Journal of Environmental Science and Technology

ISSN 1994-7887

OPEN ACCESS Journal of Environmental Science and Technology

ISSN 1994-7887
DOI: 10.3923/jest.2017.147.156

Research Article
Environmental and Microbial Investigation on the Dredged Sediment Soil of Diyala River in Iraq

Sufyan Mohammed Shartooh

Department of Biology, College of Sciences, University of Anbar, Ramadi, Iraq

Abstract

Background and Objective: Pollution of water resources is a major risk to human health and water quality throughout the world. This in turn has led to a renewed interest in protecting the environment and has focused attention on the concept of environmental monitoring and site characterization, including an evaluation of the physical, chemical and biological factors that impact on the environment. The objective of this work was to determine the effect of Rustumiya Sewage Plant on the water and sediment quality of Diyala River in Iraq. **Materials and Methods:** This study comprised the isolation and identification of some pathogenic bacterial species using Bio-chemical tests, the coliforms enumeration was achieved by appropriate cultural media provided with suitable chemical indicators. Also, heavy metal ions concentration was identified using Flame Atomic Absorption Spectroscopy (FAAS). However, one-way analysis of variance by Statistical Package for the Social Science (SPSS) program (Version 19.0) was employed for the statistical analysis. **Results:** The results show certain pathogenic bacterial groups, including *Clostridium perfringens*, *Pseudomonas aeruginosa*, *Salmonella* sp., *Shigilla* sp. and *Vibrio cholera* that were isolated from six locations of sewage wastewater and dredged sediment of Diyala River. The numbers of total coliforms, total faecal coliforms and total viable count reached 120×10^6 cell mL^{-1}. Some of biological and physiochemical parameters were also determined such as: Biochemical oxygen demand, chemical oxygen demand, total suspended solids, total dissolved solids and electrical conductivity. Concentration of Zinc, Nickle, Copper, Cadmium and Lead ions were measured in examined samples. Ni ions concentration was (101.7 ± 1.2 mg kg^{-1}) in sediments and Cd ions concentration was (0.09 ± 0.0 mg L^{-1}) in water. **Conclusion:** The extracted results revealed that Diyala River water and its dredged sediments contained high concentrations of both pathogenic bacteria and toxic heavy metals, which indicated the lack of efficient sewage treatment processes.

Key words: Dredged sediments, *Vibrio cholera*, sewage plant, coliforms, nickel, aquatic environment, aquatic pollutants

Received: January 13, 2017 Accepted: March 19, 2017 Published: April 15, 2017

Citation: Sufyan Mohammed Shartooh, 2017.Environmental and microbial investigation on the dredged sediment soil of diyala river in Iraq. J. Environ. Sci. Technol., 10: 147-156.

Corresponding Author: Sufyan Mohammed Shartooh, Department of Biology, College of Sciences, University of Anbar, Ramadi, Iraq
Tel: 009647901779543

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Water is essential natural resource needed by living organisms, it represents a strategic dimension for all various forms of life and ensures the continued sustainability. Most of the surface water is contaminated with municipal sewages which are the main source of microbial pollution, especially near large population centers[1,2]. The Iraqi Rivers including Diyala River and Tigris River seem to be polluted with pathogenic bacteria particularly during summer[3]. Most bacterial isolates are of human origin as a result of the discharge of untreated wastewater directly into the rivers as well as the high percentage of heavy metals in the water and sediments that are exceeding the permissible environmental limits due to the accumulation in the river bed over time[4,5]. However, the lack of proper wastewater treatment may result in accelerating transmission of waterborne diseases and other resulted contaminates to vegetable plants being irrigated by such wastewater[6].

It is important to mention that Diyala River is suffering from different changes in physiochemical properties due to discharging of polluted water from Al-Rustumiya Sewage Plant (RSP) as well as trocars water that thrown directly into the river without any pretreatment. Previous studies indicated the disqualification of Diyala River for human, industrial and even agricultural consumption[7,8].

The RSP (26.61'33°16 N, 06.21'44°32 E) is considered one of the largest sewage water treatment projects in Iraq. It treats municipal sewage water for half the population of Baghdad city. The treated sewage water is then disposes into Diyala River, which mixed later with Tigris River water near Diyala bridge area[9]. Although there are many studies on the river, nevertheless very few information are available on the contents of sedimentary clays of the river bottom ecosystem. The aim of this study was to examine the physical, chemical and biological characters of water and dredged sediment samples collected from Diyala River. Also, to examine several heavy metals content in both water and sediment samples.

MATERIALS AND METHODS

This study was conducted beside Diyala bridge area within Baghdad city for testing samples of the river water and also testing waste clays resulted from the processes of sediments dredging of river bed in the form of dirt piles that kept on the river side within the area between RSP and Diyala Bridge.

Water and sediment samples were collected during the period of July-December, 2015 from 6 locations (Fig. 1) of the river bed dredged soil in triplicates for each location at a depth of 20 cm. Also, water samples from Diyala River were collected for the necessary bacteriological and environmental chemical tests. The collected samples were kept in 500 mL sterilized glass bottles and then moved to the laboratory for immediate use.

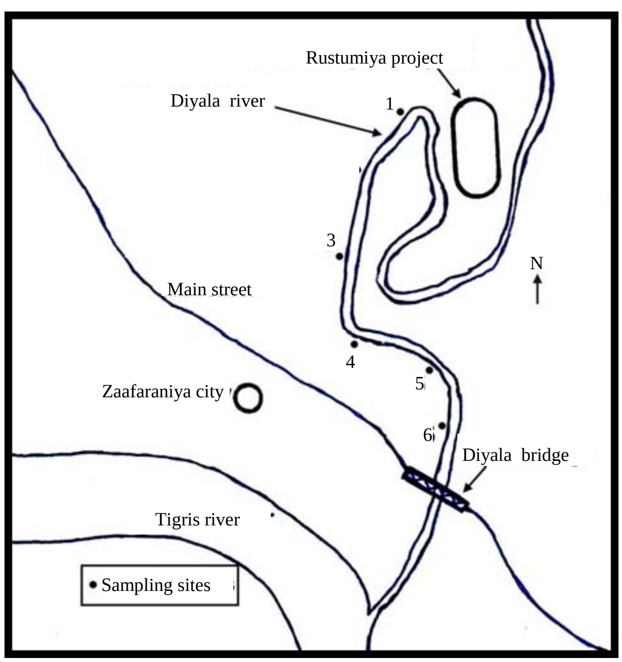


Fig. 1: Study areas and sample sites (1-6)

To determine the bacterial communities in water samples, filtration method was employed by using 0.2 mm filtration unit. Hundred mL of water samples were taken and passed through the filtration unit, thereafter, the Resulted Filter (RF) was transferred to a sterile culture media.

Sediment soil samples were air dried and weighted to obtain the dry mass. The samples were ground with an agate mortar and sieved with 2 mm stainless steel sieve. The samples were then digested chemically with conc. HNO_3, conc. H_2SO_4 and 5M HCl. The digested samples were filtered using 0.2 mm filtration unit. To avoid heavy metal contamination, all tools were cleaned beforehand with HNO_3 and rinsed with double distilled water. The heavy metal ions were measured using Flame Atomic Absorption Spectroscopy (FAAS). Microbial and biochemical tests were used according to specified manuals[10-12].

Bacterial isolation: To isolate *Salmonella* and *Shigella*, the RF was transferred to Tetrathionate broth and incubated at 37°C for 24-48 h and then transferred to Brilliant green agar. For *Vibrio* and *Aeromonas* isolations, the RF was transferred into alkaline peptone water with pH of 8.8 and incubated for 6-8 h. at 37°C and then cultured on Thiosulphate citrate bile salt agar for 10 h. Concerning *Clostridium perfringens*, the RF was incubated on blood agar at 37°C for 24-48 h. For *Pseudomonas aeruginosa*, the RF was cultured on nutrient agar at 37°C for 24 h and incubated using Pseudomonas agar at 37°C for 48 h.

Biochemical tests: These included Oxidase test, Indol test, Simmon citrate test, VP test, Methyl red test and Urea test. The identification of total Coliforms and faecal Coliforms were also conducted using the method of Most Probable Number (MPN), the water samples test tubes containing MacConky Broth were incubated for 24-48 h at 37°C till green metallic shine colonies appeared after culturing on Eosin Methylene Blue (EMB) agar. Total viable bacterial count was accomplished using Total Plate Count (TPC) method to estimate the bacterial enumeration in each milliliter of sample. Moreover, confirmatory tests were conducted for *Vibrio*, *Shigella* and *Salmonella* bacterial isolates using VITEK2 compact system equipped by Bio Merieux Company.

Physicochemical examination: This work examined the following variables depending on Abbawi and Hassan[13]. Biological Oxygen Demand (BOD) was done by measuring the amount of oxygen in waste water before and after inoculation, where samples were placed in a shaker incubator for 5 days at 20°C, thereafter the oxygen content was measured using dissolved oxygen meter (manufactured by WTW, Germany) after calibration. Chemical Oxygen Demand (COD) was measured using strong oxidizers in terms of Ferroin indicator reagent. Total Suspended Solids (TSS) was measured by using ceramic evaporating dish with 0.45 μ filter paper and drying oven at temperature of 103-105°C by measuring the difference between empty and loaded items weights to extract results. Other variables such as; Turbidity, Electrical Conductivity (EC), Total Dissolved Solids (TDS) and pH were recorded by using the appropriate portable electronic devices after calibration such as pH-meter, EC-meter (HI9813-6) and Turbidity meter (HI98703) equipped by Hanna instruments.

Heavy metal ions: Heavy metal ions contents such as Zn, Pb, Ni, Cu and Cd were determined by using Flame Atomic Absorption Spectroscopy (FAAS), model PG-990, England[12].

Statistical analysis: The data was analyzed using one-way analysis of variance by Statistical Package for the Social Science (SPSS) program (Version 19.0), in order to find out if there are significant differences (at $\alpha = 0.05$) among the means of the studied parameters and according to Sandar and Richard[14].

RESULTS

Bacterial examination results of Diyala River showed that the river was heavily polluted by several genes of pathogenic bacteria, the percentage of this microbial community is seen in (Fig. 2). The statistical analysis (Table 1) indicated the existence of statistically significant differences among the percentage of pathogenic bacterial genes (LSD = 4.375). *Escherichia coli* gave the highest percentage (85%), followed by *Enterobacter aerogenes* (60%), while the lowest percentage (12%) was for *Vibrio cholera* as presented in Table 2.

For the number of Coliform group, the statistical analysis (Table 3) indicated no significant differences among the means, as it seen in the data of Table 4.

Regarding the heavy metal ions concentration in the water samples, statistical analysis (Table 5) shows significant differences among the means of heavy metal concentrations in water samples (LSD = 0.037). The highest mean values of heavy metal ions concentration were recorded for Cu and Ni (0.4 and 0.2 mg L^{-1}), respectively, while the lowest mean value was for Cd (0.09 mg L^{-1}), as it seen in Table 6.

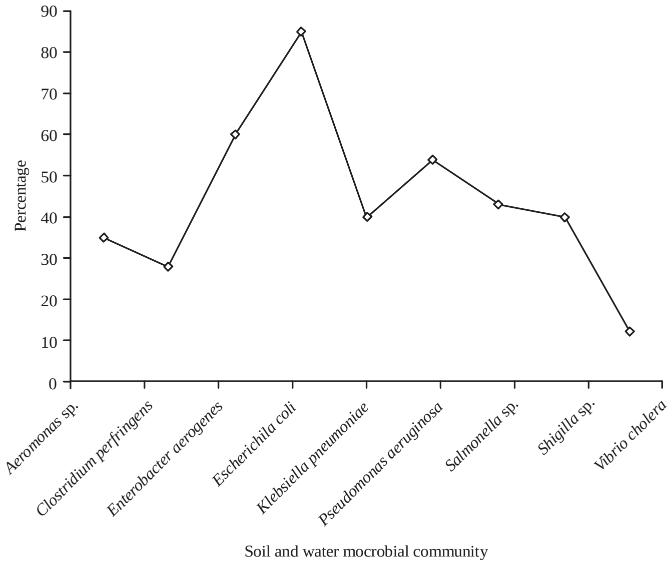


Fig. 2: Soil and water microbial community for samples of Diyala River

Table 1: Analysis of variance for the data of microbial community in Diyala river

	Sum of squares	DF	Mean square	F	Sig.
Between groups	20153.333	8	2519.167	177.129	0.000
Within groups	640.000	45	14.222		
Total	20793.333	53			

Df: Degree of freedom, Sig: Significance, F: Frequency

Table 2: Microbial community percentage in Diyala river

	Sampling sites						
Bacteria	Loc. 1	Loc. 2	Loc. 3	Loc. 4	Loc. 5	Loc. 6	Mean (%)
Aeromonas sp.	42	40	37	35	32	30	35e
Clostridium perfringens	32	30	29	27	26	25	28f
Enterobacteraerogenes	64	64	62	60	55	55	60b
Escherichia coli	90	88	84	84	81	80	85a
Klebsiellapneumonia	42	42	41	38	39	38	40d
Pseudomonas aeruginosa	58	57	55	51	51	50	54c
Salmonella Sp.	48	46	45	42	40	40	43d
Shigilla sp.	43	42	40	40	38	38	40d
Vibrio cholera	17	15	13	14	13	zero	12g

LSD: 4.375 at α: 0.05, Vertically different characters for indicating significant differences

Table 3: Analysis of variance for the data of coliforms number Means and total plate count in water samples of Diyala river

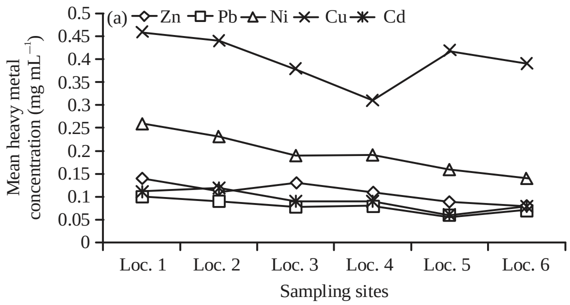
	Sum of squares	DF	Mean square	F	Sig.
Between groups	6427.090	2	3213.545	2.773	0.094
Within groups	17386.036	15	1159.069		
Total	23813.126	17			

Df: Degree of freedom, Sig: Significance, F: Frequency

Table 4: Coliforms number Means and total plate count in water samples of Diyala river

	Months						
Bacteria	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
TC (cell/100 mL)	24×10^6	24×10^6	46×10^6	2.4×10^6	1.1×10^6	0.11×10^6	16.3×10^6
TFC (cell/100 mL)	11×10^6	2.4×10^6	2.4×10^6	0.11×10^6	0.11×10^6	0.08×10^6	2.7×10^6
TPC (cell/100 mL)	120×10^6	120×10^6	15×10^6	12×10^6	10×10^6	10×10^6	48.0×10^6

Again, the data of Table 7 reveals significant differences among the heavy metal ions concentration in the samples of dredged soil of the river bed (LSD: 6.55). The heavy metal concentration means were found to be vary from 0.13 mg kg^{-1}



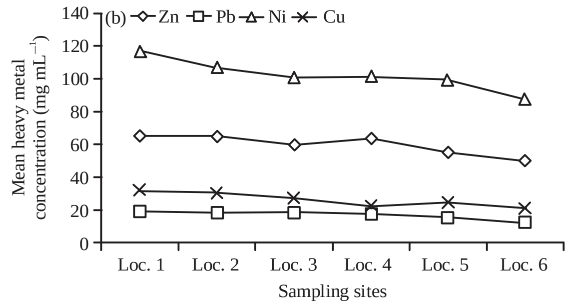


Fig. 3(a-b): (a) Means of heavy metal ions concentration for water samples and (b) Means of heavy metal ions concentration for sediment samples

Table 5: Analysis of variance for the data of means of heavy metal ions content (mg L^{-1}) in water samples of Diyala River

	Sum of squares	DF	Mean square	F	Sig.
Between groups	0.427	4	0.107	89.521	0.000
Within groups	0.030	25	0.001		
Total	0.457	29			

Df: Degree of freedom, F: Frequency, Sig.: Significance

Table 6: Means of heavy metal ions content (mg L^{-1}) in water samples of Diyala River with WHO limits

Heavy metal	Loc. 1	Loc. 2	Loc. 3	Loc. 4	Loc. 5	Loc. 6	Mean	WHO limits
Zn	0.14	0.11	0.13	0.11	0.09	0.08	0.11^{c}	2.00
Pb	0.10	0.09	0.08	0.08	0.07	0.06	0.08^{c}	5.00
Ni	0.26	0.23	0.19	0.19	0.16	0.14	0.20^{b}	0.20
Cu	0.46	0.44	0.38	0.31	0.39	0.42	0.40^{a}	0.20
Cd	0.11	0.12	0.09	0.09	0.06	0.08	0.09^{c}	0.01

LSD: 0.037at α: 0.05. Vertically different characters for indicating significant differences

Table 7: Analysis of variance for the data of means of heavy metal ions content (mg kg^{-1}) in dredged soil samples of Diyala River

	Sum of squares	DF	Mean square	F	Sig.
Between groups	39056.498	4	9764.124	321.075	0.000
Within groups	760.267	25	30.411		
Total	39816.765	29			

Df: Degree of freedom, F: Frequency, Sig.: Significance

Table 8: Means of heavy metal ions content (mg kg^{-1}) in dredged soil samples of Diyala River with WHO limits

Heavy metal	Loc.1	Loc.2	Loc.3	Loc.4	Loc.5	Loc.6	Mean	WHO limits
Zn	65.20	64.60	59.30	63.20	55.10	49.8	59.50^{b}	300
Pb	19.10	18.40	18.50	17.40	15.20	12.1	16.80^{d}	100
Ni	116.00	106.60	100.50	101.10	98.80	87.3	101.70^{a}	50
Cu	31.70	30.10	26.90	22.30	24.60	20.8	26.00^{c}	100
Cd	0.17	0.16	0.11	0.14	0.12	0.1	0.13^{e}	3

LSD: 6.55at α: 0.05. Vertically different characters for indicating significant differences

in case of Cd to 101.7 mg kg^{-1} in case of Ni (Table 8). Figure 3a presented the mean of heavy metal ions concentrations in examined water samples in the six locations during the study period. The values of Zn, Pb and Ni ions ranged from 0.08, 0.06 and 0.14 mg L^{-1} in location no. 1-0.14, 0.1 and 0.26 mg L^{-1} in location no. 6, respectively. However, the highest Cu concentration was 0.46 mg L^{-1} in location no. 1 and the lower value was 0.31 mg L^{-1} in location no. 4, While for Cadmium ions, values ranged from 0.06 mg L^{-1} in location no. 5-0.12 mg L^{-1} in location no. 2. Regarding, heavy metal ions concentrations in the examined sediment samples, the mean values of Zn, Pb, Ni, Cu and Cd ranged from 49.8, 12.1, 87.3, 20.8 and 0.1 mg kg^{-1} to 65.2, 19.1, 116, 31.7 and 0.17 mg kg^{-1}, respectively for all sampling locations (Fig. 3b and 4).

Pertains the examined environmental parameters Table 9, no important differences were found between the studied locations. The values of pH were ranged from 7.1 in location no. 3-7.6 in location no. 6 during the study period Fig. 5a. The BOD values were varied from 215 mg L^{-1} in location no. 2-242 mg L^{-1} in location no. 3 (Fig. 5b). The COD amount was ranged from 560 mg L^{-1} in location no.

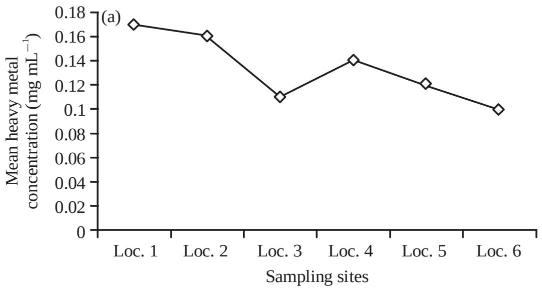


Fig. 4: Means of Cadmium ions concentration for sediment samples

Table 9: Mean environmental factors in water samples of Diyala River

Item	Range	Mean±SD
pH	7.1-7.6	7.55±0.04
BOD (mg L^{-1})	215-242	229.83±10.42
COD (mg L^{-1})	560-592	581.16±14.14
TSS (mg L^{-1})	462-509	488.51±13.61
TDS (mg L^{-1})	571-598	583.16±14.55
E.C. (mmho cm^{-1})	1350-1400	1379.33±19.22
Turbidity (NTU)	98-110	102.83±0.1

2-592 mg L^{-1} in location no. 4 (Fig. 5c). In case of TSS, highest value (509 mg L^{-1}) was found in location no. 5 and the lowest value (462 mg L^{-1}) was found in location no. 3 (Fig. 5d). However, regarding the TDS, EC and Turbidity, the values were 571 mg L^{-1}, 1350 Mmho cm^{-1} and 98 NTU, respectively for location no. 1, while the values were 598 mg L^{-1}, 1400 Mmho cm^{-1} and 110 NTU, respectively for location no. 5 (Fig. 5e-g).

DISCUSSION

The sewage water and river bed dredged sediments are loaded with billions of microorganisms, particularly pathogenic species. In low enumeration, *Aeromonas* sp. was found in all samples in which it may cause some cases of diarrhea and wound infections. Also, *Clostridium perfringens* causes myonecrosis, blood haemolysis and gangrene due to wounds contamination and a fatal disease. *Enterobacter aerogense, Escherichia coli* and *Klebsiella pneumoniae* were found in all studied locations in which they considered as a pathogenic species that cause severe diarrhea. Moreover, the advent of *Pseudomonas aeruginosa,* which causes urinary tract infection, included through river water and dredged river bed. *Salmonella* sp. that causes enteric fever disease was also found in the examined samples (typhoid and paratyphoid). The presence of this genus in nature depends on the presence of cultivated animals as hosts along the river[15]. *Shigella* sp. that causes bacillary dysentery was also found in all samples. However, the appearance of *Vibrio cholera* is considered one of the important results since it causes severe watery diarrhea and leads to loss of large amounts of fluids causing drought that may lead to death. These kinds of waters are increasingly dangerous by the appearance of pathogens for both man and his environment[16]. This may be due to the incorrectly treatment method of such kind of wastes, as well as the increased concentrations of both organic and faecal materials, in which its presence in water indicate the presence of pathogenic intestinal bacterial species[17]. In addition, the water and sediments of river bed are considered as carriers of diseases for most pathogenic bacteria[18]. In fact water is loaded with organic contaminants which are a suitable media for transferring these pathogenic microbes[19].The appearance of such pathogens effect the health situation of individuals who lived along the river, especially those who use the river water to irrigate their crops beside using dredged sediment clays as fertilizers for cultivated lands[8,20].Enterobacteriaceae family contains a large number of genera that are biochemically and genetically related to one another. The high percentage of *Enterobacter aerogense*, *Escherichia coli* and *Klebsiella pneumoniae* in tested samples could be due the dominance of these intestinal bacterial species in such sewage water that containing suitable organic matter for their living[21]. Nevertheless, these organisms have simple nutritional requirements and are found in large quantities comparing to other accompanied pathogenic bacteria[22,23]. *Vibrio cholera* cells can grow at 40°C with pH 9-10, the growth is stimulated by the presence of sodium chloride. *Vibrio cholera* strains are isolable from the environment only in epidemic areas just like the study area[16]. However, these living conditions of pH, temperature and sodium chloride are not well presented in the study area, which explain the low percentage (12%) of this bacterium. Additionally, when *Vibrio cholera* cells face adverse environmental conditions, they reduce cell size, became coccoid and enter a dormant stage inside exopolysaccharide biofilm. Cells display a certain metabolism, but are not able to growth and multiply till living environmental conditions became suitable to cause infection[21].

Coliforms were used as an evidence of faecal bacterial contamination of river water[24]. The reason behind the high values of TC, TFC and total viable count in examined samples was the relatively appropriate temperatures with an annual mean of 22°C, though, sewage water is enriched by organic contents from fertilizers and some agricultural pesticides containing nitrogen and phosphorus[25]. However, faecal Coliforms were considered as a good indicator for the detection and investigation of the faecal pollution in sewage water, being found permanently in stool with varied numbers[26]. Thus, it would be the most used indicators to refer for water contamination by human pathogenic bacteria, with

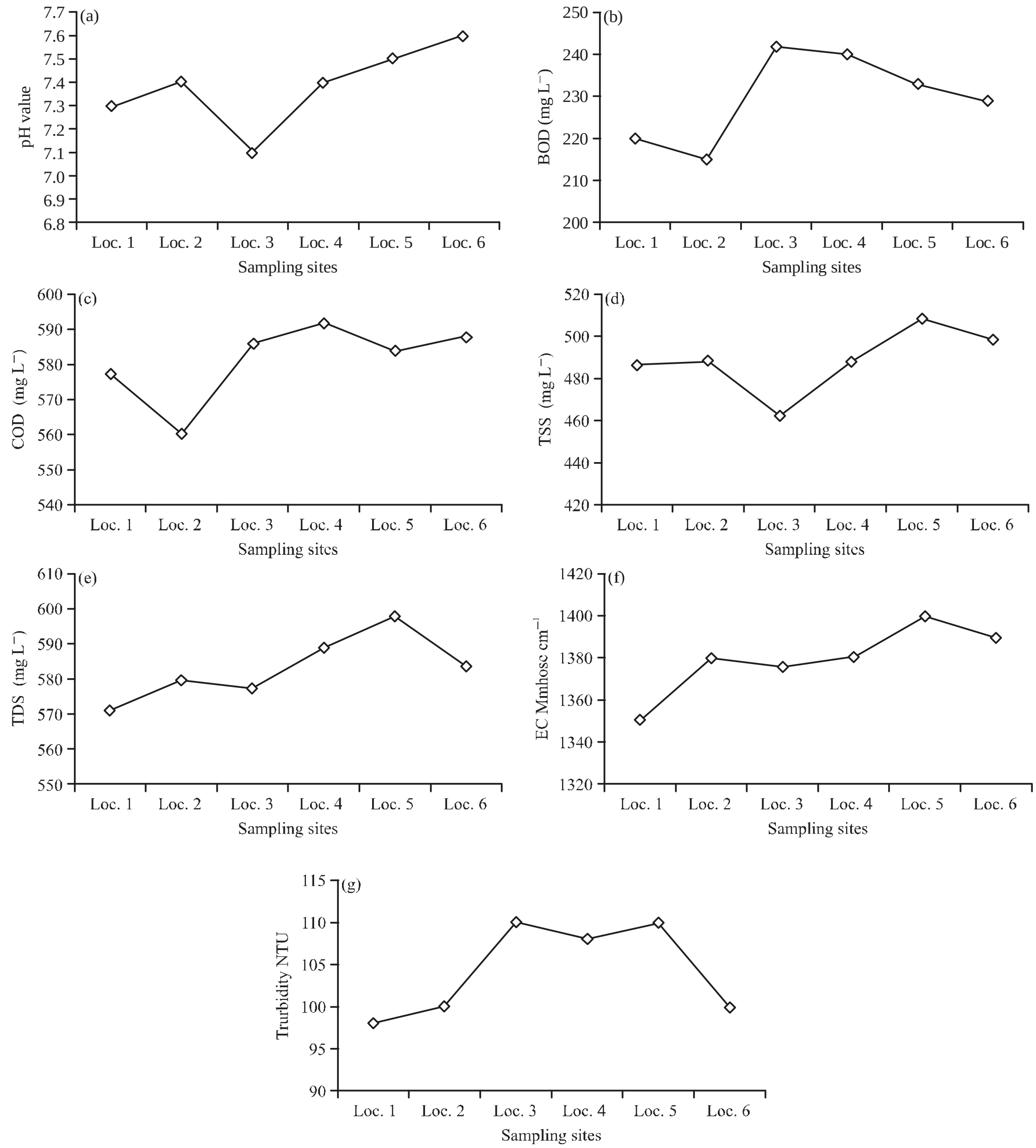


Fig. 5(a-g): (a) pH values for the sampling sites within study duration, (b) BOD values for the sampling sites within study duration, (c) COD values for the sampling sites within study duration, (d) TSS values for the sampling sites within study duration, (e)TDS values for the sampling sites within study duration, (f) EC values for the sampling sites within study duration and (g) Turbidity values for the sampling sites within study duration

longer survival duration than other accompanying microbes[27]. Bashy and Alabd-Rabah[28] mentioned that the capture basin in the RSP first stage is not efficient because of falling the separation wall (during the Gulf War 1991), which causing a lot of problems in the other stages. In addition, highly sedimentation occurs in ventilation process and increase the number of bacteria in all posterior stages as well as river water. The results obtained from this study are in agreement with those previously reported by Al-Khalidi[8], Al-Timimi[20], Sarkar and Rashid[29].

The similarity patterns of heavy metal concentrations for both water and sediment samples could be explained as follow: Location no. 1, which receives large amount of untreated municipal sewages, was the nearest sampling site to the RSP, while location no. 6 was the furthest one. In other words, the increasing mean concentrations of heavy metals in location no. 1 and the decreasing in the mean concentrations in location no. 6 may be due to the distances of sampling sites from the source of pollutants and due the self-purification ability of the river. It seems clearly that Ni ions gave the highest mean (101.7 ± 1.2 mg kg^{-1}) in river sediment samples, while cadmium ions gave the lowest mean (0.13 ± 0.0 mg kg^{-1}). For river water samples, it is obviously that Copper ions gave the highest mean (0.4 ± 0.01 mg L^{-1}) while both Lead and Cadmium gave the lowest means (0.08 ± 0.002 and 0.09 ± 0.0 mg L^{-1}), respectively. The results of the heavy metal content in river sediments and water samples indicated an important rise comparing with permitted environmental limits as a result to the inefficiency treatment techniques in RSP which led to the deposition of these heavy metal concentrations in the bottom of Diyala River for quite a long time. However, the high concentrations of both Cu and Ni ions in water samples may be due to the random diffusion of private sector factories, located just before RSP in Zaafaranya area in Baghdad city, which were built without any environmental control from the competent authorities, such as: Electric cable manufacturing, tannery, metal plating factories and car radiator manufacturing, which use such metals more than other heavy metals. Furthermore, these factories dispose their industrial wastewater loaded with high concentrations of these heavy metal ions directly in to the municipal sewerage without any pretreatment process, hence it was reflected negatively in the same pattern on the studied sediment samples. Also, it could be due the excessive use by farmers in the region of some agricultural pesticides that contain high levels of these heavy metals. In addition, the thrown of car wastes such as tires and batteries in the course of the river may causes danger on the life of individuals living in neighboring areas along the river because of the harmful effects on the public health and ecological system of the bioaccumulation in food webs during the biological exchange of sediments in aquatic systems[6]. These results are in agreement with previous studies refer to that the effluents from RSP contribute significantly to the rise of heavy metal values in Diyala and Tigris Rivers continuously[8,9,20].

Regarding the data of pH, BOD, COD, TSS, TDS, EC and Turbidity which were higher than those of the permissible environmental limitations as a result of increasing concentrations of organic materials generated from agricultural waste produced from adjacent lands of the river. Also, municipal civil wastes not treated probably in RSP, due to maintenance work process, flowing final stage water into Diyala River as shown in Table 9. The results are in agreement with those previously reported by Al-Ghabban[30], Al-Obaidy *et al.*[31], Rasheed[32], Friedel *et al.*[33].

The appearance of the pathogenic bacteria species that isolated and identified from sewage water and the high concentrations of heavy metals in the examined samples are an evidence of inefficient treatment of sewage, due to the increased human activity and the absence of the required maintenance operations on the sections of RSP. The current work confirmed the need of developing the treatments and operation techniques in RSP.

CONCLUSION

In conclusion, Diyala River water contains high levels of heavy metals that exceed environmental limits, especially in case of Cadmium which reached at the rates of 0.09 ± 0.0 mg L^{-1}. The river water is contaminated by high levels of microbial pollutants, where the total viable count reaches 120×10^6 cell mL^{-1}, in addition to the presence of pathogens such as Cholera. The heavy metals concentration in river dredged soil exceeds the permitted environmental limits, where Ni concentration was 101.7 ± 1.2 mg kg^{-1} of soil. The deteriorated water quality of Diyala River participates in disease spreading among the population lived with the river course, especially farmers who are in direct contact with river contents. Due to the high levels of heavy metals in river sediment soils, it is possible to use these types of soil to bury low-laying areas during roads construction on a selected impermeable land. Exposing the dredged soil to sunlight for one month, taking into consideration the soil aeration process every four days could contribute to the soil sterilization naturally by UV-light.

SIGNIFICANCE STATEMENT

This study discovers the environmental pollution grade of Diyala River, that reveals high level of pollutants such as: pathogenic bacteria and hazardous heavy metal ions, which provide valuable information for postgraduate students and other researchers, that can be beneficial for further investigational studies of the river bed and the effect of the deteriorated treatment of sewage plant on the river quality, especially this study is the first one on the river sediments since 2003. The present study will help related researchers to uncover the critical areas of the river quality that many researchers were not able to explore. Thus, a new theory on the sewage plant treatment processes may be explored.

ACKNOWLEDGMENTS

The author would like to thank the Ministry of Science and Technology, Directorate of Hazardous Wastes Treatment and Disposal research center laboratories and Ministry of Water Resources, Iraq for supporting this work.

REFERENCES

1. Richman, M.I., 1997. Water pollution. Wastewater, 5: 24-29.
2. Al-Aroussi, H.M., 2004. Pollution of the environment and pollutants. The Library of Modern Knowledge of Hamada Zaghloul, Alexandria, pp: 261-271.
3. Rabee, A.M., B.M. Abdul-Kareem and A.S. Al-Dhamin, 2011. Seasonal variations of some ecological parameters in Tigris river water at Baghdad Region, Iraq. J. Water Resourc. Prot., 3: 262-267.
4. Wada, M., 1994. Relationship between bacteria decomposing organic substances and water pollution in river water. Nippon Eiseigaku Zasshi, 49: 782-790.
5. Meyers, A., 1995. Modern management of acute diarrhea and dehydration in children. Am. Family Phys., 51: 1103-1118.
6. Da Costa, A.C.A. and F.P. Duta, 2001. Bioaccumulation of copper, zinc, cadmium and lead by *Bacillus* sp., *Bacillus cereus*, *Bacillus sphaericus* and *Bacillus subtilis*. Braz. J. Microbiol., 32: 1-5.
7. Al-Jubbori, T.H., 1990. Hydrology and geomorphology of Diyala river. Ph.D. Thesis, University of Baghdad, Iraq.
8. Al-Khalidi, S.H., 2003. A bacteriological study on the southern part of Diyala river. M.Sc. Thesis, University of Baghdad, Iraq.
9. Hussein, A.A., 2009. Monthly changes of some physiochemical parameters for Tigris river-Baghdad between 2002-2003. Eng. Technol. J., 2: 64-70.
10. Bergey, D.H. and J.G. Holt, 2000. Bergey's Manual of Determinative Bacteriology. Lippincott Williams and Wilkins Inc., Baltimore, MD., USA.
11. Atlas, R.M., 2005. Handbook of Media for Environmental Microbiology. 2nd Edn., Taylor and Francis Group, USA.
12. APHA., 2005. Standard Methods for Examination of Waste Water. 21st Edn., American Public Health Association, Washington, DC.
13. Abbawi, S.A. and M.S. Hassan, 1990. Environmental Engineering, Water Analysis. Dar Al-Hekma for Printing and Publishing, Mosul, Iraq.
14. Sandar, R.P. and J. Richard, 1996. An Introduction to Biostatistics. 3rd Edn., Hamol Press, USA.
15. Taylor, D.J. and A.W. Philbey, 2010. *Salmonella* infections in garden birds and cats in a domestic environment. Vet. Record, 167: 7-26.
16. Shaker, H.M. and B.A. Abd-Alhameed, 2016. Effect of application treated water and dry sludge on soil contamination with pathogenic bacteria. Iraqi J. Agric. Sci., 46: 726-734.
17. Da Costa, P.M., P. Vaz-Pires and F. Bernardo, 2006. Antimicrobial resistance in *Enterococcus* spp. isolated in inflow, effluent and sludge from municipal sewage water treatment plants. Water Res., 40: 1735-1740.
18. Al-Saadi, H.A., N.K. Al-Dham and L.A. Hassan, 1986. Limnology. Ministry of Higher Education and Scientific Research, University of Baghdad, Iraq.
19. Mueller-Spitz, S.R., L.B. Stewart, J.V. Klump and S.L. McLellan, 2010. Freshwater suspended sediments and sewage are reservoirs for enterotoxin-positive *Clostridium perfringens*. Applied Environ. Microbiol., 76: 5556-5562.
20. Al-Timimi, A.S., 2004. Environmental study on Tigris and Diyala rivers in southern part of Baghdad. M.Sc. Thesis, University of Baghdad, Iraq.
21. Das, P., D. Mukherjee and A.K. Sarkar, 2005. Study of a carrier dependent infectious disease-cholera. J. Biol. Syst., 13: 233-244.
22. Sansonetti, P.J., 2001. III. Shigellosis: From symptoms to molecular pathogenesis. Am. J. Physiol. Gastrointestinal Liver Physiol., 280: G319-G323.
23. Alhazmi, A., 2015. *Pseudomonas aeruginosa*-pathogenesis and pathogenic mechanisms. Int. J. Biol., 7: 44-67.
24. Bitton, G. and R.W. Harvey, 1992. Transport of Pathogens Through Soils and Aquifers. In: Environmental Microbiology, Ford, T. and R. Mitchell (Eds.). Wiley-Liss Inc., USA., pp: 103-124.
25. Kinnaman, A.R., C.Q. Surbeck and D.C. Usner, 2012. Coliform bacteria: The effect of sediments on decay rates and on required detention times in stormwater BMPs. J. Environ. Prot., 3: 787-797.
26. Field, K.G. and M. Samadpour, 2007. Fecal source tracking, the indicator paradigm and managing water quality. Water Res., 41: 3517-3538.
27. Lipp, E.K., K. Kurz, R. Vincent, C. Rodriguez, S.R. Farrah and J.B. Rose. 2001. The effects of seasonal variability and weather on microbial fecal pollution and enteric pathogens in a subtropical estuary. Estuaries, 24: 266-276.
28. Bashy, N.Y. and W.M. Alabd-Rabah, 2000. Finding efficient removal using activated sludge with a long-term ventilation. J. Environ. Sustain. Dev. Res., 3: 82-86.
29. Sarkar, M.J.A. and M.M. Rashid, 2012. Pathogenicity of the bacterial isolate *Aeromonas hydrophila* to catfishes, carps and perch. J. Bangladesh Agric. Univ., 10: 157-161.
30. Al-Ghabban, M.M.J., 2010. Environmental auditing of rustimiyah wastewater treatment plant effluents based on the world bank requirements using remote sensing technology. Ph.D. Thesis, University of Technology, Iraq.

31. Al-Obaidy, A.H.M.J., Z.Z. Al-Janabi and E. Shakir, 2015. Assessment of water quality of Tigris river within Baghdad city. Mesopotamia Environ. J., 1: 90-98.
32. Rasheed, K.A., 2016. Study the efficiency of two waste treatment plants in the Al-Karkh and Al-Rusafa of Baghdad region in 2015. J. Int. Environ. Applic. Sci., 11: 176-179.
33. Friedel, J.K., T. Langer, C. Siebe and K. Stahr, 2000. Effects of long-term waste water irrigation on soil organic matter, soil microbial biomass and its activities in central Mexico. Biol. Fertil. Soils, 31: 414-421.