Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 –6131
Vol. 28(4): 617–626(2024)
www.ejabf.journals.ekb.eg

Assessment of Natural and Municipal Liquid Wastes Discharged into the Tigris River in Mosul – Iraq

Rawaa M. Hmoshi[1], SaharLukman AL-Saleem[2], Mahmmoud Ismail Mohammed[2*]

[1]College of Environmental Science and Technology, University of Mosul, Mousl, Iraq
[2]College of Science, University of Mosul, Mousl, Iraq

***Corresponding author:**mahjsbio74@uomosul.edu.iq

ARTICLE INFO
Article History:
Received: Jan. 7, 2024
Accepted: June 27, 2024
Online: July 25, 2024

Keywords:
Environmental,
Estuaries,
Tigris River water,
Mosul City

ABSTRACT

The Tigris River is the only source of raw water in Ninevah province. Hence, water quality is of a high importance for all living organisms. The aim of the present study was to determine the extent of the effect of various and large amounts of liquid waste discharge on the water quality of the Tigris River. Water samples were collected from several estuaries: Shreikhan, Qara Sarai, Khoser Valley, WadiAkab, Al Danfelly Valley, and Maidan. Chemical and physical analysis of samples such as pH, electrical conductivity, total dissolved salts, turbidity, chemical oxygen demand, phosphate, hardness with all types, total bacterial count were conducted in addition to the identification of pathogenic bacteria. The results showed that the variation in the values of pH was between 6.4- 8.7 and E.C values were between 700-1230µs/cm. The highest turbidity values were observed at WadiAkab (101NTU), while the lowest turbidity was detected at Khoser with a value of 9.71 NTU. Chemical oxygen demand in waste products of Al-Danfelly Valley was 370mg/l compared with the lowest value of 85mg/l at Al- Khoser. The total bacterial count in Danfelly, Wadiakab, and Khosar Valley was found to be 2x102, 3x104, and 5x102 cells/ml, respectively. Pathogenic bacteria were identified in waste products of the above locations.

INTRODUCTION

Water is considered a vital and indispensable substance for all living organisms. Water makes up about 50-60% of the living cell's total weight, 70% of vegetables, and increases to about 90% in fruits which means it is present in all living forms. For human beings, it is the second most vital thing after oxygen; therefore, there is an urgent need for the provision of pure and safe drinking water that meets national standards to reduce environmental health risks **(Kannah&Shihab, 2021; Rabeea*et al.* 2021; Rabeea*et al.* 2022)**. An adequate amount of safe water is necessary to prevent water-borne diseases.

Unfortunately, the widespread presence of environmental pollutants is becoming one of the drawbacks to achieving such levels of water sanitation. Water pollution is a serious problem that threatens the life of living organisms and is no less dangerous than air pollution since they both share the special nature of the pattern of pollution prevalent in developing countries **(Mukhlif *et al*., 2021; Rabeea *et al.*, 2021; Kannah & Shihab, 2022)**.

The Tigris River is considered to be the main source of surface water for the city of Mosul and its surrounding towns and villages, where it is used for various purposes including drinking water, industrial, agricultural, and recreational purposes **(Al-Hadedi *et al.*, 2024)**. After crossing the Iraqi-Turkish border by about 188km, the Tigris River reaches Mosul City center. North of Mosul City, by about 63km, a great dam was constructed on the river in 1985. The width of the Tigris ranged between 2 to 10km and its mean discharge was equal to $650m^3$/sec **(Mustafa, 2000)**.

Wadi-Ekab's length reaches about 11km, and its maximum discharge reaches $32m^3$/sec. This wadi carries rainwater, domestic, and industrial wastewater, whereas Al-Khouser's length reaches almost 75km, and its maximum discharge equals $1000m^3$/sec. It carries industrial, domestic, and agricultural wastewater. Wadi Shrechan, on the other hand, has an 11km length and a maximum discharge of $86m^3$/sec. It carries domestic wastewater in addition to animal and plant wastes. Moreover, these estuaries carry various industrial, domestic, and agricultural pollutants **(Reem,2012)**.

The emergence of agricultural and industrial construction projects in addition to the increase in population has led to the disposal of untreated industrial as well as agricultural wastes in the river at levels exceeding that of the standard specifications. Liquid wastes discarded in the Tigris River in Mosul City are estimated to be about 6598m3/ hour. These wastes turned the Tigris River into a wretched flow of waste with an unpleasant sight **(Hussein, 1988)**. The direct disposal of these wastes is considered one of the violations that threaten human life by causing epidemics, such as cholera, dysentery, typhoid fever, meningitis, hepatitis, and polio **(Kannah *et al.*, 2019)**. The distribution of fresh water on the earth's surface is shown in Fig. (1).

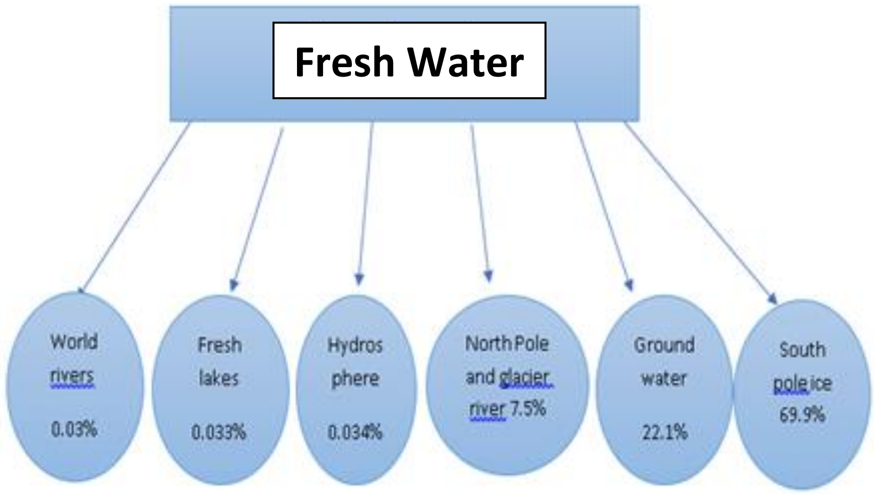


Fig. 1. The percentage of freshwater distribution in the world **(AlOmar, 2009)**

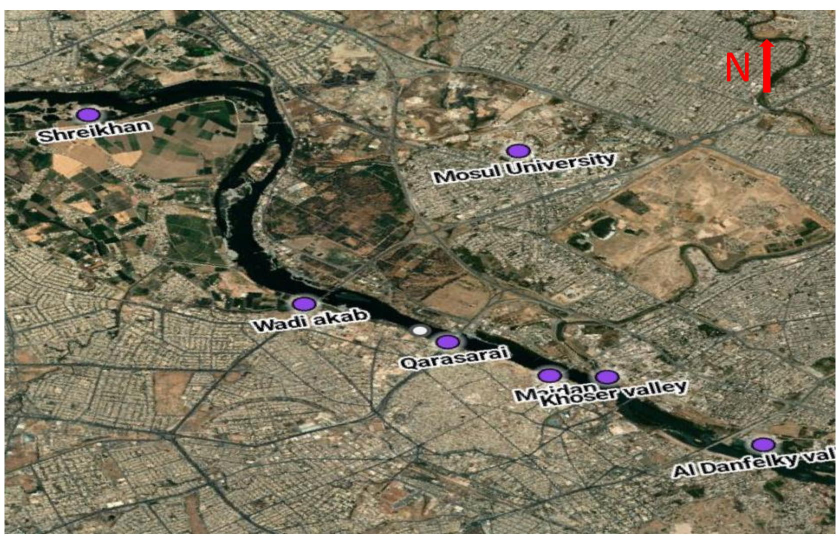
Liquid water pollutants discharged in the Tigris River are as follows **(AlOmar, 2009)**:

1- Natural pollutants: Organic pollutants have always been present since the existence of plants and animals on Earth. Running waters swiftly sweep away all the dead and organic matter, especially when rainfall sweeps over soil, rocks, minerals, and organic waste.
2- Thermal pollution: This normally occurs along with the existence of electric power stations and industrial cooling water. This adds hot water, which harms plants and animals more than the pollutants themselves by affecting the natural balance of the environment.
3- Bacterial pollution: Pathogenic microbes that cause contagious diseases like cholera, dysentery.
4- Oil pollution: Oil is one of the most common pollutants since it spreads as fast as 700km from its leakage source.
5- Industrial pollutants: Chemical pollution is one of mankind's biggest complications.

Many studies have demonstrated the continuous drop in water quality of the Tigris River; one of which showed a persistent bacterial contamination due to the constant sewage discharge into the river **(Al-Hadedi, 2024)**. This study aimed to evaluate the degree of pollution of these effluents by determining their physical and chemical properties, assessing the total bacterial count, and identifying pathogenic bacteria present.

MATERIALS AND METHODS

Contaminated water samples were collected from various debouches (Shreikhan, Qara Sarai, Khoser Valley, WadiAkab, Al Danfelly Valley, and Maidan) at Dijlah River during the period from January to April 2022, as shown in map (1). Analysis testing was carried out at the University of Mosul/ College of Science /Department of Biology. Moreover, chemical and physical analysis were performed according to the guidelines outlined by **APHA (1979)**. The pH values were measured using a field pH-meter (Hanna Microprocessor 211), and electrical conductivity was recorded using an EC-meter. Some properties were measured in the field, such as temperature, pH, and electrical conductivity. While, several physical and chemical properties were measured in the laboratory after they were collected in bottles and delivered directly to the laboratory. The total number of bacteria was calculated after collecting samples from these outfalls using sterile tubes and cultured on nutrient agar medium. Biological analysis (bacterial cell count) was estimated using the standard plate count method as recommended by the World Health Organization. Furthermore, the identification of pathogenic bacteria was carried out at the Bacterial Bank at the University of Mosul/ Department of Biology **(Abawi & Hassan, 1990)**. Turbidity measurements were recorded using a turbidity meter. Additionally, dissolved oxygen was determined by using a modified Winkler method. Dissolved solids were measured by drying the sample at 103-105^{o}C, and chemical oxygen demand (COD) was performed using the open reflux method according to the standard Orchidis hot plate uniplac.



Map 1. Samples collection sites (google earth)

RESULTS

Table 1. Physical and chemical characteristics of study locations

Location / Experiment	WadiShrikhan	Qara Sarai	Al-Khusair	WadiAkab	Al-Danfali Valley	Al-Madan
Potential hydrogen (pH)	6.8	6.8	7.6	8.7	7.3	6.4
Electrical conductivity (EC)	700	1030	1230	1070	740	990
Total dissolved solid (T.D.S) (mg / L)	430	510	660	530	360	490
Turbidity (N.T.U)	15.35	66	9.71	101	22.90	69
Chemical oxygen demand (C.O.D) (mg /l)	144	153	70	85	370	220
Total salts (mg / l)	305	490	425	330	536	494
Total hardness (mg / l)	130	226	220	230	186	590
Calcium hardness (mg / l)	72	86.4	68.8	124.8	130	305
Magnesium hardness (mg / l)	58	139.6	35.95	105.2	56	285
Phosphate (mg / l)	0.041	1.03	0.132	0.115	0.367	0.903

Table 2. Concentration of DO,saturation ratio and total number of bacteria

Location / Experiment	WadiShrikhan	Qara Sarai	Al-Khusair	WadiAkab	Al-Danfali Valley	Al-Madan
Dissolved oxygen (mg / l)	0	0.98	1.7	1.64	1.89	0
Saturation ratio (%)	0	9.8	21.3	15.9	12.20	0
Total number of bacteria (cell/100ml)	$1 * 10^2$	$5 * 10^2$	$5 * 10^3$	$3 * 10^4$	$2 * 10^3$	$5 * 10^2$

Table 3. Bacteria species identified in study location

Location	Oxidase test	Pathogenic species identified	Percentage among bacterial species
WadiShrikhan	---	---	---
Qara Sarai	+	*Pseudomonas* and *Klebsiella*	*80%,80%*
Al-Khusair	+	*Pseudomonas*	*%80*
WadiAkab	+	*Pseudomonas*, *Klebsiella*, and *Staphylococcus*	*%80,%60,%20*
Al-Danfali valley	+	*Klebsiella, Staphylococcus,* and *E.Coli*	*%80,%60,%20*
Al-Madan	+	*Pseudomonas* and *Klebsiella*	*80%,80%*

DISCUSSION

The results shown in Table (1) present pH values that varied between 6.4 to 8.7. The highest value (8.7) was recorded at Wadi Akab detachment. This is due to the presence of carbonate and bicarbonate ions as well as the detergents which increase the alkalinity of water **(Jacoby & Welch, 2004)**. Moreover, the lowest pH value was shown at Maidan, which was about 6.4. This value could be due to the decomposition of organic matter sinceit gives carboxylic and mineral acids caused by the disposal of municipal domestic liquid wastes, as shown by the following equation **(Jacoby &Welch, 2004)**:

$$4CH_3H_7O_2NS + 8H_2O \rightarrow 4CH_3COOH + 4NH_3 + 4H_2S$$

However, comparing the results of the present study with the maintenance system limitations confirmed that residual water is within the allowed range.

EC values for the liquid wastes ranged between 700-1230µs/cm. The highest EC values were demonstrated by the Khoser Valley, while the lowest was at Shreikhan Canyon. The increased EC values may be a result of the addition of salts to the sewage waters in addition to the active microbial decomposition and the excretion of municipal waters from domestic, industrial, and agricultural usage **(Al-Jahsani, 2003)**.

The results shown in Table (1) reveal a high concentration of these salts in Khoser Valley (660milligrams/liter), compared tothe lowest concentration at Shreikhan Canyon with a value of340milligrams/liter.

The turbidity values shown in Fig. (5) clearly demonstrate that most of the liquid water discharged into the Tigris River from various sources has exceeded the standard limits recommended by the WHO. The highest values were found in WadiAkab (101NTU), while Khoser Valley had the lowest value (9.71 NTU). This variation may be explained by the presence of organic planktons (Colloidal materials) in waste products disposed into the Tigris River compared to the former river turbidity, which depended on inorganic particles represented by surface soil components swept by rain and snow waters. This inorganic particle load decreased significantly following the concentration of the river water in Mosul Dam **(Mustafa, 2000)**.

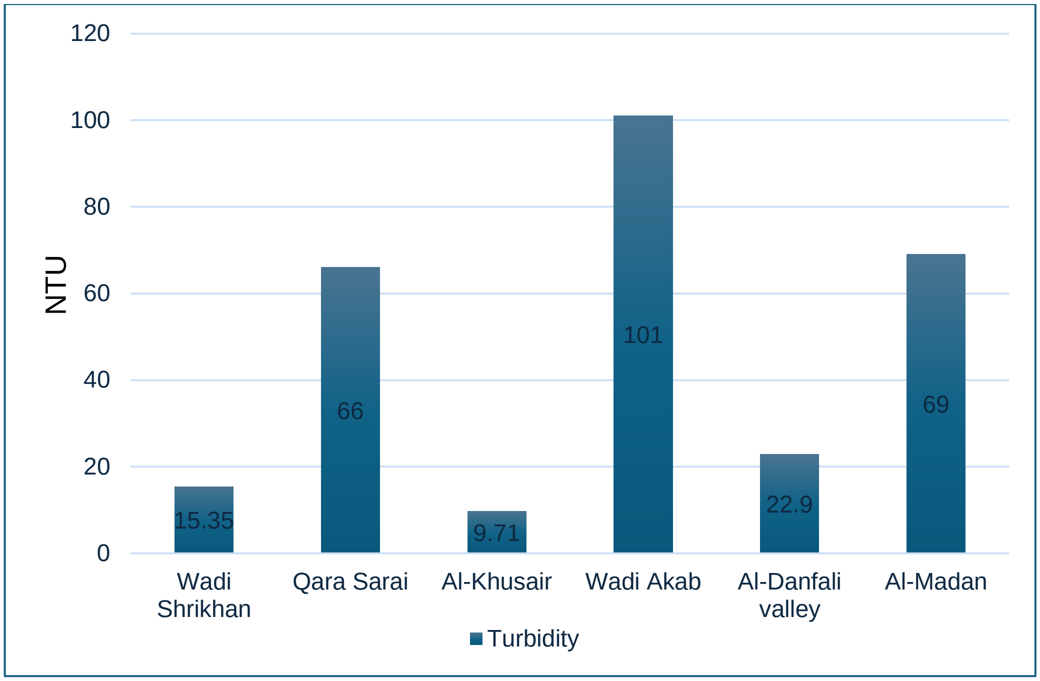


Fig. 2. Turbidity values (NTU) for study locations

Phosphate water concentration in various debouches wastes ranged between 1.034- 0.041mg/ liter with the highest value at QaraSaray, followed by Maidan, Danfelly, KhoserValley, WadiAkab, and finally, Shreikhan, with 1.034, 0.903, 0,36, 0.132, 0.115, 0.041mg/l, respectively, as shown in Table (1). The source of phosphate in water is limited to phosphate fertilizers in addition to various other waste materials. Additionally, the development of liquid and dry detergent factories contributes to the increase of phosphates **(Baird & Cann, 2005)**. However, the present study found that all debouches had phosphate concentrations among the allowed levels, as shown in Table (5).

The results also demonstrate an increase in organic and inorganic concentrations in liquid waste shed in the Tigris River at all detachment locations. The values varied between 70- 220mg/l which are considered above the permissible levels **(Abawi & Hassan, 1990)** for river maintenance. This may be attributed to the vast quantity of organic and inorganic wastes submitted in sewage waters which has a negative effect on the concentration of dissolved oxygen followed by anaerobic decomposition and resulting in harmful products in water environments, such as H_2S, ammonium gas NH_3 and the emission of foul odors **(Al-tai, 2011)**.

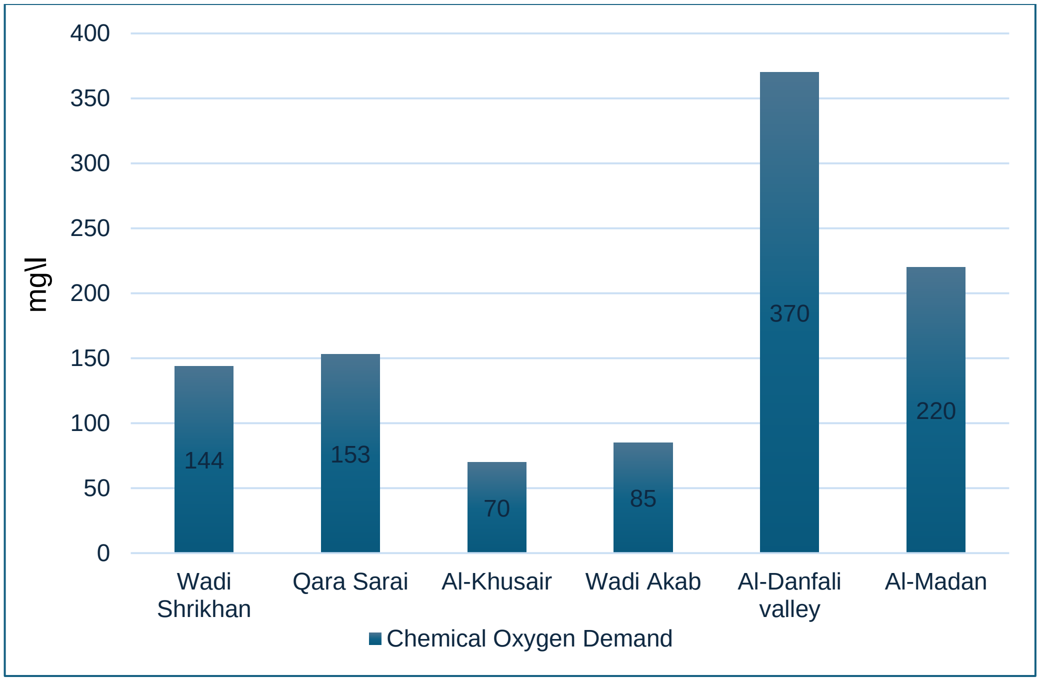


Fig. 3. The concentration of chemical oxygen demand (mg/l)

Hardness values did not exceed 590mg/ l, as indicated by CaCO3 measurements in Maidan debouches. The lowest value was found to be 130mg/l at Shreikhan compared to the higher calcium and magnesium hardness of 305 and 139.6mg/ l measured as CaCO3 at Maidan and QaraSaray. This may be caused by liquid wastes from human sources, drifts from banks, and contaminants in nearby soils in addition to animal wastes **(Saffawi, 2007)**.

Low dissolved oxygen was found in all debouches with contaminated liquid wastes; the lowest concentration ranged from zero to 1.89, accompanied by a saturation rate of about 0 to 21.3%. This could be explained by the quality of waste products with high organic and inorganic contents that need large quantities of oxygen to be degraded.

The results of the present study showed heavy growth in all samples. Moreover, the total bacterial count varied between $1x10^2$- $5x10^3$ cells/ml (Table 1). The most predominant genera were *Pseudomonas* and *Klebsiella*, followed by *E. coli* and *Staphylococcus*. Contaminated water is well known to transmit many diseases as it contains all types of waste **(Salih *et al.*, 2021)**.

CONCLUSION

All measured variables such as the total count of bacteria showed concentrations beyond the limits allowed by the World Health Organization (WHO). Additionally, all water samples from these estuaries exhibited heavy bacterial growth, including species such as *Pseudomonas* and *Klebsiella*, as well as the presence of pathogenic species discharged into the Tigris River.

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