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Spatial Assessment of Heavy Metal Pollution and Physicochemical Characteristics of Al-Gharraf River Water in Al-Rifai City, Dhi Qar Governorate

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I. Abstract

The Al-Gharraf River is facing growing environmental problems from the combination of increased population growth and industrial as well as agricultural expansion. The study was carried out in order to evaluate the surface water quality and heavy metal pollution in Al-Gharraf River, passing through Al-Rifai City, southern Iraq. Water samples were collected from four different sites along a 20 km stretch (before, within, and after the city) and physicochemical characteristics (pH, EC, TDS, TH, SAR) and heavy metal loads (Cu, Cd, Pb, Zn, Fe) calculated using the technique. The findings were consistent with spatial diversity of values of the studied variables, salt and heavy metal concentrations gradually increased downstream, especially in urban areas. The analytical analysis identified concentrations of majority (mostly lead (Pb), cadmium (Cd), iron (Fe)) of heavy metals that exceed upper limits set by World Health Organization (WHO, 2022) and Iraqi Standard Specification (IQS, 2009). The worsening of water quality and quality control was mainly due to direct effluent of untreated sewage, industrial by-products, and agricultural runoff loaded with pesticides and fertilizers. This study indicates that chemical pollution poses a threat to public health of the study area river water, thus urgent methods for treatment and preventing pollution are needed.

Keywords: Water pollution, heavy metals, Al-Gharraf River, Al-Rifai City, water quality assessment, environmental impact.

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II. Introduction

The three natural resources are the foundation for sustainable life on Earth—water, air, and soil. Among these resources, water occupies a privileged place because of its critical role in maintaining living things' very survival, ensuring food security, and aiding economic development. With global water demand rising by nearly six times since 1900, environmental issues, sustainability and the carrying capacity of the Earth have all been brought into line with the policy of international organizations (Dwivedi, 2017). Rapid population and economic growth in the world puts pressure on available safe and reliable water, and is creating genuine challenges for the world to meet the Sustainable Development Goals. Human activities are affecting water systems with direct impacts since surface and groundwater contamination due to urbanization, industrial expansion, and climate change, have been attributed to the degradation of water quality in the aquatic systems (Halder and Islam, 2015). As a growing portion of the population of developing countries such as Iraq has been displaced by urbanization, rivers are particularly prone to higher environmental pollution due to the abundance of nutrients, heavy metal and pesticides contaminants, mostly as a consequence of both sewage discharge and agriculture (Kroeze et al., 2016). Iraq experienced sharp depletion of the water quality over the last two decades, which is attributed to multiple sources of pollution and an absence of effective treatment (Abdul Razzaq, 2016). The purpose of this study is to evaluate the surface water quality of Al-Gharraf River (a Tigris River tributary) as it passes through the city of Al-Rifai through assessments of its physical and chemical characteristics as well as heavy metal concentrations, and assessing the effects of the sewage and industrial effluents (industrial effluents from oil companies) and activities from agriculture on water quality for drinking and irrigation applications.

1- Physical and Chemical Properties of Water and Measurement of Water Quality Indicators (pH, EC, TDS, TH) and Major ion concentrations are all essential to assessing the water's suitability for different uses.

2- Estimating pollution levels of heavy metals (lead, cadmium, copper, zinc, and iron) in different sections of the river.

3. Spatially assessing pollution sources and studying the variation in pollutants between areas (before entering the city, within the city, and after leaving it) to determine the impact of domestic and industrial wastewater on the river environment.

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2- Materials and Methods

2.1Study Area

The study was conducted on Al-Gharraf River, which is the main water source in Al-Gharraf Basin extending from Wasit Governorate (Al-Kut) through the northern districts of Dhi Qar. Four sampling sites were identified along a 20 km stretch in the city of Al-Rifai (as shown in Figure 1). These sites were located (before the river enters the city, at the beginning of the river's entry into the city, in the city center, and at the southern city boundary).

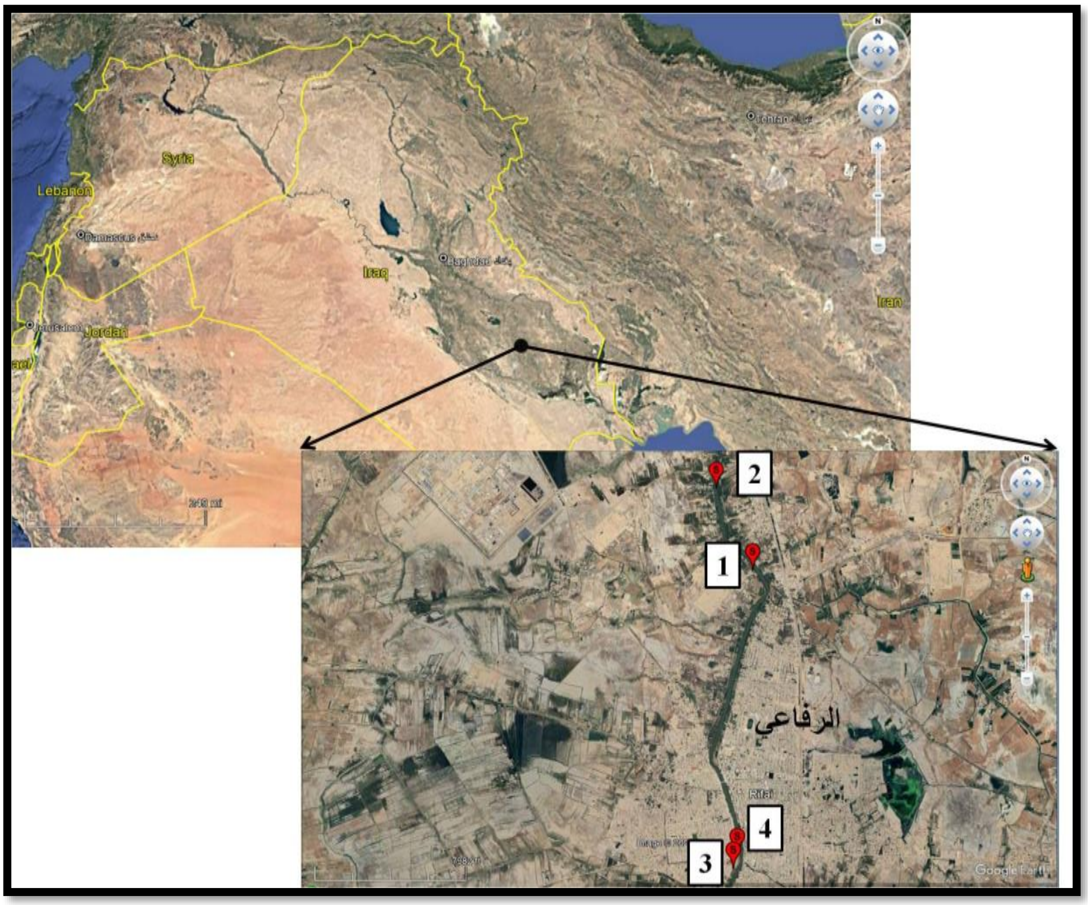

Figure (1) Sampling sites for the study area.

2-2 Measurement of some physicochemical properties of water samples.

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Table 1. Some physicochemical properties of water samples from Al-Gharraf River - Al-Rifai District.

Properties	Sites			
	1	2	3	4
Electrical Conductivity (dsm^{-1})	1.21	1.40	1.47	1.43
pH	7.42	7.60	7.85	7.73
Calcium and magnesium (millieq L^{-1})	16	18	20	20
Sodium (millieq L^{-1})	3.12	3.46	3.71	3.86
SAR (millieq L^{-1})	1.56	1.63	1.66	1.73
T.D.S (mg L^{-1})	518.8	5.525	574.8	564.7
T.H (mg L^{-1})	276.2	287.6	365.76	386.7

2.2.1 Electrical Conductivity

Electrical conductivity was determined using an EC-meter according to the method described in Page et al. (1982).

2.2.2 pH

The pH was determined using a pH-meter according to the method described in Page et al. (1982).

2.2.3 Calcium and Magnesium Determination

Calcium and magnesium ions were determined in the water samples using EDTA titration as described in Jackson (1958).

2.2.4 Sodium

Sodium concentrations were measured using a flame photometer according to Jackson (1958).

2.2.5 Sodium Adsorption Ratio (SAR)

The sodium adsorption ratio was determined using the following equation.

$$SAR=............\frac{Na^{+}}{\sqrt{\frac{(Ca^{+2}+Mg^{+2})}{2}}}$$

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2-2-6 Total Dissolved Salts (TDS)

TDS were estimated according to the method (3030 D2) described in 1998 APHA, by filtering (100) milliliters of the sample and collecting the sample in a vessel of known weight (b), then evaporating the filtrate in an oven at a temperature of (105-1qw03) °C, and after that it was weighed (a).

$$T.D.S(mg\ L^{-1}) = (a - b)\times 10^{3} / V \text{ of sample}$$

2-2-7 Total Hardness (T.H)

Total hardness was estimated by titration with Na2 EDTA N 0.001 and Eriochrome Black T as an indicator. Results were expressed in mg L^{-1} (Richard, 1954).

2-2-8 Heavy Metals

To estimate heavy metals in water samples (Cu, Cd, Pb, Zn, and Fe), 100 mL of the sample was first digested with 5 mL of concentrated nitric acid ($3HNO_3$) and 1 mL of concentrated hydrochloric acid (HCl) using a hot plate. The filtrate was then measured using an atomic absorption spectrometer (APHA, 2017).

3- Results and Discussion

The physicochemical determination of water samples of Al-Gharraf River as per the data in Table 1 provided a remarkable spatial variation. The electrical conductivity (EC) and TDS also gradually elevated with greatest values recorded at the third place, 574.8 mg L^{-1}. This is an increment of higher salt load created with human activity and wastewater runoff, while remaining within internationally acceptable limits. The measured water quality was also toward slightly alkaline water with an pH of 7.42-7.85. This was in parallel to a rise of total hardness (T.H) to 386.7 mg L^{-1}, rendering the water very hard and raising the likelihood of limescale precipitation. Notwithstanding an increase in SAR to 1.73, the water was still in the excellent category of irrigation, indicating a lack of soil risk of sodium salinization if used for agriculture.

The results (Table 2 and figures ….) showed that the concentrations of most heavy metals exceeded the limits allowed according to the standards of the World Health Organization (WHO, 2022) and the Iraqi Standard Specifications (IQS, 2009), noting the high concentrations within the city (the third and fourth sites) compared to the previous sites.

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Table 2. Concentrations of heavy metals (mg.L^{-1}) in water samples from Al-Gharraf River - Al-Rifai District.

T	Heavy metal	Site 1	Site 2	Site 3	Site 4	Average
1	(Cu)	1.08	1.29	2.03	1.67	1.51
2	(Cd)	0.01	0.02	0.06	0.04	0.03
3	(Pb)	0.1	0.2	1.12	1.00	0.60
4	(Zn)	2.00	2.28	3.13	3.05	2.61
5	(Fe)	2.67	3.13	3.66	3.45	3.22

3-1 Copper (Cu)

This showed a large variation in copper concentrations. Site 1 (before entering the city) had the lowest value of 1.08 mg.L^{-1}, and the values increased, peaking at site 3 at 2.03 mg.L^{-1} and reaching 1.67 mg.L^{-1} at site 4. When compared with the standard parameters, these values were found to exceed the internationally permissible limit prescribed by the World Health Organization (WHO, 2022) of 0.3 mg.L^{-1}. This huge increase, especially within the city, is due to industrial pollutants and untreated sewage running straight into the river through irregular sewer and pipe networks. Human activities have also been shown to enrich water bodies with copper, where agricultural runoff has been found to be involved in the transportation of pesticide and fertilizer residues containing copper into the waterway.

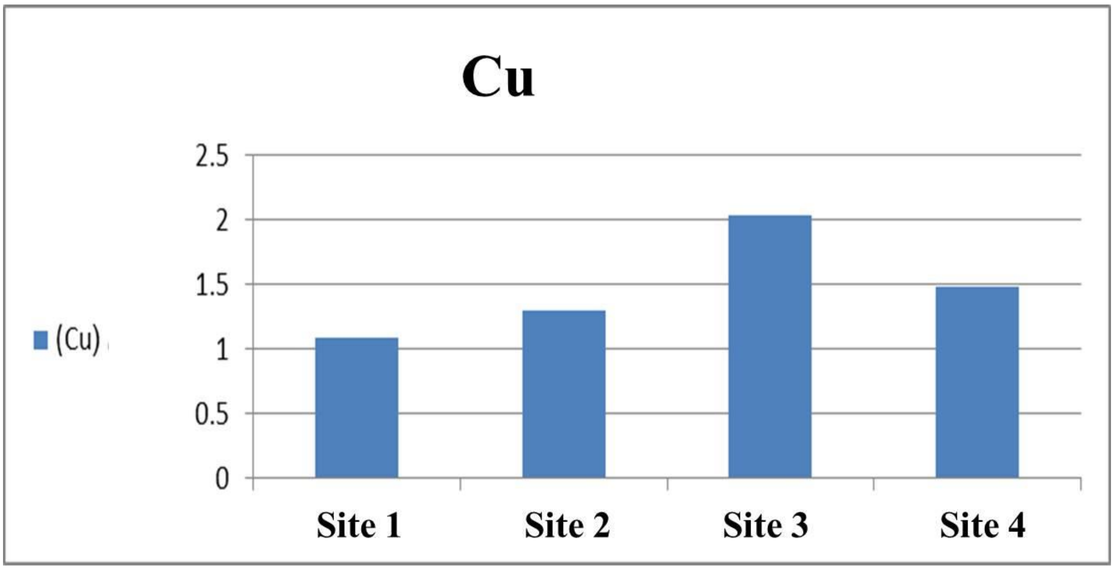

Figure (2) shows the copper levels (mg/L^{-1}) for the study area sites.

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3-2 Cadmium (Cd)

Cadmium levels were lowest at sites1 and 2, with concentrations of (0.01 and 0.02) mg.L⁻¹ respectively, while the highest concentrations were recorded at sites 3 and 4, with (0.06 and 0.04) mg.L⁻¹. These data indicate a clear exceedance of the permissible limits for drinking and other uses, which is 0.003 mg.L⁻¹ according to the standards of (WHO, 2022). The high concentrations of cadmium at the study sites are associated with surface water pollution from industrial liquid waste and wastewater from inefficient treatment plants that may contain compounds of this toxic element. This finding supports the findings of (Rani et al., 2014) regarding the mechanisms of cadmium transport and accumulation in aquatic environments affected by urban activity.

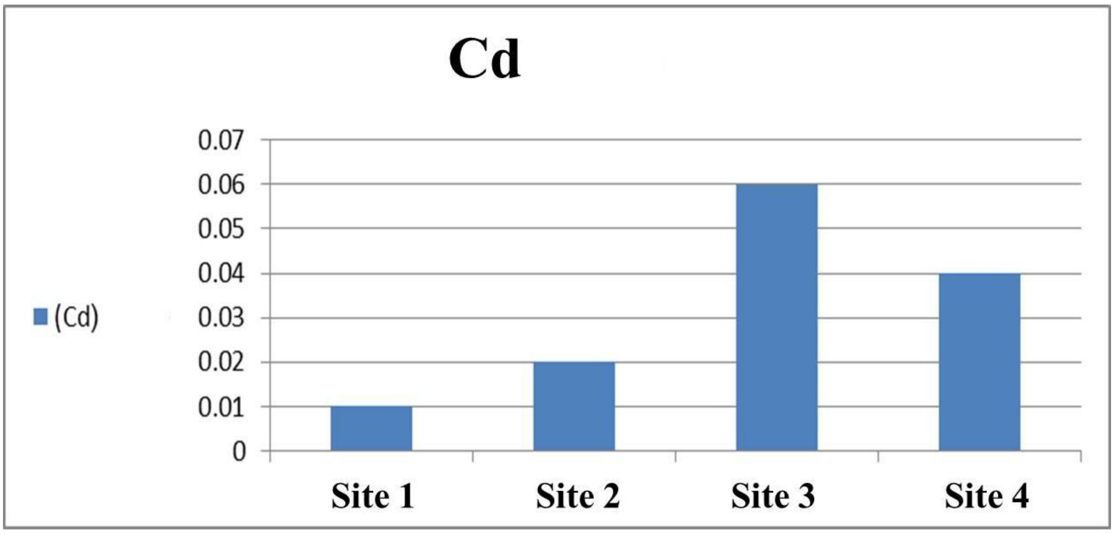

Figure (3) Cadmium level values (mg.L^{-1}) for sites in the study area

3-3- Lead (Pb) Concentrations:

A sharp increase in lead concentrations was observed within the city compared to its entrances. The lowest values in the sites 1 and 2 ranged between (0.1 - 0.2) mg.L⁻¹, jumping significantly in sites 3 and 4, recording (1.12 and 1.00) mg.L⁻¹ respectively. These concentrations are very high and environmentally hazardous when compared to the internationally permissible limit of 0.01 mg.L⁻¹ (WHO, 2022). The main cause of this pollution is attributed to liquid industrial waste laden with suspended solids, the use of certain types of pesticides, and toxic organic and inorganic compounds resulting from urban activities and vehicle exhaust that may reach the river, thus constituting a primary source of lead, This is consistent with what was stated in (Paul et al., 2019).

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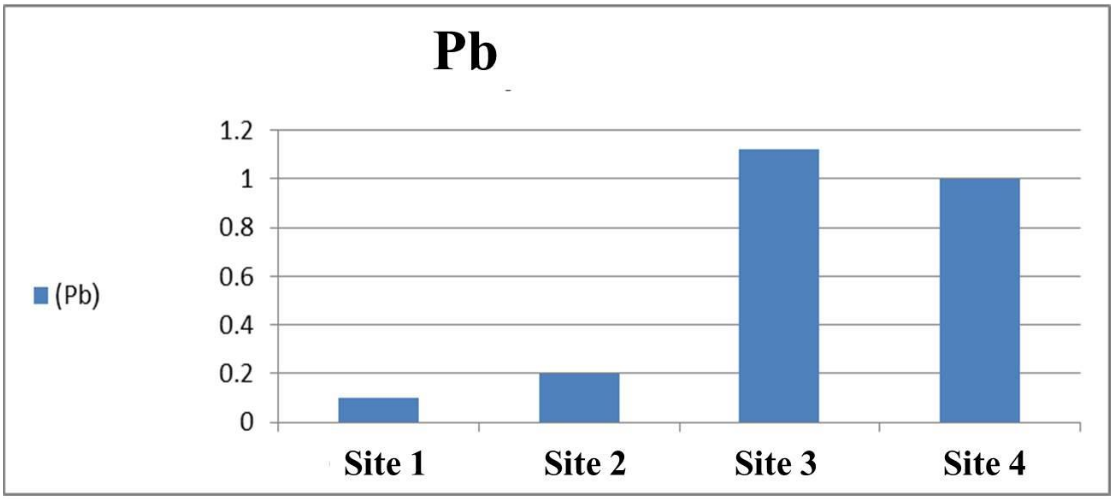

Figure (4) shows the values of lead levels (mg.L^{-1}) for the study area sites.

3-4 Zinc (Zn)

Zinc concentrations gradually increased downstream, starting from 2.00 mg.L^{-1} at the site 1 and reaching their highest levels at sites 3 and 4, with concentrations of 3.13 and 3.05 mg.L^{-1} respectively. Comparing the results with environmental parameters, it was found that the sites within the city exceeded the permissible limit of 3.0 mg.L^{-1} (WHO, 2022). The high zinc levels are attributed to multiple sources, including domestic wastewater and the intensive use of agricultural fertilizers and pesticides in the lands surrounding the river basin. Chemical reactions in freshwater also play a role in the solubility and transport of zinc compounds and their interaction with other compounds (Wiener, 2013).

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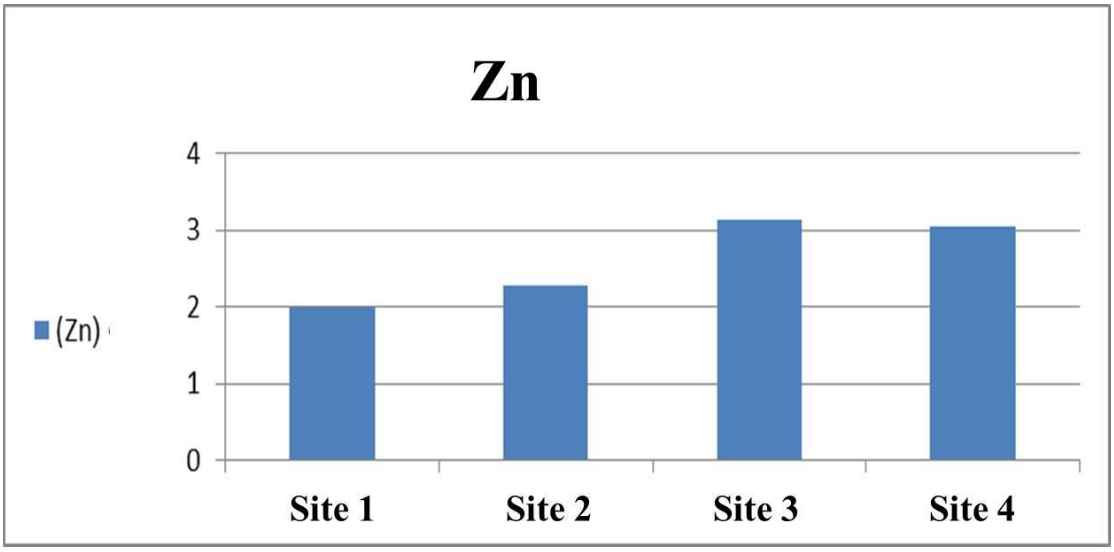

Figure (5) shows the average zinc values (mg.L^{-1}) for the study area.

3-5 Iron (Fe)

The iron analysis results showed high concentrations at all sites, with the lowest value of 2.67 mg.L^{-1} at the site 1and the highest value of 3.66 mg.L^{-1} at the site 3. All recorded values are outside the permissible limits of 0.3 mg.L^{-1} according to the (WHO, 2022) standard. The high presence of iron is associated with a combination of natural and human factors. Human activities include agricultural practices (fertilizers and herbicides), solid waste decomposition, and sewage discharge. In addition, airborne dust pollution and vehicle exhaust contribute to increased mineral load in the river. As Mokarram et al. (2020) indicated, levels of heavy elements such as iron are significantly higher in rivers and soil sediments near urban and industrial areas.

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Figure (6) shows the values of iron levels (mg/L^{-1}) for sites in the study area.

3- Conclusions

1-The study disclosed severe Pb, Cd and Fe contamination above the permissible limits internationally and locally at all locations. It makes the water unfit for consumption without treatment by sophisticated methods.

2- Spatial deterioration of water quality, as a continuous decline in water quality was observed when heading towards the center of Al-Rifai city (Sites 3 and 4), with total hardness (T.H) and total dissolved salts (T.D.S) recording their highest levels, which indicate the direct effect of urban and industrial activities.

4- Recommendations

1- Urgent obligation of industrial plants, hospitals and oil enterprises in that area to set up primary treatment facilities for their liquid waste before disposal to Al-Gharraf River and prohibition of direct discharge of untreated sewage.

2- Modernisation of drinking water facilities in Al-Rifai district and provision of technologies to facilitate the removal of heavy metals (eg, activated carbon adsorption or ion exchange) to provide safe water to customers.

3- Implement a monitoring system of river water quality, bottom sediments, etc at near-real time, and carry out ongoing research studies of the overall transfer of heavy metals from water to the food chain (e.g. plants and fish) to protect the public's health.

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