Desalination and Water Treatment
www.deswater.com
doi: 10.5004/dwt.2021.26526

211 (2021) 331–337
January

Assessment of some physico-chemical and microbial pollutants in the water of the Euphrates River between the cities of Hit and Fallujah in Iraq

Wahran Monam Saod[a,*], Safa Sabah Awad[a], Khadra Mokadem[b]

[a]*Department of Chemistry, College of Science, University of Anbar, Ramadi, Iraq, emails: sc.wahran.s@uoanbar.edu.iq (W.M. Saoud), bara80saf@gmail.com (S.S. Awad)*
[b]*Laboratory of Valorization and Promotion of Saharan Resources (VPRS), University of Ouargla, 30000 Ouargla, Algeria, email: mo2kadem@gmail.com (K. Mokadem)*

Received 29 April 2020; Accepted 29 August 2020

ABSTRACT

Safe and reliable drinking water is one of the major prerequisites for a healthy life, as water is of fundamental importance for life on earth. Microbiological contamination is an important water-quality problem faced all over the world. Pathogen contamination of rivers that are primarily used for drinking water is an urgent consideration. For this study, seven samples were taken from different sites at different seasonal periods across four months: January, March, July, and October, all in 2019. The physico-chemical evaluation focused on the pollution of water caused by human activities. The Canadian Council of Ministries of the Environment Water Quality Index methodology (CCME WQI) was used in this study for rating the water quality index (WQI) of the Euphrates River. Physico-chemical parameters including pH, temperature, nitrate ion, calcium, magnesium, total hardness, sulfate ion, chloride, total dissolved salts, electrical conductivity, alkalinity, and turbidity were determined. Water samples were analyzed for the presence of trace elements (copper and zinc). The microbiological examination included the determination of counts of bacteria *Enterobacteriaceae* cultivated at 36°C–37°C for 18–24 h. The results of the physico-chemical analysis and mean microbial counts of the investigated water samples were compared with the set standards (WHO guidelines for drinking water quality). Most of the physico-chemical term data indicated poor quality concerning turbidity, conductivity, and sulfate ion concentration with values much higher than the permissible standards. Water pH varied 7.6 with 574.714 ± 65.688 mg/L dissolved solids, EC (1,105.821 ± 143.986 μS/cm), tur (19.289 ± 2.845 NTU), and hardness (405.8 ± 40 mg/L) (within limit). Calcium (106.629 ± 7.244 mg/L), magnesium (43.232 ± 4.439 mg/L), and sulfate (299.964 ± 11.397 mg/L) exceeded permitted levels whereas nitrate ions were below the limit (3.564 ± 0.342 mg/L). The concentrations of trace elements, including zinc, in the current water samples were >0.01 mg/L. The bacteriological quality of most water samples analyzed in the current study did not meet the standards set for drinking water as the results showed that the count of total aerobic bacteria had reached the maximum level (114×10^{-6}) cell/mL. The results of this study, therefore, show that the bacteriological data and physico-chemical parameters of the different water samples had values beyond the maximum tolerable limits recommended by the WHO for drinking water. The second part of this work focused on the spatial variability of the WQI of the Euphrates River study area, and the water samples reveal that the majority fall under marginal to poor WQI.

Keywords: Euphrates River; Iraq; Water; Pollution; Chemical; WQI

* Corresponding author.

Presented at the International Conference on Sustainable Water Treatment Technologies and Environment (SUST-WATER 2019), 14–16 October 2019, Tipasa, Algeria

1. Introduction

The Euphrates River, the longest river in southwest Asia, is one of two defining rivers of Mesopotamia (the "land between the rivers"). The river rises in Turkey and flows southeast across Syria and through Iraq, joining the Tigris to form the Shatt al-Arab in southern Iraq, which empties into the Arabian Gulf. The Euphrates is considered a vital resource for Turkey, Syria, and Iraq because of its role in communities, agriculture, drinking, and industry. Iraq is an arid country, so the Euphrates and Tigris are major sources of freshwater. As a result of natural factors and the extended human occupation and improper human activities in the riparian states (Turkey, Syria, and Iraq), problems have arisen with the river water. Construction of dams, barrages, and canals to divert the maximum river water for irrigation has changed the river flow regime over the last 50 y. Several studies on the Euphrates have been conducted in the Iraqi province of Anbar, providing up-to-date information on the physical conditions there. All the studies have concluded that poor environmental management, population growth, the impact of three wars, as well as climate change have all had a seriously detrimental impact on the water quality of the Euphrates. Growth in water-intensive agriculture has often been associated with a loss of water quality caused by salt, pesticides, and fertilizer runoff and leaching [1]. Water quality can be assessed by measuring different physical, chemical, and bacteriological parameters. To be able to compare multiple parameters between water samples/sources, a mathematical model is used to express the water quality in a single value, known as water quality index (WQI). Seasonal analysis for water quality using different types of WQIs has been undertaken worldwide [2]. Water is vital for our existence and its importance in our daily life makes it imperative that thorough microbiological and physio-chemical examinations are conducted on it. Potable water is water that is free from disease producing microorganisms and chemical substances that are dangerous to health [3]. The effects of human activity on aquatic ecosystems have been reported for over 200 y [4]. Trace elements such as copper, iron, manganese, selenium, and zinc, and those potentially toxic elements such as silver, aluminum, arsenic, cadmium, lead, and nickel, which are essential for plant growth can be toxic when concentrations are raised above specific cut-off levels [5,6]. Along with fast population growth, industrialization, as well as some agricultural activities, water pollution from agriculture has direct and negative impacts on human health. Approximately 80% of diseases are waterborne according to the world health organization (WHO) [7], and unsafe water causes around 3.1% of deaths worldwide [8]. There is also a strong association between pollution and health problems. Disease causing microorganisms are known as pathogens, and these pathogens are spreading disease directly among humans. Some pathogens are worldwide while others are found in well-defined areas [9]. The ingestion of contaminated water containing pathogenic bacteria from human and animal feces is regarded as a main source of infection, and contaminated water may pollute the freshwater because it contains pathogenic bacteria, protozoa, parasites, and viruses [10,11].

The WQI is one of the most effective tools to communicate information on the quality of water to concerned citizens and policy makers. It has thus become an important parameter for the assessment and management of surface water, and is widely used in multiple scientific publications related to the necessities of sustainable management [12]. Horton [13] developed the first WQI [14]. Today, most WQIs are reviewed by the American Public Health Association [15]. In these WQIs, water quality is a unitless number describing the water quality of the water body state. It is acquired by aggregating the reading and measurement values of the selected water quality parameters. The benefits of using a WQI were reported by Sutadian et al. [16]. As a result of poor environmental management, population growth, the impact of three wars, as well as climate change impacts, water quality has become a serious issue on the Euphrates River. Several studies on the Euphrates River have been done in the Iraqi provinces of Anbar, provided up-to-date information on the physical conditions of the river, paying special attention to hydrology and water quality [17,18]. This work aims to (1) investigate the effects of pollutants in the water quality of Euphrates River and (2) study the extent of water deterioration of Euphrates River water.

2. Materials and methods

2.1. Study area and water sampling

This study was focused on chemical and microbial pollutants occurring in the water of the Euphrates River. The water samples were collected in 2019 from seven stations in cities along Euphrates River, starting from the city of Hit and ending in the city of Fallujah:

- Site no. (*S*1) is situated west of Hit.
- Site no. (*S*2) is situated south of Ramadi.
- Site no. (*S*3) is situated north of Ramadi.
- Site no. (*S*4) is situated near Fallujah.
- Site no. (*S*5) is situated near Alwarar.
- Site no. (*S*6) is situated near Alwarar.
- Site no. (*S*7) is situated in Al-Habbaniyah Lake.

The water samples (250 mL) were collected from the surface in sterile bottles in each site, and then the bottles were closed tightly and kept at 4°C, and chemical analysis and was conducted as soon as possible in the laboratories of the Departments of Chemistry and Biology of Directorate of Environment of Anbar Governorate, University of Anbar to avoid unpredictable changes in the microbial population.

2.2. Chemical and microbiological analysis

In this study, 15 physico-chemical and bacteriological were measured: the parameters were acidity (pH), temperature (Tem), nitrate ion (NO_3^-), calcium (Ca^{+2}), magnesium (Mg^{+2}), total hardness (TH), sulfate ion (SO_4^{-2}), chloride (Cl^-), total dissolved salts (TDS), electrical conductivity (EC), alkalinity (Alk), turbidity (tur), copper, and zinc, in addition to total bacteria (TB). The values of pH, temperature, turbidity, and electrical conductivity were measured in the field while the levels of TDS were performed in the laboratory.

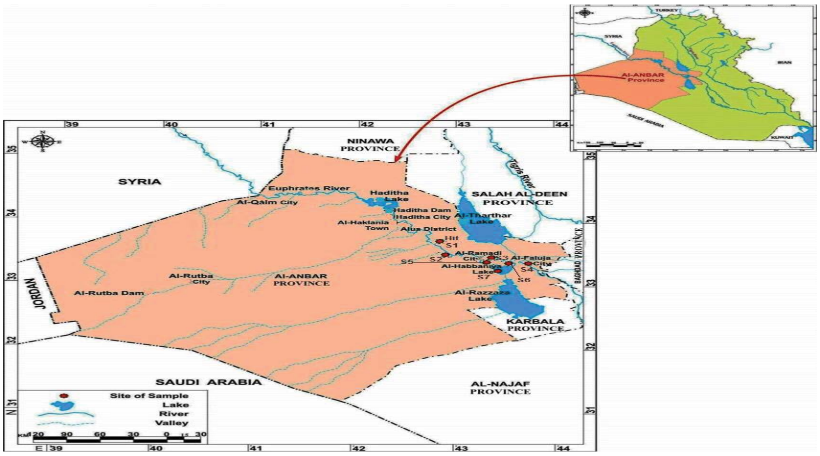


Fig. 1. Location map of Anbar governorate, sampling stations of the Euphrates River from Hit to Fallujah [18].

Total hardness (TH) and alkalinity were measured by titration. The concentrations of calcium, magnesium, copper, and zinc were measured using atomic absorption spectrometry (AAS). The standard solution 1,000 mg/L was prepared by dissolving the required weight in a liter of distilled water and kept in a bottle made of polyethylene, after which a series of diluted standard solutions was prepared at different concentrations. Concentrations of chloride, alkalinity, nitrate ion, and sulfate ion were estimated using UV-VIS spectrophotometric analysis. Total count (TC) of bacteria was determined on plate-count agar (PCA) media and the colony counts expressed as total plate count units (TPC) per milliliter.

3. Results and discussion

The descriptive statistics results of water quality parameters of the Euphrates River in Al-Anbar Governorate, Iraq, are listed in Table 1. A comparison of mean values of the Euphrates water quality parameters with WHO guidelines showed that the mean value of temperature, sulfate, total dissolved salts, electrical conductivity, turbidity, copper, zinc, and TBC all exceeded WHO guidelines, while the other parameters were within permissible limits. The spatial variation of temperature, sulfate ion, total dissolved salts, electrical conductivity, turbidity, copper, zinc, and TBC is shown in Fig. 2. Temperature plays an important role in changing water chemistry. Increases in temperature enhance the ability of water, particularly groundwater, to dissolve minerals quickly from the surrounding rock, and will, therefore, have a higher electrical conductivity. Water temperature can also affect the growth of aquatic organisms and their biological activity [19]. Temperature thus plays a major role in controlling what is able to survive in surface water, temperature thus plays a major role in controlling what is able to survive in surface water [19].

Table 1
Descriptive statistics of water quality parameters of Euphrates River and WHO guidelines

Parameter	Mean	Minimum	Maximum	Range	Standard deviation	Coefficient variation	WHO guidelines [20]
pH	7.675	7.475	7.825	0.350	0.133	1.734	6.5–8.5
Temperature (°C)	23.179	22.225	23.800	1.575	0.533	2.299	20
NO_3^{-1} (mg/L)	3.564	2.9000	4.000	1.100	0.342	9.599	10
Ca^{+2} (mg/L)	106.629	94.150	113.175	19.025	7.244	6.794	200
Mg^{+2} (mg/L)	43.232	39.000	50.000	11.000	4.439	10.269	50
TH (mg/L)	405.800	347.450	467.275	119.825	40.025	9.863	600
SO_4^{-2} (mg/L)	299.964	255.000	365.750	110.750	34.187	11.396	200
Cl^{-1} (mg/L)	169.364	128.375	201.550	73.175	25.199	14.878	200
TDS (mg/L)	574.714	494.5000	705.000	210.5000	65.688	11.429	500
EC (μS/cm)	1,105.821	938.000	1,394.250	456.250	143.986	13.020	750
ALK (mg/L)	158.783	141.600	182.650	41.050	14.439	9.093	200
TUR (NTU)	19.289	14.500	22.075	7.575	2.845	14.748	5
Cu^{+1} (mg/L)	0.038	0.027	0.050	0.023	0.007	19.346	>0.01
Zn^{+2} (mg/L)	0.038	0.027	0.050	0.023	0.008	22.664	>0.01
LogTBC (cell/mL)	6.607	5.980	7.104	1.1240	0.430	6.509	0

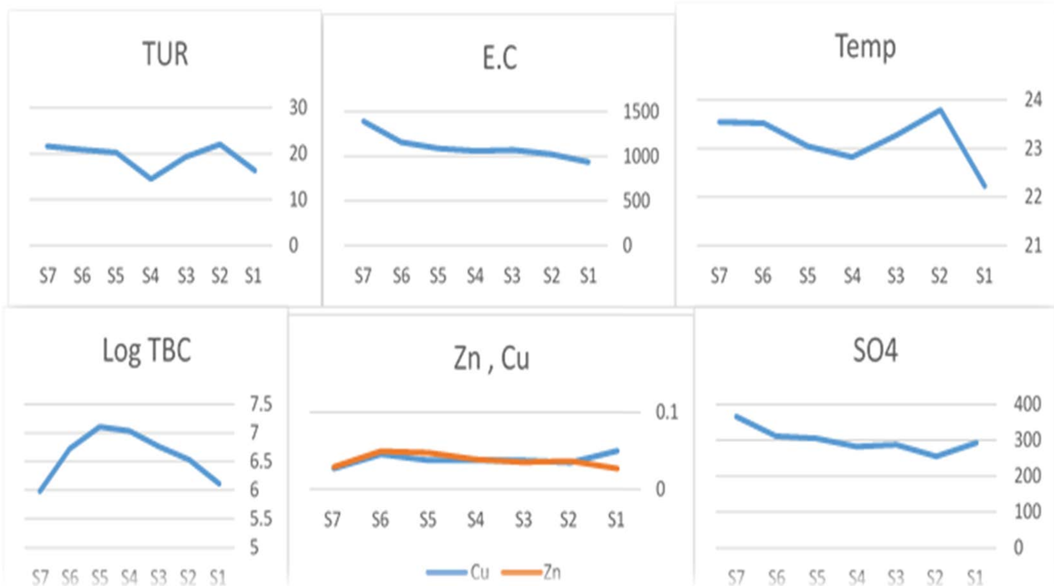


Fig. 2. Tem, Tur, EC, SO_4, Cu, Zn, and total count bacteriological analysis of Euphrates River.

The descriptive statistics results of water quality parameters of the Euphrates River in Al-Anbar Governorate, Iraq is listed in Table 1. Comparison of mean values of the Euphrates river water quality parameters with WHO guidelines showed that the mean value of temperature, sulfate, total dissolved salts, electrical conductivity, turbidity, copper, zinc, and TBC exceeded the WHO guidelines, while the other parameters are within the permissible limits. The spatial variation of temperature, sulfate ion, total dissolved salts, electrical conductivity, turbidity, copper, zinc, and TBC is shown in Fig. 2. Temperature plays an important role in changing water chemistry. Increase in temperature enhances the ability of water, particularly groundwater to dissolve minerals quickly from the surrounding rock and will therefore have a higher electrical conductivity. Water temperature can also affect the growth and biological activity [19]. The temperature has a major role in control ling living things that can live in surface water.

In the current study, we observed spatial changes in sulfate ion concentration (Fig. 2). The reason for this rise is due to the chemical content of Iraq's groundwater, which is mainly determined by four positive ions – calcium, magnesium, sodium, and potassium – and four negative ions – bicarbonate, carbonate, chloride, and sulfate [21]. Copper and zinc showed a slight increment in the study area (Fig. 2). The reason for this rise is due to multiple human activities such as agrarian overflow, urbanization, industrialization, and drainage of untreated sewage into the river [22,23]. Increasing the accumulation of copper and zinc in the soil and crops is a danger to human and animal life, so it is necessary to consistently monitor the concentration of these elements [24,25]. The total number of bacteria increased with spatial and seasonal changes in the logarithm total number of aerobic bacteria, with an average of 6.6 cell/mL (Fig. 2). In these situations, it is more likely that water may contain huge numbers of pathogenic bacteria due to the wastewater that drains water directly into the river without treatment. Higher temperatures and rains can ultimately lead to increased levels of bacterial numbers in the river water as well as increase the activity and proliferation of bacteria. Floods also contribute to a high number of bacteria, organic matter, plant residues, and bacteria present in the soil [26].

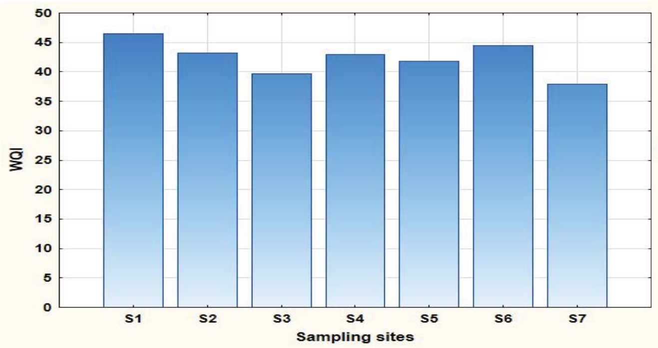
3.1. Water quality index

The WQI values of the Euphrates River in the study area range from 42.24 to 52.88 with a mean value of 47.1, and the water quality of the Euphrates is classified as marginal according to the classification of CCME. WQI water standards are defined as 95–100 (excellent), 80–94 (good), 65–79 (fair), 45–64 (marginal), and 0–44 (poor) [27]. The obtained result is consistent with the results of previous studies [28,29]. The spatial variation of WQI in the study area did not show a remarkable pattern (Fig. 3). The highest and lowest values of WQI are in *S*4 and *S*7, respectively. The *S*2, *S*3, and *S*5 locations are in Ramadi and Fallujah city, the latter being the capital of Anbar Governorate and the largest urban center. The WQI values in *S*2, *S*1, *S*5, and *S*7 are interpreted in terms of increasing concentrations of total dissolved salts, sulfate ion, electrical conductivity, total dissolved salts, chloride ion, and sulfate ion. The WQI value decreases in downstream sampling sites compared with the upstream sites. The WQI values in *S*2, *S*3, *S*5, and *S*7 are interpreted in terms of increasing concentrations of total dissolved salts, electrical conductivity, and decreasing concentrations of sulfate ion. The temporal variation of WQI in the study area is shown in Fig. 3. The WQI categories range from poor (March, July, and October) to marginal (January). The poor water quality of Euphrates River in Anbar governorate from Hit to Fallujah city (March, July, and October) is attributed to an increase of alkalinity levels. The deterioration of the Euphrates water quality in July is

Table 2
Correlation matrix analysis of water quality parameters and water quality index

	PH	T	NO_3	Ca	Mg	TH	SO_4	Cl	TDS	EC	ALK	TUR	Cu	Zn	LogTBC	WQI
PH	1.00															
Temperature	0.18	1.00														
NO_3	0.08	0.49	1.00													
Ca	–0.17	0.08	0.18	1.00												
Mg	–0.32	0.67	0.07	–0.11	1.00											
TH	0.10	0.43	0.07	0.71	0.37	1.00										
SO_4	–0.27	0.10	0.42	0.69	0.21	0.69	1.00									
Cl	0.30	0.63	0.35	0.50	0.36	0.78	0.47	1.00								
TDS	–0.28	0.56	0.40	0.65	0.60	0.82	0.83	0.63	1.00							
EC	–0.19	0.54	0.41	0.66	0.56	0.86	0.86	0.69	0.99	1.00						
ALK	–0.65	0.35	0.38	–0.08	0.75	0.07	0.44	0.04	0.57	0.51	1.00					
TUR	0.22	0.82	0.78	0.00	0.50	0.27	0.26	0.67	0.48	0.49	0.44	1.00				
Cu	0.26	–0.62	0.01	–0.31	–0.82	–0.68	–0.37	–0.70	–0.71	–0.69	–0.47	–0.44	1.00			
Zn	0.74	0.31	0.24	0.34	–0.43	0.26	–0.13	0.43	–0.05	–0.00	–0.70	0.22	0.16	1.00		
Log TBC	0.42	0.02	–0.27	0.28	–0.47	0.05	–0.44	0.18	–0.31	–0.31	–0.82	–0.21	0.10	0.77	1.00	
WQI	0.34	–0.63	–0.65	–0.21	–0.58	–0.27	–0.44	–0.59	–0.61	–0.59	–0.68	–0.80	0.64	0.13	0.31	1.00

Marked correlations are significant at $p < 0.05$.



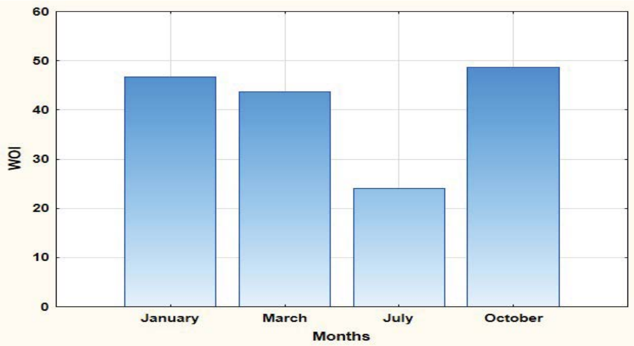


Fig. 3. Spatial variation and temporal variations of WQI of the Euphrates in Anbar Governorate.

due to the high levels of total dissolved salts, nitrate, chloride, and sulfate ion.

3.2. Correlation matrix analysis

The results of the correlation matrix analysis are shown in Table 2. Generally, a correlation coefficient >0.7 reflects a strong correlation between two variables, whereas coefficient values between 0.50 and 0.70 are interpreted as a moderate correlation [30]. Turbidity showed a strong positive correlation with temperature (R = 0.82) and with nitrate ion (R = 0.8). The correlation coefficient between WQI and turbidity (r = –0.82) showed a significant positive relationship (P < 0.05). The correlation coefficient between total hardness with total dissolved salts, sulfates ion, and chloride ion showed a significant positive relationship (P < 0.05). TBC showed a significant positive relationship (P < 0.05) with alkalinity and zinc ion.

Water temperature affects most of the chemical reactions that occur in water and also affects dissolved-gas concentrations in the water such as oxygen, carbon dioxide, nitrogen, and ammonium. When the water temperature is high, the dissolved-oxygen concentration is often lower [30]. This heat then travels from the debris to the surrounding water molecules, causing a change in the temperature of the surrounding water [30–32]. The relationship between the turbidity and the temperature cannot be explained accurately because of climatic changing conditions; however, the association is strong around midday, the time of maximum incoming solar radiation ("load reaches the earth's surface"). The linear relationship between turbidity and water temperature leads to more turbidity and the water having a higher near-surface temperature [33]. The geological structure which the water is in contact with affects water hardness and is considered the main reason for this [34]. The electrical conductivity and sulfate ion increase due to soil washing in the river domain. The important indicator for a group of eutrophication due to phytoplankton is a group of organisms that is sensitive to nutrient variation [35].

4. Conclusion

From the obtained results, the following conclusions are drawn:

- The Euphrates River water in the study area and during the monitoring period is polluted with bacteria and is unsuitable for use without treatment.
- Many of the Euphrates river water quality parameters in the study area and during the monitoring period exceeded WHO guidelines and although the other parameters were within permissible standards, the water is unsuitable for drinking purposes without treatment.
- The WQI value of the Euphrates River in the study area and during the monitoring period is classified as marginal. The consistency of this result with that of the previous studies reflects the continuity of the river retaining its deteriorating marginal quality.
- There are no significant temporal and spatial variations in WQI of the Euphrates River. This suggests the stability of the sources of pollution qualitatively and quantitatively.

References

[1] N. Shamout, G. Lahn, The Euphrates in Crisis Channels of Cooperation for a Threatened River, Energy, Environment and Resources, Chatham House, The Royal Institute International Affairs, April, 2015, pp. 1–43. Available at: https://www.chathamhouse.org/sites/files/chathamhouse/field/field_document/20150413Euphrates_0.pdf

[2] C. Shaji, H. Nimi, L. Bindu, Water quality assessment of open wells in and around Chavara industrial area, Quilon, Kerala, J. Environ. Biol., 30 (2009) 701–704.

[3] A. Lamikaran, Essential Microbiology for Students and Practitioners of Pharmacy, Medicine and Microbiology, 2nd ed., Amkra Books, 1999, 406pp.

[4] R. Vink, H. Behrendt, W. Salomons, Development of the heavy metal pollution trends in several European rivers: an analysis of point and diffuse sources, Water Sci. Technol., 39 (1999) 215–223.

[5] G.H. Sanai, Industrial Toxicology, 7th Revision, University of Tehran Press, Iran, 2006.

[6] E.J. Massaro, Handbook of human toxicology, Choice Reviews Online, 35 (1998) 35-3903-35–3903, doi: 10.5860/choice.35-3903.

[7] N. Khan, S.T. Hussain, A. Saboor, N. Jamila, Physicochemical investigation of the drinking water sources from Mardan, Khyber Pakhtunkhwa, Pakistan, Int. J. Phys. Sci., 8 (2013) 1661–1671.

[8] P. Sagar Gawande, Ground water pollution and its consequences, Int. J. Eng. Res. Gen. Sci., 3 (2015) 2007–2010.

[9] J. Halder, N. Islam, Water pollution and its impact on the human health, J. Environ. Hum., 2 (2015) 36–46.

[10] P.K. Pandey, P.H. Kass, M.L. Soupir, S. Biswas, V.P. Singh, Contamination of water resources by pathogenic bacteria, AMB Express, 4 (2014) 1–16.
[11] I. George, P. Crop, P. Servais, Use of β-D-galactosidase and β-D-glucuronidase activities for quantitative detection of total and fecal coliforms in wastewater, Can. J. Microbiol., 47 (2001) 670–675.
[12] A. Parparov, K.D. Hambright, L. Hakanson, A. Ostapenia, Water quality quantification: basics and implementation, Hydrobiologia, 560 (2006) 227–237.
[13] R.K. Horton, An index number system for rating water quality, J. Water Pollut. Control Fed., 37 (1965) 300–305.
[14] K.A. Shah, G.S. Joshi, Evaluation of water quality index for River Sabarmati, Gujarat, India, Appl. Water Sci., 7 (2017) 1349–1358.
[15] S. Tyagi, B. Sharma, Water quality assessment in terms of water quality index, Am. J. Water Resour., 1 (2014) 34–38.
[16] A.D. Sutadian, N. Muttil, A.G. Yilmaz, B.J.C. Perera, Development of a water quality index for rivers in West Java Province, Indonesia, Ecol. Indic., 85 (2018) 966–982.
[17] E.A. Al-Heety, A.M. Turky, E.M. Al-Othman, Physico-chemical assessment of Euphrates River between Heet and Ramadi Cities, Iraq, J. Water Resour. Prot., 3 (2011) 812–823.
[18] F.T. Mhaisen, J.M. Al-jawda, K.R. Asmar, M.H. Ali, Checklists of fish parasites of Al-Anbar province, Iraq, Biol. Appl. Environ. Res., 1 (2017) 17–56.
[19] K.U. Kramer, E. Guest, C.C. Townsend, Flora of Iraq, Taxon, 16 (1967) 53–54.
[20] RS2, Potable Water Specification, 2nd ed., Rwanda Bureau of Standard, Kigali, 2012.
[21] R. Bhateria, D. Jain, Water quality assessment of lake water: a review, Sustainable Water Resour. Manage., 2 (2016) 161–173.
[22] F.M. Hassan, M.M. Saleh, J.M. Salman, A study of physicochemical parameters and nine heavy metals in the Euphrates River, Iraq, J. Chem., 7 (2010) 685–692.
[23] L. Djordjević, N. Živković, L. Živković, A. Djordjević, Assessment of heavy metals pollution in sediments of the Korbevačka River in southeastern Serbia, Soil Sediment Contam., 21 (2012) 889–900.
[24] P. Wongsasuluk, S. Chotpantarat, W. Siriwong, M. Robson, Heavy metal contamination and human health risk assessment in drinking water from shallow groundwater wells in an agricultural area in Ubon Ratchathani province, Thailand, Environ. Geochem. Health, 36 (2014) 169–182.
[25] M.Y. SouDakouré, A. Mermoud, H. Yacouba, P. Boivin, Impacts of irrigation with industrial treated wastewater on soil properties, Geoderma, 200–201 (2013) 31–39.
[26] M.N. Al-Sanjari, Environmental Study of the Tigris River within the City of Mosul Master Thesis, Faculty of Science - Department of Life Sciences, University of Mosul, 2001.
[27] A. Lumb, D. Halliwell, T. Sharma, Application of CCME water quality index to monitor water quality: a case of the Mackenzie River Basin, Canada, Environ. Monit. Assess., 113 (2006) 411–429.
[28] W.M. Saod, E.A.M.S. Al-Heety, M.M. Mohammed, Spatial and temporal variation of water quality index of Euphrates River in Anbar Governorate, Iraq, AIP Conf. Proc., 2213 (2020) 020042-5-020042-6.
[29] W.M. Saod, F.A. Rashid, A.M. Turki, M.J.M. Al-Taee, Water quality indices for Euphrates River, J. Vet. Res., 23 (2019) 407–413.
[30] I.C. Nnorom, U. Ewuzie, S.O. Eze, Multivariate statistical approach and water quality assessment of natural springs and other drinking water sources in Southeastern Nigeria, Heliyon, 5 (2019) 1–4.
[31] WHO, International Standards for Drinking Water, 3rd ed., Geneva, 1971.
[32] R.M. Pangborn, L.L. Bertolero, Influence of temperature on taste intensity and degree of liking of drinking water, J. Am. Water Works Assoc., 64 (1979) 511–515.
[33] K.P. Paaijmans, W. Takken, A.K. Githeko, A.F.G. Jacobs, The effect of water turbidity on the near-surface water temperature of larval habitats of the malaria mosquito *Anopheles gambiae*, Int. J. Biometeorol., 52 (2008) 747–753.
[34] J.A. da Costa, J.P. de Souza, A.P. Teixeira, J.C. Nabout, F.M. Carneiro, Eutrophication in aquatic ecosystems: a scientometric study, Acta Limnol. Bras., 30 (2018) 2–6.
[35] E.B. Thorstad, A.H. Rikardsen, A. Alp, F. Okland, The use of electronic tags in fish research - an overview of fish telemetry methods,Turk. J. Fish. Aquat. Sci., 13 (2013) 881–896.