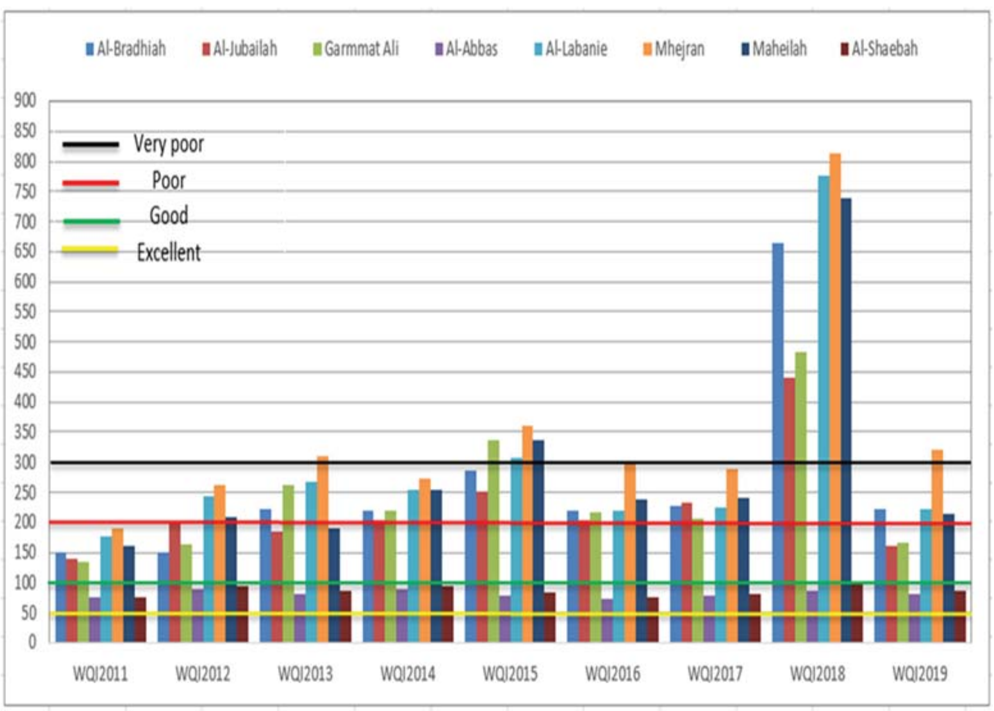

FIGURE 2. Annual water quality index in Basrah City of treated water produced from 8 WTPs over the period (2011–2019)

FIGURE 3. Histogram of treated water of each station in the GIS program during the period 2011-2019.

Spatial and temporal variation of the findings revealed that none of the samples were given either "Excellent" (range 0-50) or "Good" (range 51-100) water quality for the treated water, except Al-Shaebah and Al-Abbas plants in all years which range between 72 to 100, therefore it considered as good water quality. Indicating that the other stations were generally either “Poor” (range 101-200) or “Very poor” (range 201-300) or “Unsuitable” (above 300). The cause of the deterioration of the water quality of these stations, with the exception of the Al-Shaebah and Al-Abbas plants, was the impact of the contamination and salinity intrusion of the Arabian Gulf into the SAR, where all the stations that near to its banks taken the raw water from it.

The Al-Shaebah and Al-Abbas stations which draw the raw water from R-Zero have a somewhat better water quality as compared with other stations.

It can also be seen that the stations of Mhejran, Al-Labanie, and Maheilah were mostly very poor or unsuitable water quality due to the reason that illustrated before as well as the effects of agricultural lands drainages. On temporal basis, the WQI levels for treated water for all stations increased that means a deterioration the water quality for the years 2011-2013 followed by a little improve of the quality for the year 2014 then an increase of WQI in the year of 2015 followed by a two years of improved then a rapid increase of WQI in the year of 2018, then returned to where it was in 2019, as in 2017 except the Mhejran station.

CONCLUSIONS

1. Results identified that the deterioration of the water quality of the stations Al-Bradhiah, Al-Jubailah, Garmmat Ali, Al-Labanie, Mhejran, and Maheilah plants except for Al- Shaebah and Al-Abbas plants were due to the effects of Arab Gulf runoff and salinity intrusion into the SAR.
2. Al-Labanie, Mhejran, and Maheilah plants suffered from agricultural land drainages as well as the previously mentioned reasons.
3. WQI analysis found that for treated water neither of the samples reached excellent nor good water quality except Al- Shaebah and Al-Abbas stations which considered as good water quality.
4. Stations have been designed to provide physical and biological treatment rather than chemical raw water treatment, and this would likely have more effects if combined with the already high levels of raw water chemical contamination shown in most of the results.
5. The year 2018 showed a highly increased in all Ions, and salinity values in all stations except Al-Shaebah and Al-Abbas stations. It can be shown that when the WTP was close to the estuary, the salinity of the raw water increases due to its influence with the salt wedge coming from Arabian Gulf.

ACKNOWLEDGMENT

The authors appreciate the contributions of the laboratory staff in the Water directorate of Basrah governorate for their contributions and help by doing the samples tests for this research.

REFERENCES

1. N.S. Hanna, Y.A. Shekha and L.A.Q. Ali, 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), pp. 2550–2560.
2. P.M. Pujar, H.H. Kenchannavar, R.M. Kulkarni and U.P. Kulkarni, Real-time water quality monitoring through Internet of Things and ANOVA-based analysis: a case study on river Krishna (Applied Water Science [Internet], 2020).
3. A.M. Rabee, B.M. Abdul-Kareem and A.S. Al-Dhamin, Seasonal Variations of Some Ecological Parameters in Tigris River Water at Baghdad Region, Iraq (Journal of Water Resource and Protection, 2011), pp. 262-270.
4. M.M. Noori, K.A. Abdulrazzaq, A.H. Mohammed and A.I. Abbas, Assessment Of Water Quality And Suitability Of Euphrates River In Iraq For Drinking Purpose By Applying Water Quality Indices (Wqis) And Geographical Information System (Gis) Techniques (I.J.S.N., 2017), pp. 741-756.
5. C.B. Karakuş, Evaluation of water quality of Kızılırmak River (Sivas/Turkey) using geo-statistical and multivariable statistical approaches (Environment, Development and Sustainability, 2019).
6. J. Muralitharan and K. Palanivel, GIS based Water Quality Index Method for Groundwater Quality Assessment– Using Hydro Geochemical Data: Karur District, Tamil Nadu, India (Int J S Res Sci. Tech., 2018), pp. 833-842.
7. A. Honarbakhsh, M. Tahmoures, B. Tashayo, M. Mousazadeh, B. Ingram and Y. Ostovari, GIS-based assessment of groundwater quality for drinking purpose in northern part of Fars province, Marvdasht (Journal of Water Supply: Research and Technology – AQUA, 2019), pp. 187-196.
8. JICA, The Feasibility Study on Improvement of the Water Supply System in Al-Basrah City and Its Surroundings in the Republic of Iraq (Tokyo Engineering Consultants Co, Ltd Nippon Koei Co, Ltd, 2007).
9. M. S. Moyel and N. A. Hussain, Water quality assessment of the Shatt al-Arab River, Southern Iraq (Journal of Coastal Life Medicine, 2015), pp. 459-465.
10. APHA, Standard Methods for the Examination of Water and Wastewater, 21st ed. (American Public Health Association (APHA), American Water Works Association, and Water and Environment Federation: Washington, DC, USA, 2005).
11. Voth, L. M., Dealing with Matrix Interferences in the determination of the priority pollutant metals by Furnace AA., Varian Instruments at Work, No. AA-35, Varian Techtron (September 1983) (1983).
12. Basrah Water Directorate (Basrah Governorate, Iraq, 2020).
13. N.S. Kawo and S. Karuppannan, Groundwater quality assessment using water quality index and GIS technique in Modjo River Basin, central Ethiopia (Journal of African Earth Sciences [Internet], 2018), pp. 300-311.
14. H.M. Issa and R.A. Alrwai, Long-Term Drinking Water Quality Assessment Using Index and Multivariate Statistical Analysis for Three Water Treatment Plants of Erbil City, Iraq (UKH Journal of Science and Engineering, 2018). Pp. 39-48.
15. C.R. Ramakrishnaiah, C. Sadashivaiah and G. Ranganna, Assessment of water quality index for the groundwater in Tumkur taluk, Karnataka state, India (E-Journal of Chemistry, 2009), pp. 523-530.