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Study of Heavy Metals Pollution in Diwaniyah River Water

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Abstract

Water quality changes due to pollution are a major environmental concern in developing countries. Urban wastewater and industrial effluents are discharged into nearby water bodies with limited or no treatment. The main objective of this study was to determine the extent of pollution of the Diwaniyah River with some heavy metals (nickel, lead, and cadmium) and evaluate its suitability for irrigation based on some water quality characteristics for irrigated agriculture and classify it according to the most common international classification systems. Three sites along the river were selected, and water samples were collected from the river monthly for a year, from June 2023 to May 2024. The average values of the measured characteristics were calculated for each of the three months, divided over the four seasons. The concentrations of heavy metals in the water samples were measured in the laboratory according to standard procedures. According to the three metals measured during the study, the results of this study showed that the river water is polluted with nickel, as the highest concentration (0.374 mg L^{-1}) was recorded in the summer at the third site. River water can be classified as C3S1, which is considered slightly saline and slightly sodic, meaning that the risk of sodium ions in river water to the soil is low. It is permissible to use it for irrigation provided that the soil leaching requirements are met.

Key Words: Diwaniyah River, Heavy Metals, Pollution, Irrigation, classification.

1. Introduction

Global freshwater scarcity is not only caused by insufficient natural resources but also by the gradual deterioration of water quality in many countries, reducing the amount of usable water [1]. Various natural factors and multiple human activities affect river water quality. Industrialization and urbanization negatively impact fragile water supplies, creating new demands and pollution risks [2]. Factories consume large quantities of water, which are withdrawn from rivers. In turn, they release effluents (containing suspended and dissolved solids, oils and grease, heavy metals, phosphates, ammonia, acids, etc.) into rivers, negatively impacting river water quality [3]. Pollution makes water unsuitable for irrigation, and treating it to an acceptable quality is difficult and expensive. On the other hand, as water quality declines, soil and crop problems develop, which in turn reduce yields unless specialized management practices are adopted to maintain or restore maximum production capacity under specific conditions [4].

From a quality perspective, the suitability of water is determined by the problems it causes. Water quality problems in irrigated agriculture include salinity, low water infiltration rates, specific ion toxicity, and various other problems [5]. A salinity-related water quality issue arises when the concentration of salts in irrigation water becomes excessive, causing accumulation in the root zone of crops to an extent that it negatively influences crop yields. Additionally, toxicity may occur when certain ions from the water are absorbed by the crops and build up within the plant. This is typically linked to the presence of one or more heavy metal ions in the water. In Diwaniyah, environmental pollution from residential and industrial activities poses a significant risk to surface water quality [6]. Most factories in the region release their wastewater into local water sources with little to no treatment [7]. As the demand for irrigation water rises, agricultural lands frequently resort to using subpar irrigation water. Effluents from industries, released into surface waters and inactive treatment facilities, may be utilized for irrigation purposes [8]. Nevertheless, the persistent use of low-quality irrigation water can curtail agricultural output and impact on the environment, farmers, and consumers of food products [9]. The unregulated application of hazardous chemicals in various industries and the release of their wastewater into water bodies can have detrimental effects on human health and aquatic ecosystems [10].

The current study aims to determine the extent of pollution of the Diwaniyah River water with some heavy elements, evaluate its suitability for irrigation, and classify it according to the most common international classification systems. To achieve this goal, some chemical and physical properties of the river water were measured in the area extending from the city of Al-Saniyah, passing through the city of Diwaniyah and ending in the city of Al-Hamza.

2. Materials and methods

2.1. Study Area:

The current study was conducted in Diwaniyah Governorate along the Diwaniyah River, a branch of the Hilla River, a tributary of the Euphrates River. The river enters Diwaniyah Governorate from the north in Al-Saniyah city and covers approximately 121 km. The river's width ranges between 20-25 m, and its depth is 2-4 m. The river passes through agricultural areas, and various industrial, agricultural, and domestic activities affect the quality of its water. The river ends at the junction of the Al-Kat'a and Abu Sakhir branches [11] (Figure 1). Diwaniyah Governorate is located within the alluvial plain of central Iraq. Its lands are generally flat and low in slopes, and it has a desert climate, with hot, dry summers and cold to moderate winters, with fluctuating rainfall averaging 114.8 mm/year. The rainy season extends from early November to late April, with uneven rainfall distribution. The average annual temperature is approximately 24.74°C [12]. Agricultural lands in Diwaniyah Governorate are utilised for growing various cereal crops, including wheat, barley, rice, and corn, as well as fodder and vegetable crops. These crops are irrigated from river water using flood and drip irrigation systems.

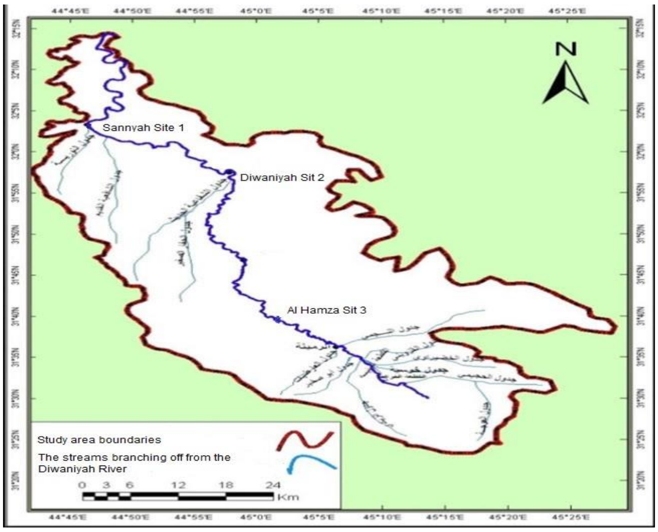

Figure 1: Map of the Diwaniyah River (study area)

2.2. Sampling Sites:

To analyze water quality, sampling sites along the river were selected based on accessibility and safety, considering pollution sources [6]. Therefore, the selected sampling sites were primarily located downstream of industries that discharge liquid waste into the river. Three sites were selected along the river, the distance between one sit and another is 20 km.: the first, in the Al-Saniyah city, served as a comparison site, located before the various pollution sources that flow into the river; the second, in the center of Diwaniyah city; and the third, in Al-Hamza city, served as the final site after all pollution sources had reached their outlets. Water samples were collected monthly for a year, from June 2023 to May 2024. The average values measured for each three months were taken, divided into the four seasons: summer (June, July, August); autumn (September, October, November); winter (December, January, February); and spring (March, April, May). Composite water samples were taken from each site of the river, considering spatial variations, according to standard sampling methods [13]. Sterile plastic bottles (2 liters) were used for sampling, washed with river water, filled to the brim, tightly closed, and stored in cold conditions until transported to the laboratory. Samples were kept refrigerated until laboratory analysis was performed. All analyses in this study were performed in three replicates.

2.3. Sample Analysis Methods:

To determine the extent of river water pollution with heavy metals, nickel, lead, and cadmium were selected and their concentrations in water samples were measured using an Atomic Absorption Spectrometer (AAS). To assess the suitability of the water for irrigation, some chemical and physical properties associated with water quality problems were measured: pH, salinity, which was measured by calculating electrical conductivity (EC) and total dissolved solids (TDS); concentrations of positive ions (calcium, magnesium, and sodium) and negative ions (sulfate and chloride) were also measured. Chemical and physical analyses of the sampled water were conducted according to approved standard methods [13]. Sulfate was measured using the turbidity method according to [14], and the sodium adsorption ratio (SAR) was calculated according to the following equation [5]:

$$\text{SAR} = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$

The measured chemical and physical properties of the river water were compared with the most common irrigation water classification systems such as the American Salinity Laboratory Classification USDA, 1954, the Food and Agriculture Organization (FAO) Classification of 1992 and the Fipps Classification of 2003, to verify the suitability of the Diwaniyah River water for irrigation use, and to know the extent of its pollution with heavy metals and the various possible consequences on the quality of water used in irrigation.

Table 1. Water quality classification based on salinity risk

USDA, 1954		
Class	EC (dS m^{-1})	TDS (mg L^{-1})
C1	>0.25	>200

C2		0.25-0.75	200-500
C3		0.75-2.25	500-1500
C4		2.25-5	1500-3000
FAO, 1992			
Class	EC (dS m^{-1}**)**	TDS (mg L^{-1})	Water Type
Non-saline	0.75 >	>500	Drinking and Irrigation Water
Low saline	0.75-2	500-1500	Irrigation Water
Moderate saline	2-10	1500-7000	Primary Drainage Water and Groundwater
High saline	10-25	7000-15000	Secondary Drainage Water and Groundwater
Very saline	25-45	15000-35000	Very Saline Groundwater
Extremely saline water	45<	< 35000	Seawater
Fipps, 2003			
Classes of water		EC (dS m^{-1})	TDS mg L^{-1}
Class 1, Excellent,		>0.25	>175
Class 2, Good		0.25-0.75	175-525
Class 3, Permissible1		0.75-2	525-1400
2Class 4, Doubtful		2-3	1400-2100
Class 5, Unsuitable2		<3	<2100

Table 2. Water quality classification according to the SAR value

USDA, 1954		
Class	**symbol**	**SAR**
low	S1	0-10
medium	S2	10-18
high	S3	18-26
Very high	S4	< 26
Fipps, 2003		
Sodium hazard of water		**SAR**
low		0-10
medium		10-18
high		18-26
Very high		< 26

2.4. Statistical Analysis Methods:

Mathematical and statistical analyses and data analyses were conducted using Microsoft Office Excel 2010.

3. Results and Discussion

3.1. Heavy metals: Table 3 shows spatial and temporal variation in the concentration of the heavy metals under study in the Diwaniyah River water. The table indicates that the lowest concentration of heavy elements was in the winter due to the increase in the water level in the river as a result of water releases and rainfall, while the highest concentration was during the summer due to increased evaporation resulting from high temperatures. In addition, there is a gradual increase in the concentration of heavy metals towards the south of the river, which may be attributed to the discharge of industrial and domestic liquid waste into the river without treatment. The movement of river water towards the south also plays a role in increasing the concentration of these metals in the southern regions.

Table (3) The average values of heavy metals in Diwaniyah River water

Heavy metals mg L-1	**Summer**			**Autumn**			**Winter**			**Spring**		
	Sit1	**Sit2**	**Sit3**	**Sit1**	**Sit2**	**Sit3**	**Sit3**	**Sit2**	**Sit1**	**Sit1**	**Sit2**	**Sit3**
Ni	0.150	0.153	0.374	0.145	0.148	0.362	0.071	0.053	0.026	0.038	0.062	0.136
Pb	0.43	0.47	0.73	0.383	0.421	0.674	0.046	0.024	0.014	0.104	0.203	0.378
Cd	0.003	0.008	0.009	0.0026	0.0051	0.0038	0.0014	0.0008	0.0006	0.0013	0.0018	0.0021

3.1.1. Nickel Ni: Figure 2 shows the concentration of nickel in the Diwaniyah River water at the three selected sites during the four seasons. The highest nickel concentration (0.374 mg L^{-1}) was recorded in the summer at the third site, which is higher than the maximum recommended by the FAO for irrigation water (0.20 mg L^{-1}), which was determined based on good irrigation practices. This result is similar to what [15] reached. The high nickel concentration in the river water may be attributed to the high temperatures in the summer and increased evaporation, in addition to the pollution of the river water with wastewater when it passes through the city center, as well as its pollution with partially treated industrial wastewater from the cotton textile factory and the tire factory near the river. In addition to the agricultural drainage water that is discharged into the river, which in turn affects the quality of the water and its suitability for human, agricultural and industrial uses [16]. The lowest concentration of nickel (0.026 mg L^{-1}) was recorded in the winter at the first site because this site is relatively far from pollution sources. When comparing the average nickel concentration for the three sites for each of the four seasons, we find that it is within the permissible limits of (0.20 mg L^{-1}), which is consistent with the FAO specifications.

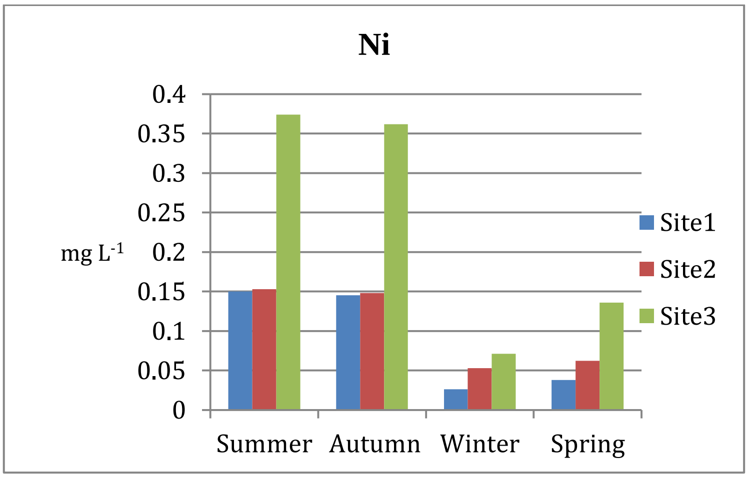

Figure 2: Ni concentration in Diwaniyah River water

3.1.2. Lead Pb: Figure 3 shows the concentration of lead in the Diwaniyah River water in the three selected sites during the four seasons. The highest concentration of Pb (0.674 mg L^{-1}) was recorded in the Autumn at the third site, while the lowest concentration of Pb (0.014 mg L^{-1}) was recorded in the winter at the first site. The average Pb concentration for the three sites for all four seasons is within the permissible limits of (5.0 mg L^{-1}), which is consistent with [17].

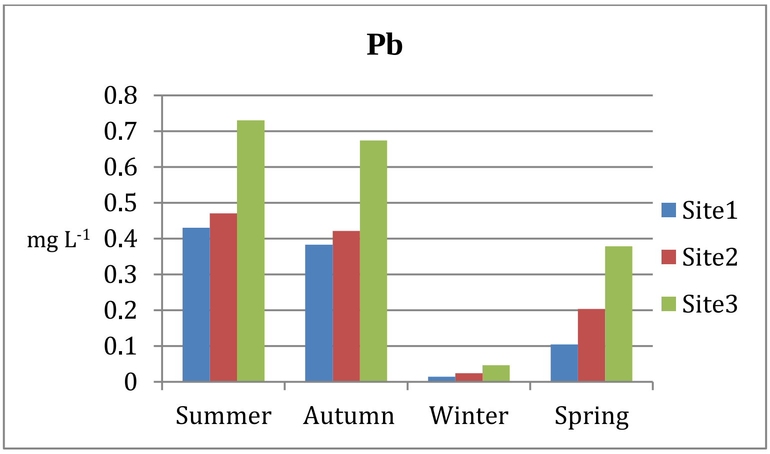

Figure 3: Pb concentration in Diwaniyah River water

3.1.3. Cadmium Cd: Figure 4 shows the concentration of cadmium in the Diwaniyah River water at the three selected sites during the four seasons. The highest Cd concentration (0.009 mg L^{-1}) was recorded in the summer at the third site, while the lowest concentration (0.0006 mg L^{-1}) was recorded in the winter at the first site. The average Cd concentration for the three sites for each of the four seasons is within the permissible limits (0.01 mg L^{-1}) set by the [17] based on concerns about the accumulation of cadmium in soil and plants when this limit is exceeded, which may lead to toxic effects on crops and thus health risks to humans when consuming contaminated agricultural products. Therefore, it is recommended to regularly monitor the quality of irrigation water, especially in areas close to industrial pollution sources or wastewater, to ensure that the cadmium concentration does not exceed the permissible limits in the water.

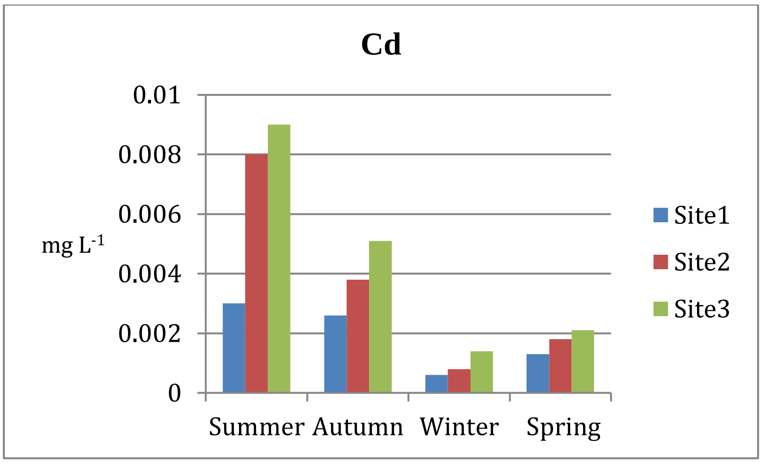

Figure 4: Cd concentration in Diwaniyah River water

3.2. pH: pH significantly affects biological activity, some river water properties, and the effectiveness of toxic substances present in the aquatic environment [18]. Table 4 shows that there is spatial and temporal variation in the pH values of river water. This variation is caused by differences in the concentrations of alkaline ions resulting from the dissolution of some soil salts in the water over the seasons. Increased alkaline ions lead to higher pH values, which occur in the summer due to higher temperatures and increased salt solubility. In the winter, heavy rainfall increases river flow, diluting pollutants and slightly decreasing pH [19]. The highest pH value (7.80) was recorded in the summer at Site 1, and the lowest value (7.10) was recorded in the winter at Site 3. The table shows a gradual decrease in pH values as the river slopes southward. This decrease may be due to domestic and industrial wastewater discharged into the river, which contains many acidic components [20]. The Diwaniyah River water is considered slightly alkaline, and based on pH values, it is classified within the permissible limits (6.5–8.5), which do not cause problems when used for irrigation, according to [5].

3.3. Salinity: Salinity risk is the most important factor in assessing the quality of irrigation water. The salinity of river water samples was expressed by measuring the electrical conductivity (EC) of river water, which measures the concentration of dissolved salt ions, as well as measuring the (TDS), which mainly indicates the presence of different types of mineral ions such as ammonium, nitrite, nitrate, phosphate, sulfate, alkalis, some acids, etc. It is also an important chemical standard for water [21] Table No. (4). Table 4 indicates that the salinity of the river water was higher during the summer months compared to the winter months, with the highest EC (1.32 dS m^{-1}) and TDS (844.8 mg L^{-1}) values at Site 3 during the summer and the lowest EC (0.75 dS m^{-1}) and TDS (480 mg L^{-1}) values at Site 1 during the winter. This is attributed to the fact that high temperatures during the summer increase evaporation, leading to higher salt concentrations in the river water [22]. Conversely, rainfall during the winter, increased water releases, and decreased evaporation lead to lower salt concentrations in the river water [23]. It is also noted that the salinity of the river water at Site 3 was higher than at the other sites, which may be due to the pollution of the river water with sewage and industrial wastewater in the center and south of the city. Based on the EC and TDS values, the Diwaniyah River water falls into the C3 category according to the American classification system and is considered slightly saline irrigation water according to the FAO classification and falls into the 3 category according to the Fipps system and is considered permissible water for irrigation provided that the requirements for leaching the soil from salts are met.

3.4. Sodium adsorption ratio (SAR): This ratio determines the suitability of water for irrigation use and provides a reliable assessment of irrigation water quality in relation to sodium hazards, as it is closely related to exchangeable sodium levels in the soil [24]. Irrigating soil with water containing high concentrations of sodium ions leads to the potential emergence of these ion hazards to the soil, represented by weak soil structure due to the dispersion of soil particles, which leads to reduced permeability and prevents crops from absorbing sufficient water [25]. Calcium and magnesium ions in the Diwaniyah River water were at appropriate concentrations, which reduced the effect of sodium ions on the soil [26]; [4]. Table 3 indicates that the SAR value of river water varies from one location to another and according to the seasons. The SAR value ranged between (1.93-2.83), which is within the permissible limits, which means that the Diwaniyah River water is low in sodium according to the American classification and falls within the S1 category, and the danger of sodium ions in the river water is low on the soil according to the Fipps classification.

3.5. Negative ions: Chloride ions are a specific ion that affect sensitive crops. Crop yields are affected when the chloride ion concentration is higher than the permissible limit for irrigation water (6 meq L^{-1}) according to the FAO standard. The chloride ion concentration of the Diwaniyah River water ranged between (2.19-3.46 meq L^{-1}), this result is similar to what was found by [27]. However, the chloride content of the river water at the third site was relatively high. The high concentration indicates pollution caused by industrial waste leakage into the river [28]. As for the sulfate ion, its concentration in the Diwaniyah River water ranged between (2.00-4.69 meq L^{-1}), this result is similar to what was found by [27], and Table 3 indicates that the high values were in the center and south of the city, and the reason for this may be attributed to the dumping of liquid waste into the river, but these values are within the permissible limits in irrigation water (20 meq L^{-1}) and do not constitute a danger or toxicity to crops irrigated with this water according to [5].

Table (4) Some chemical and physical properties of the Diwaniyah River water and its classification

Properties	Summer			Autumn			Winter			Spring		
	Sit1	Sit2	Sit3	Sit1	Sit2	Sit3	Sit1	Sit2	Sit3	Sit1	Sit2	Sit3
PH	7.80	7.73	7.42	7.75	7.70	7.31	7.42	7.33	7.10	7.43	7.35	7.12
EC dS m^{-1}	1.16	1.20	1.32	1.02	1.05	1.07	0.75	0.89	0.98	1.06	1.09	1.09
TDS mg L^{-1}	742.4	768	844.8	652.8	672	684.8	480	569.6	627.2	678.4	697.6	697.6
Na meq L^{-1}	4.04	4.23	6.04	4.04	4.13	4.21	4.17	4.74	5.26	5.57	6.00	4.30
mg meq L^{-1}	2.83	3.43	3.44	3.40	2.67	2.94	3.43	3.09	2.97	3.01	3.58	2.76
Ca meq L^{-1}	5.30	6.20	6.01	6.05	6.15	5.80	3.41	3.50	3.92	5.62	5.70	6.30
SO4 meq L^{-1}	4.00	4.35	4.69	4.06	4.09	4.25	2.5	3.79	2.63	3.14	3.50	4.17
CL meq L^{-1}	2.99	3.21	3.46	2.90	3.18	3.32	2.19	2.87	2.60	3.15	3.18	3.29
SAR	1.93	2.00	2.78	1.86	1.97	2.01	2.25	2.61	2.83	2.02	2.68	2.79
USDA	C3-S1	C3-S1	C3-S1	C3-S1	C3-S1	C3-S1	C3-S1	C3-S1	C3-S1	C3-S1	C3-S1	C3-S1
FAO	Low salinity, irrigation water											
Fipps	Leaching is needed if used											

4. Conclusions

A chemical and physical assessment of the Diwaniyah River water quality was conducted based on water quality standards to determine the suitability of the river water for irrigation. According to this study, the Diwaniyah River water is polluted with nickel, with concentrations exceeding permissible limits. River water can be classified as C3S1, which is considered slightly saline and slightly sodic, meaning that the risk of sodium ions in river water to the soil is low. It is permissible to use it for irrigation provided that the soil leaching requirements are met. Therefore, attention should be paid to the type of crops grown when using river water for irrigation. To protect water quality within its current state, the government, environmental protection organizations, and other relevant stakeholders should enact laws to prevent river water pollution and impose taxes on violators. This should ensure that water meets the requirements and is more suitable for human consumption and agricultural use. Continuous assessments of the river water should also be conducted, along with regular and proper monitoring of the efficiency of industrial and sewage treatment plants before they reach the river. Furthermore, it is important to raise awareness among water users to protect river water from pollution. Finally, a detailed study taking into account seasonal changes is recommended to fully investigate the extent of river water pollution.

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