Evaluation of Water and Sediment Quality by Bacteriological Diversity Studies on Certain Locations of the Diyala River, Baghdad

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ABSTRACT

With a focus on the impact of the Rustumiya sewage treatment facility, the physio-chemical and indicator bacterial contamination pollution of the Diyala River (Iraq) was examined. The Diyala River in Baghdad was sampled on a monthly basis from March 2022 to February 2023 for surface water and sediment. The findings demonstrated seasonal and geographical variation in physio-chemical parameters (pH, EC, salinity, and TDS) and bacteriological markers (TC, FC, *E. coli*, and FS). The research procedures and methods showed that some physicochemical parameters (pH, EC, TDS) in sediment exceeded their standard limits concerning aquatic life protection in spring and summer. The level of bacteriological pollution in the water and sediments, evaluated by tracking of faecal indicator bacteria (*E. coli* and Enterococci), during the autumn and winter seasons had the largest concentration of bacterial contaminants. In this study, the main finding was the majority of the studied stations had water classified as not recommended or unacceptable and sediment classified as acceptable or conservatively accepted. The source of contamination, determined by the ratio value of faecal coliform bacteria to faecal Streptococcus, was from human origin in the majority of studied stations, and from mixed origin during the spring and summer. Bacterial indicators in this research exhibited both quantitative and qualitative fluctuation, suggesting their potential utility as a bio-indicator for contamination of water and sediment in the Diyala River.

1. INTRODUCTION

The majority of cases where the faecal contamination factor (FC:FS ratio) was greater than 4 showed that the area was predominately affected by human-borne faecal contamination. The release of untreated wastewater into rivers or rivers that have received inadequate treatment from water treatment facilities is a major contributor to the detriment of the aquatic ecosystem. This is due to the fact that heavy water is discharged into rivers without treatment. Since man began storing the earth, water systems have been the most heavily used natural resource (Yehia and Sabae, 2011; Khaled, 2016; Hawraa and Mrooj, 2018; Humudat et al., 2020). Human and animal waste, as well as temperature, oxides, salt, and pesticides are examples of biological pollutants that have deleterious effects on microbial populations in water and sediments (Filimon et al., 2010; Diwan et al., 2018; Abdus et al., 2019).

Due to their quick adaptation to new conditions, bacteria provide excellent sensors for monitoring microbiological contamination of surface water (Gunda and Mitra, 2016; Kirschner et al., 2017; Chen et al., 2019). Bacteria may be used as indicators of water quality from two perspectives: either they indicate fecal pollution of the water supply or they pose a health concern (Baghed et al., 2005).

Although there is no consensus on how best to measure microbial contamination in water systems, total coliform bacteria (TCB) and fecal coliform bacteria (FCB) have historically been used as microbial indicators of water (APHA, 2005). While FCB are not directly harmful to humans or animals, their presence in water systems is a sign that waste from humans and other warm-blooded species has made its way there (Yehia and Sabae, 2011; Sudip et al., 2021).

Commonly used indicators include coliform bacteria, which may have been reduced from total

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coliform to fecal coliform and faecal Streptococci (Kistemann et al., 2002). Commonly used indicators include coliforms, which may have been reduced from total coliforms to faecal coliforms and faecal Streptococci (Messner et al., 2017; Ramos-Ramírez et al., 2020).

The removal and degradation of pollutants and their conversion into lower risk compounds through sedimentation, aeration, filtration, chlorination and other processes at treatment plants such as the Al-Rustamiya Wastewater Treatment Plant are important steps in the process of reducing pollutant levels. Water Spill Hazard (RSTP). Pollution of most of the rivers and streams in Baghdad governorate is increasing exponentially due to a combination of factors including the carelessness of citizens and the irregularities of many authorities dumping waste directly into the rivers. The Diyala River is considered to be one of the largest rivers in the province, stretching for more than 150 km. Early roads in Iran, considered one of the most important tributaries of the Tigris. Several writers have examined the Diyala River, focusing on water quality (Al-Lami et al., 1996; Ayad, 2017; Abd Alkhder et al., 2019).

Bacterial pollution in the water body is one of the major issues concerning the sanitary quality of drinking and recreational water. The pollution of water samples by bacteria might become the cause of a severe epidemic of enteric diseases. So, the purpose of this research was to study the prevalence of the bacterial indicator in the Diyala River in Iraq, both in its water and in its sediments.

2. METHODOLOGY

2.1 Area of study

The objective of this research was to investigate the degree to which the bacterial indicator was prevalent in the Diyala River in Iraq, both in the water and the sediment. At Sanandaj in Iran's Zagros Mountains, the Diyala River begins its journey. This river serves as the border between Iran and Iraq for more than 30 km. The river drains an area that is 32,600 km^2, and its length is 574 km (UN-ESCWA and BGR, 2013). The objective of this research was to investigate the degree to which the bacterial indicator was prevalent in the Diyala River in Iraq, both in the water and the sediment.

The three main tributaries of the river are Don Lo, Sarawang and Vander. It crosses the Hemreen Mountains before branching into many other streams including Diyala, Al-Khalis, Rose, Haronia, Shahraban, Mahrute and Khraisan. Three dams were built on the river; their numbers are as follows: Darbandekhan (three times 109 m^3), Diyala (a controlled dam), and Hemreen (four times 109 m^3).

One of the most important projects is the Al-Rustumiya treatment facility, which provides services to the Rusafa neighborhood in the eastern part of Baghdad. The community's sewage is discharged into the Diyala River, which eventually flows into the Tigris River. The former Al-Rustmiya Sewage Treatment Plant consists of two stations, the first being the Al-Rustmiya South Station. This station has been in operation since 1963 and is comprised of the integrated projects three zeros (F0) and expansion I (F1), respectively. Since 1984, the Extension II (F2), also known as the Al-Rustumiya north station, has been in service. The Diyala River will ultimately become the site of the plant's discharge (Al-Sakini, 2016). Four sites along the Diyala River were chosen. Site (1) was about 800 meters north of the Rustamiya Wastewater Treatment Plant. Site (2) was located at the new Diyala Bridge after the outflow of the north Rustamiya into the Diyala River, which was approximately 1.8 km away from the first site. The site (3) was located on the army channel after the outlet south of Rustamiya in the Diyala River, which was approximately 3 km away from the second site. The fourth site is located near the AL-Rasool Bridge, which is about 3 km away from the third site (Figure 1).

2.2 Sample collection

Water and sediment samples will be collected monthly at four different locations from March 2022 to February 2023. The water was sampled from mid-stream, from the surface layer (25-35 cm deep) directly into sterile flasks. These samples are analysed at the environmental laboratory as soon as practicable after collection. Sediment samples were collected using a van veen scoop sampler; from which the samples were aseptically transferred into sterile glass containers. The samples were then placed in thermo insulated bags, and transported to the environmental laboratory for analyses.

2.3 Physicochemical analysis

Use a pH meter as a sample, and measure the pH value of the river water after calibration with a standard solution (buffer solution). EC conductivity was analyzed using the HANNA-type electrical conductivity meter and the results were expressed in units of microsiemens/cm (µs/cm). Total dissolved solids (TDS) were measured using a multimeter (manufactured by Hanna) and expressed in mg/L. The salinity was measured according to (APHA, 2017) based on the conductivity measurement and the following equation were uses to calculate the salinity.

$$\text{Salinity\%} = \text{EC} - 14.78/1589.08 \quad (1)$$

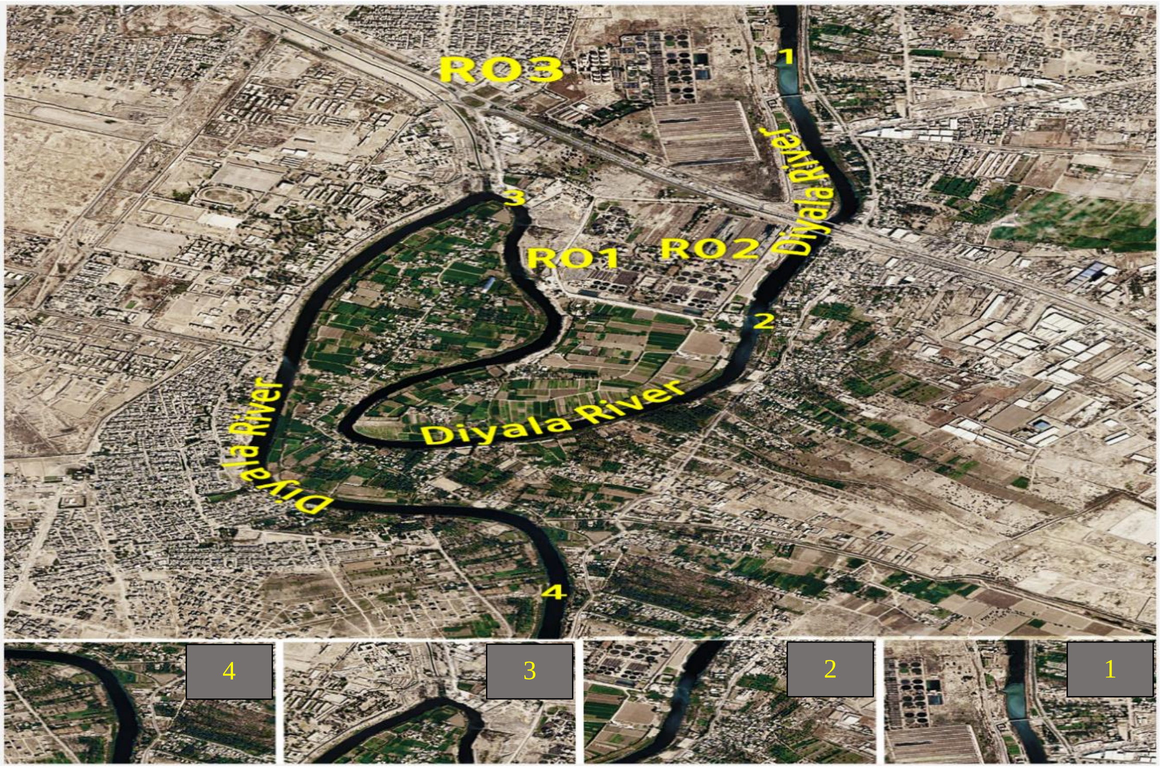

Figure 1. Study area with sampling stations

2.4 Bacterial identification

Total bacterial count (TCB) and fecal coliform bacteria (FCB) were determined using the most probable number (MPN) method. Incubate for 48 h at 37°C for total coliforms and 24 h for fecal coliforms at 44°C (in a water bath), and a positive result is indicated by an increase due to gas evolution in the tubes, and the identification was finalized by microscopic inspection and biochemical tests. Using the MPN technique, positive tubes showed severe turbidity and purple color after incubation in azide-dextrose broth at 37°C for 48 h (APHA, 2005; Filimon et al., 2010). There were three tubes used for each of the three decimal dilutions of each sample. Use of MacConkey broth for inferential TC and FC testing next, a gram stain is used to validate the results of the TC test using vivid green bile. The EC medium was tested at 44.5±0.5°C to confirm cases of FC (by water bath). The MPN technique was employed to identify faecal Streptococci, with azide-dextrose broth serving as the presumptive test and ethylvioletazide broth serving as the confirmatory test.

3. RESULTS AND DISCUSSION

3.1 Grain size analysis

Soil physicochemical characteristics at the locations of the different sediments of the Diyala River are listed in Table 1. According to Table 1, this kind of soil is called sandy loam. A grain size study showed that sand ranged from 612 to 712 mg/kg of soil, silt from 140 to 260 mg/kg of soil, and clay from 108 to 148 mg/kg of soil.

3.2 Sediment composition analysis

The Diyala River deposition site was characterized using scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDS) of sediment grain and pore structure. The sediment from site 1, site 2, site 3 and site 4 was magnified at a magnification scale of 20 µm according to (Wang et al., 2017).

Table1. Grain size analysis of different sediment sites in the Diyala River at Baghdad city

Locations	Grain size analysis (g kg/soil)			
	Sand	Clay	Silt	Tissue class
Site 1	632	108	260	Sandy loam
Site 2	612	128	260	Sandy loam
Site 3	692	108	200	Sandy loam
Site 4	712	148	140	Sandy loam

Figure 2 (a1-a4) shows the energy dispersive X-ray spectroscopy (EDS) curve for sediments, showing that (SE, C, Si, Ca, Al, Mg, K, Fe) for site 1, (SE, C, Si, Ca, Al, Mg, K, Fe, O, Na) for site 2, (SE, C, Si, Ca, Al, Mg, K, Fe, O, na) for site 3 and (SE, Si, C, Ca, Al, Fe, In, O, Mg, Ba, Co, P, S) for site 4 are present in relatively high amounts.

Figure 2 (b1-b4) shows that the scanning electron microscope (SEM) has been curved upwards to describe the comparisons showing the surface shape, particle distribution, contaminant distribution and the morphological properties according to (Rashid and Faisal, 2018; Safia et al., 2021).

3.3 Water and sediment analysis

The distribution and seasonal changes of the physical and chemical properties of the Diyala River water and sediments and bacterial pollution indicators are shown in Figures 3 and 4.

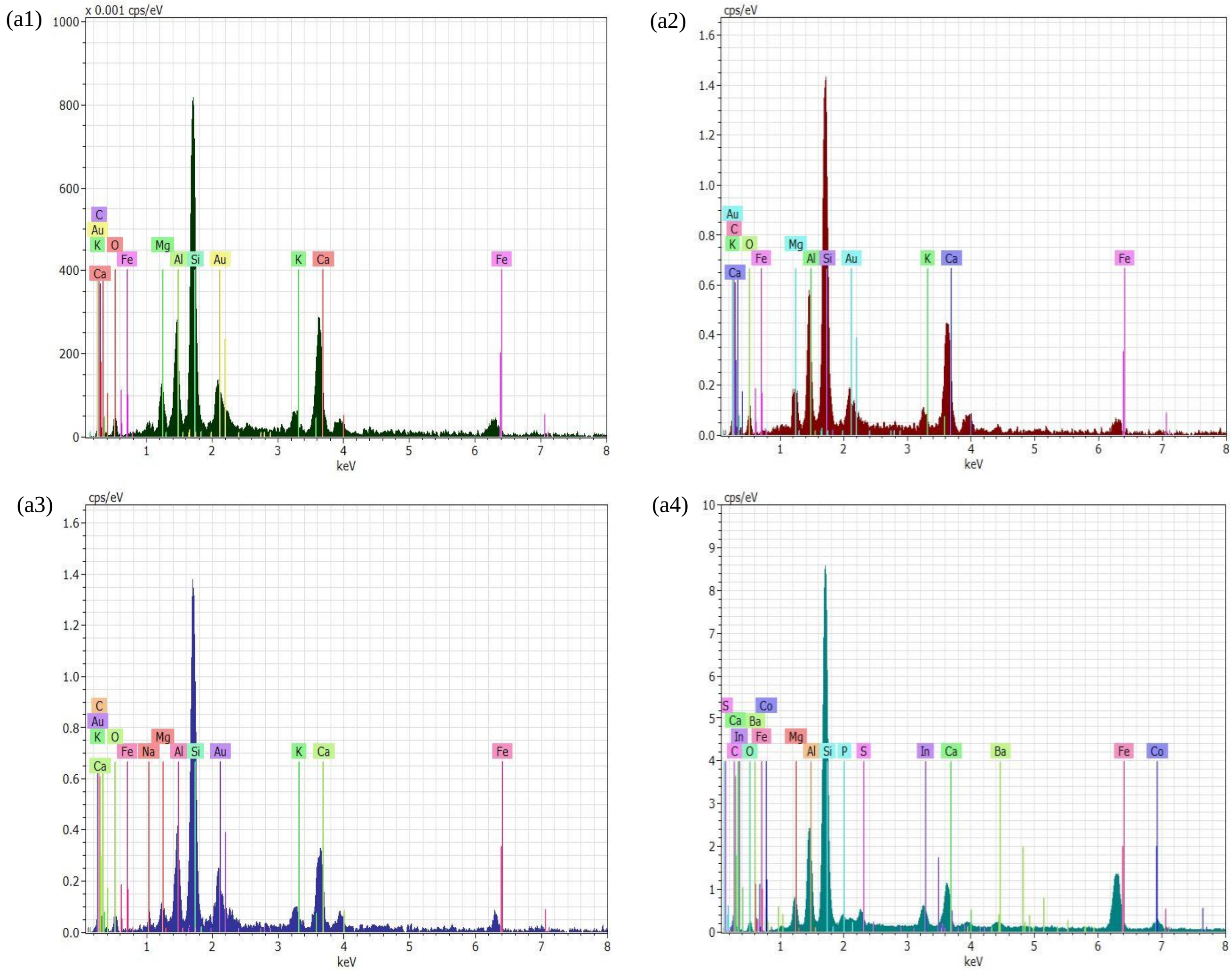

Figure 2. EDS for the composition and SEM images for the sediment samples: (a) EDS, (b) SEM

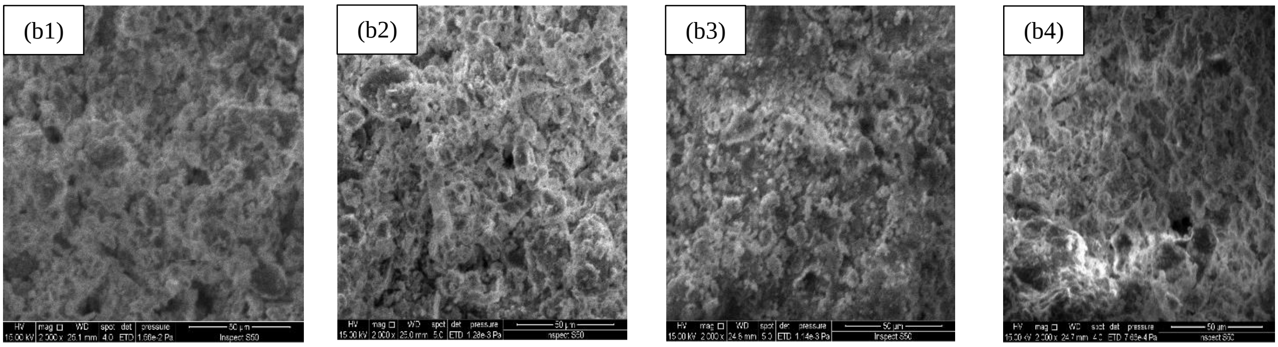

Figure 2. EDS for the composition and SEM images for the sediment samples: (a) EDS, (b) SEM (cont.)

pH values were consistent throughout the duration of the study period in all the studied stations, which is common in waters and sediment (Hashim and Rabee, 2014; Muhanned et al., 2020). High pH values were recorded in the summer at water site 4 and sediment site 1, while lower values were recorded in the winter at water site 1 and in the autumn at sediment site 4. This may be due to the decomposition of organic matter, which can be felt in large quantities at these stations. This value was within the Iraqi Water Standards (1967), as shown in Figure 3 (a-b).

Within a period, the study recorded the highest values of the EC and salinity (2,900 S/cm, 1.86%) in water, respectively, at sites 1, 2, and 3 during the summer and (2,600 S/cm, 1.66%) in sediment, respectively, at site 2 in the spring. while the lowest values were 1,900 S/cm and 1.22% in water, respectively, at site 4 during autumn and 1,180 S/cm and 0.76% in sediment, respectively, at site 4 in winter, as shown in Figure 3 (c-f). Higher value readings of conductivity and salinity may be due to the rainfall, which will cause the salts to drift from the area surrounding the river and the discharge of the Rustumiya sewage treatment plant (RSTP), increasing salt concentrations as well as many other pollutants (Ghayda et al., 2022). These values are close to those measured in other studies of this river (AL-Khaledy, 2003; AL-Sarraf, 2006).

The total dissolved solids (TDS) values showed a high value (1,856, 3,260) mg/L at water site 2 during spring and sediment site 2 in summer, The lower values (902, 770) mg/L were measured in water sample point 3 in autumn and sediment sample point 4 in winter. A high value may be due to the rainy season and a period of high discharge. These values in sediment exceeded the Iraqi Water Standards (1967), as shown in Figure 3 (g-h).

In this research, the total coliform bacteria (TCB) concentrations in the water samples varied between 3.6 and 2,300 MPN/100 mL from site 4 to site 2, and the TCB concentrations in the sediment samples varied between 3.6 and 1,100 MPN/100 mL from site 4 to site 2. According to these findings, the highest values were seen throughout the winter and autumn seasons. Increased bacterial activity led to a higher concentration of organic matter (as seen in Figure 4 (a-b)) (Othman et al., 2012). High concentrations of TCB were found across all research locations and time periods. High levels of suspended solids and nutrients in runoff water may lead to a decline in aquatic microflora and increased incidence of TCB in winter and autumn (Ankit et al., 2019).

Figure 4 (c-d) show that the total number of faecal *E. coli* found in water and sediment varied widely across all study sites, ranging from 3 to 1,150 MPN/100 mL in water and from 2 to 150 MPN/100 mL in sediment. (Kirschner et al., 2017) note that fecal coliforms are the greatest markers for gauging recent fecal contamination, which comes mostly from raw and processed sewage as well as dispersed influences from agricultural land and pasture.

In this study, the prevalence of faecal indicator bacteria was determined in samples collected from a large river in a rural area. According to studies (Quattare et al., 2011), this river was more polluted than others since it flowed through fields. In water, the MPNs for *E. coli* and *S. faecalis* range from 0.5 to 35 MPN/100 mL and 3 to 75 MPN/100 mL, respectively, and in sediment 0.5 to 20 MPN/100 mL, 0.5 and 6 per 100 mL, respectively the number of cells. Faecal Streptococci are appraised to have certain benefits over the coliform bacteria as indicators as they are more resistant to environmental pressure and chlorination than coliforms (Gerba et al., 2019).

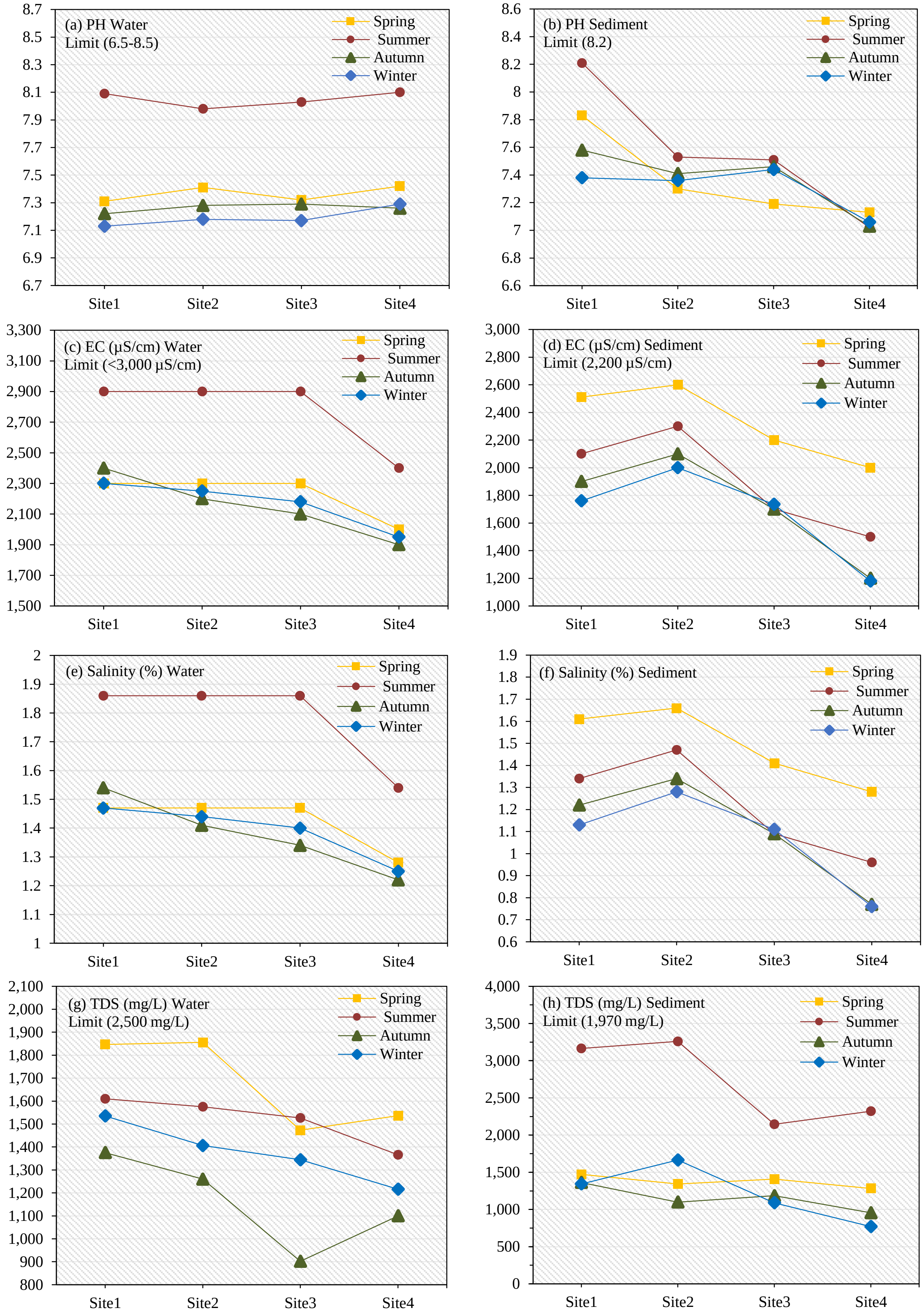

Figure 3. Seasonal variation of some physicochemical parameters (pH, EC, Salinity, TDS)

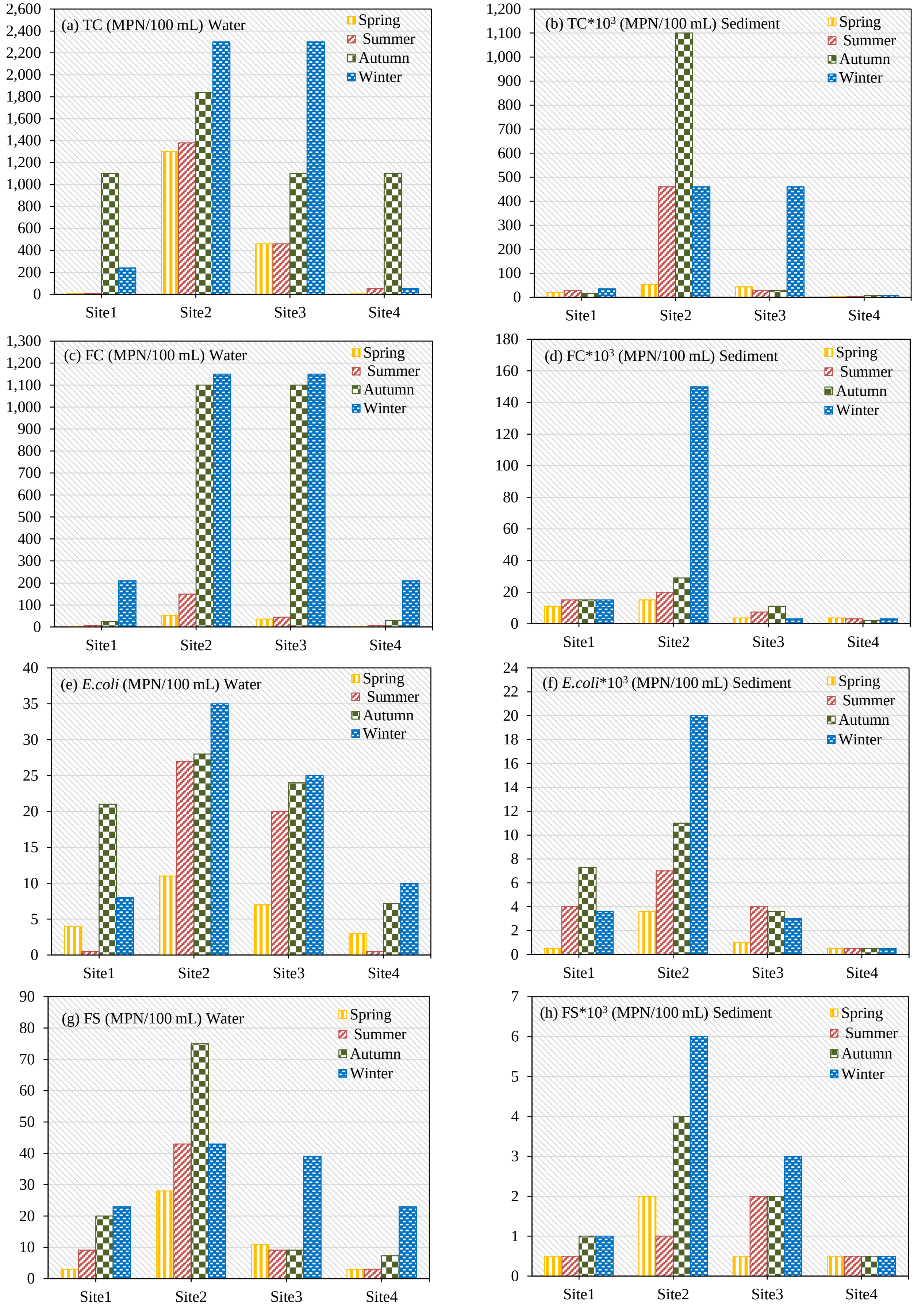

Figure 4. Seasonal variations of bacteria indicator (MPN/100 mL) in water and sediment

As illustrated in Figure 4 (e-f), the river's land and RSTP sediments affect these microorganisms. The results showed that insolation, turbidity, temperature, salinity, dissolved oxygen, and organic matter may all have effects on the variation of bacterial index values and counts in different seasons and locations in the Diyala River (Yehia and Sabae, 2011). High levels of sun radiation and high temperatures may hasten the demise of the indicator bacteria, which may explain why summer months have the lowest numbers (El-Shenawy, 2005).

As predicted from heavy, untreated water, the investigation found a rise in pollution factors in the water entering the station. Discharging this water to the Diyala River without treatment will worsen the river's low level, lack of flow, and dry conditions.

3.4 FC:FS ratio in water and sediments

Surface and groundwater samples were analyzed for the presence of bacteria by comparing the levels of faecal *E. coli* and faecal Streptococci (Baudisova, 2009). A ratio of 4 or more indicates pollution from humans, a ratio of 0.7 to 4 indicates contamination from a combination of sources, and a ratio of less than 0.7 indicates pollution from wild animals. The seasonal variation of this percentage indicates that the source of pollution at most stations is anthropogenic pollution in spring and summer. While it was of mixed origin during the winter, as shown in Table 2. These results can be attributed to human activities and sewage waste in most seasons of the year. While the source of mixed pollution can be attributed to the waste of animal farms in addition to precipitation during this period. These results agree with other studies (Donderski and Wilkk, 2002; Shawky and Saleh, 2007; Raji et al., 2015).

3.5 Water and sediment quality evaluation

Due to the high level of bacterial contamination of the river's water and sediments (WHO, 1989), it is questionable whether the use of Diyala River water for irrigation would increase the risk of infection transmission (Obasohan et al., 2010). WHO proposes an average value of 1,000 MPN/100 mL for fecal coliforms in vegetable irrigation wastewater.

Table 3 provides practical guidance for planning and implementing a freshwater quality research and monitoring program (UNEP and WHO, 1996). Therefore, the water quality of the Diyala River was assessed according to the approved test limits for bacterial indicators (TC, FC and FS) in water and sediment (UNEP and WHO, 1996). By applying the World Health Organization's criteria for assessing water quality based on bacterial indicators, it was observed that most of the surveyed sites were rated as not recommended or unacceptable in water, and acceptable or conservatively acceptable in sediment, as shown Table 4 and Table 5.

Table 2. Indicate the source of bacterial contamination as a ratio (FC/FS)

Locations	(FC/FS) Water				(FC/FS) Sediment			
	Site 1	Site 2	Site 3	Site 4	Site 1	Site 2	Site 3	Site 4
Spring	Mixed	Mixed	Mixed	Mixed	Human	Human	Human	Human
Summer	Mixed	Mixed	Human	Mixed	Human	Human	Mixed	Human
Autumn	Mixed	Human	Human	Mixed	Human	Human	Human	Mixed
Winter	Human	Human	Human	Human	Human	Human	Mixed	Human

Table 3. Evaluation of water and sediment quality in Diyala River (UNEP and WHO, 1996)

Bacterial indicator	Number of cells/100 mL (Water)	Number of cells/100 mL (Sediment)	Water quality	Symbol
(TC)	50>	50,000>	Acceptable	A
	51-500	51,000-500,000	Conservatively accepted	CA
	501-1,000	501,000-1,000,000	Not recommended	NR
	1,000-10,000	1,000,000-10,000,000	Unacceptable	UA
	10,000<	10,000,000>	Contaminated	C
(FC) or (FS)	10>	10,000>	Acceptable	A
	11-100	11000-100000	Conservatively accepted	CA
	101-1,000	101000-1000000	Not recommended	NR
	1000-10000	1000000-10000000	Unacceptable	UA
	10,000<	10,000,000<	Contaminated	C

Table 4. Water quality evaluation according to the approved limits for testing water (TC, FC, FS) MPN/100 mL

Locations	(TC)				(FC)				(FS)			
	Site1	Site2	Site3	Site4	Site1	Site2	Site3	Site4	Site1	Site2	Site3	Site4
Spring	A	UA	CA	A	A	CA	CA	A	A	CA	CA	A
Summer	A	UA	CA	CA	A	NR	CA	A	A	CA	A	A
Autumn	UA	UA	UA	UA	CA	UA	UA	CA	CA	CA	A	A
Winter	CA	UA	UA	CA	NR	UA	UA	NR	CA	CA	CA	CA

Table 5. Sediment quality evaluation according to the approved limits for testing sediment (TC, FC, FS) $*10^3$ MPN/100 mL

Locations	(TC)				(FC)				(FS)			
	Site1	Site2	Site3	Site4	Site1	Site2	Site3	Site4	Site1	Site2	Site3	Site4
Spring	A	CA	A	A	CA	CA	A	A	A	A	A	A
Summer	A	CA	A	A	CA	CA	A	A	A	A	A	A
Autumn	A	UA	A	A	CA	CA	CA	A	A	A	A	A
Winter	A	CA	CA	A	CA	NR	A	A	A	A	A	A

4. CONCLUSION

- The physico-chemical parameters (pH, EC, TDS) in sediment were exceeded their standard limits concerning of aquatic life protection at spring and summer.
- Bacterial contamination levels in Diyala River water and sediments were assessed by tracing faecal indicator bacteria (*Escherichia coli* and Enterococci). The concentrations of *E. coli* and fecal bacteria in the river water were highest in autumn and w inter.
- Fecal coliform, faecal Streptococcus and *Escherichia coli* were detected in all water samples, indicating the seriousness of the pollution of Diyala River to human health.
- The index factor FC:FS values of most samples were greater than 4, indicating the dominance of human fecal contamination.
- The water quality of the Diyala River in the study area was deteriorated by the Rustumia sewage treatment plant.

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REFERENCES

Abd Alkhder AM, Luay MA, Raaed SA. The effect of DiyalaI River drain on the environment and the two types of Iraqi Fish in the Tigris River. Plant Archives 2019;19(1):949-58.

Abdus S, Ashra F, Fazle R, Nusrat HN, Naim U, Masud R. Study of sanitary conditions and quantitative estimation of bacterial flora in Tank Goby (*Glossogobius giuris*) Fish and pond. International Journal of Fisheries and Aquatic Research 2019;4(4):10-4.

AL-Khaledy SH. Ecological and Bacteriological Study in The South Part of Diyala River [dissertation]. College of Science for Women, University of Baghdad; 2003.

Al-Lami AA, Sabri AW, Kassim TI, Rasheed KA. The ecological effect if Diyala River on Tigris River,1-Limnology. Journal College Education for Women, University of Baghdad 1996;7(1):84-92.

Al-Sakini AY. Rustumiya Sanitation Project and its effects on polluting Diyala River. Journal of Basra Arts 2016;76:243-68.

AL-Sarraf MA. Ecological and Taxanomical Study for Phytoplankton in AL-Adaim and Diyala Tributaries and Their Effects on Tigris River [dissertation]. College of Science for Women, University of Baghdad; 2006.

Ankit D, Chandra A, Shubhakriti U, Aarti N, Singh KP. Isolation and characterization of coliform bacteria and bacteriophages from Ganga River in Northern Himalayan Regions. International Journal of Current Microbiology and Applied Sciences 2019;8(11):1582-92.

American Public Health Association (APHA). Standard Methods for the Examination of Water and Wastewater. 21st ed. Washington, USA: APHA; 2005.

American Public Health Association (APHA). Standard Methods for the Examination of Water and Wastewater. 23rd ed. Washington, USA: APHA; 2017.

Ayad GH. The physico-chemical properties of southern part of Diyala River water. Iraqi Journal of Science 2017;58(C4): 2322-31.

Baghed VS, Gopal K, Dwivedi S, Tripathi RD. Bacterial indicators of faecal contamination of the Gangetic River system right at its source. Ecological Indicators 2005;5:49-56.

Baudisova D. Microbial pollution of water from agriculture. Plant, Soil and Environment 2009;55:429-35.

Chen L, Li F, Zhi XS, Zhang P, Dai Y, Xiao YC, et al. Pollution characteristics and health risk assessment of microorganism pollutions in the Beiyun River. Huan Jing Ke Xue 2019; 40:633-9.

Diwan V, Hanna N, Purohit M, Chandran S, Riggi E, Parashar V, et al. Seasonal variations in water-quality, antibiotic residues, resistant bacteria and antibiotic resistance genes of *Escherichia coli* isolates from water and sediments of the Kshipra River in Central India. International Journal of Environmental Research and Public Health 2018;15(6):Article No. 1281.

Donderski W, Wilkk I. Bacteriological studies of water and bottom sediments of the Vistula River between Wyszogrod and Torun. Polish Journal of Environmental Studies 2002;11(1):33-40.

El-Shenawy MA. *Staphylococcus aureus* and fecal indicators in Egyptian coastal waters of Aqaba Gulf and Red Sea. Egyptian Journal of Aquatic Research 2005;31(2):113-24.

Filimon MN, Borozan A, Sinitean A, Popescu R, Oance RT, Verdes D. Bacteriological studies on Timis and Bega Rivers with a role in appreciating pollution. Annals of the Romanian Society for Cell Biology 2010;15(2):217-20.

Gerba CP, Pepper IL, Brusseau ML. Environmental and Pollution Science. Academic Press; 2019: p. 191-217.

Ghayda YA, Sara AH, Husam AA, Sedik AK. Environment impact assessment of Al-Rustumiya wastewater treatment plant in Baghdad-IRAQ. Innovative Infrastructure Solutions 2022;7(2):1-15.

Gunda NS, Mitra SK. Rapid water quality monitoring for microbial contamination. The Electrochemical Society Interface 2016;25(4):73-8.

Hashim AG, Rabee AM. Impact of Diyala Tributary on the quality of Tigris River Water. Journal of International Environmental Application and Science 2014;9(4):493-504.

Hawraa MR, Mrooj SA. Evaluating the water of the Hilla River through the study of physical and chemical properties and microbial content. Journal of University of Babylon for Pure and Applied Sciences 2018;26(7):18-31.

Humudat YR, Al-Naseri SK, Al-Fatlawy YF. Assessment of microbial contamination levels of water in hemodialysis centers in Baghdad, Iraq. Water Environment Research 2020;92:1325-33.

Iraqi Water Standards. Regulation No. 25 on the Preservation of Rivers and Public Waters from Pollution. Iraqi: Official Gazette; 1967. p. 108.

Khaled SB. Microbial contamination of vegetable crop and soil profile in arid regions under controlled application of domestic wastewater. Saudi Journal of Biological Sciences 2016; 23(1):83-92.

Kirschner AK, Reischer GH, Jakwerth S, Savio D, Lxenmaier S, Toth E, et al. Multiparametric monitoring of microbial faecal pollution reveals the dominance of human contamination along the whole Danube River. Water Research 2017; 124(1):543-55.

Kistemann AT, Claben T, Koch C, Dangendorf F, Fischeder R. Microbial load of drinking water reservoir tributaries during extreme rainfall and runoff. Applied and Environmental Microbiology 2002;68:2188-97.

Muhanned RN, Fatema SM, Enaam KA, Eman HA. The effect of Diyala tributary on ecological factors of Tigris River. Journal of Physics: Conference Series 2020;1664:Aticle No. 012134.

Messner MJ, Berger P, Javier J. Total coliform and *E. coli* in public water systems using undisinfected ground water in the United States. International Journal of Hygiene and Environmental Health 2017;220(4):736-43.

Obasohan EE, Agbonlahor DE, Obano EE. Water pollution: A review of microbial quality and health concerns of water, sediment and fish in the aquatic ecosystem. African Journal of Biotechnology 2010;9(4):423-7.

Othman AA, Rabeh SA, Fayez M, Monib M, Hegazi NA. El-Salam canal is a potential project reusing the Nile Delta drainage water for Sinai desert agriculture: Microbial and chemical water quality. Journal of Advanced Research 2012;3(2):99-108.

Quattare NK, Passerat J, Servais P. Fecal contamination of water and sediments in the Scheldt drainage network. Environmental Monitoring and Assessment 2011;183(1-4):243-57.

Raji MI, Ibrahim YK, Tytler BA, Ehinmidu JO. Faecal coliforms (FC) and faecal streptococci (FS) ratio as a tool for assessment of water contamination: A case study of river Sokoto, northwestern Nigeria. Handbook on the Emerging Trends in Scientific Research 2015;3:8-11.

Ramos-Ramírez L, Romero-Bañuelos CA, Jiménez-Ruíz EI, Palomino-Hermosillo YA, Saldaña-Ahuactzi Z, Martínez-Laguna Y, et al. Coliform bacteria in San Pedro Lake, western Mexico. Water Environment Research 2020;93(4):1-9.

Rashid HM, Faisal AH. Removal of dissolved cadmium ions from contaminated wastewater using raw scrap zero-valent iron and zero valent aluminum as locally available and inexpensive sorbent wastes. Iraqi Journal of Chemical and Petroleum Engineering 2018;19(4):39-45.

Safia MK, Hassan F, Abdelazim N, Ahmed T. Measuring the engineering properties of landfill leachate-contaminated soil in Egypt. Euro-Mediterranean Journal for Environmental Integration 2021;6(23):1-12.

Shawky ZS, Saleh AR. Evaluation of the microbial quality of the river NILE waters at Damietta branch, Egypt. Egyptian Journal of Aquatic Research 2007;33(1):301-11.

Sudip S, Rittick M, Debasis M, Divya Jain, Devvret V, Samanwita D. Microbial pollution of water with special reference to coliform bacteria and their nexus with environment. Energy Nexus 2021;1:Article No. 100008.

United Nations Economic and Social Commission for Western Asia (UN-ESCWA), Bundesanstalt für Geowissenschaften und Rohstoffe (BGR). Shared tributaries of the Tigris River. In: Invent tory of Shared Water Resources in Western Asia. Beirut, Lebanon: UN-ESCWA, BGR; 2013.

United Nation Environment Program (UNEP), World Health Organization (WHO). Water Quality Monitoring: A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programmes. WHO; 1996.

Wang H, Liu T, Feng S, Zhang W. Metal removal and associated binding fraction transformation in contaminated river sediment washed by different types of agents. PLoS ONE 2017;12(3):e0174571.

World Health Organization (WHO). Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture. Geneva: WHO; 1989.

Yehia HM, Sabae SZ. Microbial pollution of water in El-Salam Canal, Egypt. American Eurasian Journal of Agricultural and Environmental Sciences 2011;11(2):305-9.