



## Assessing The Surface Water of AlKhasa River in Kirkuk City Using Irrigation Water Quality Index and Heavy Metal Pollution Index

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### Abstract

The current study aims to assess the suitability of surface water running in the AlKhasa River, located within the city of Kirkuk, for irrigation purposes. This study applied the Irrigation Water Quality Index (IWQI) and Heavy Metal Pollution Index (HPI) to analyze seasonal changes in contamination levels. To achieve this goal, sixteen samples were collected from the AlKhasa River over one year (2023), distributed across four seasons (four samples per season) to track fluctuations in water quality and determine its characteristics throughout the year. The study relied on two main indices: the Irrigation Water Quality Index (IWQI) and the Heavy Metal Pollution Index (HPI). The drinking water quality index is excluded due to the nature of the water in the river, which consists of a mixture of sewage and rainwater, making it unsuitable for assessment according to drinking water standards. The (IWQI) results reveal that all analyzed samples are of high quality and classified as "very suitable" for irrigation use, with all recording values above (37) confirming their suitability for this purpose. As for (HPI), the results show significant seasonal variation in contamination levels. In winter, the index values range between (61.777 and 90.276), placing most sampling stations in the "poor to very poor" category in terms of contamination, except Station (1), which recorded a "good" level. In contrast, all stations in the other seasons (summer, autumn, and spring) recorded "excellent" levels in terms of water quality, with index values ranging between 6.591 and 18.368, except Station (1) in spring and fall, which recorded a "good" rating. These results demonstrate that heavy metal contamination varies significantly between seasons, with levels significantly higher during winter compared to other seasons.

### Keywords:

Surface Water, Irrigation Water Quality Index, Heavy Metal Pollution Index, Pollution, Alkhasa River.

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### 1. Introduction

Water of adequate quality is crucial to the health and benignity of the environment. The kind of relation attached highly depends on the catchment and form of aquatic ecosystems, and the vital role water plays in various aspects of life (Liu et al., 2016). The relevance between water "quantity and quality" vary for different aquatic, eco-systems types (re- and unregulated rivers, ephemeral streams, estuaries, lake and wetland) due to a combination of factors such as climate, catchment geology, population growth, in addition to natural factors and human activities that also

play a significant role in influencing water quality (Al-Tamimi, 2007; Al-Gburi and Al-Tamimi, 2020; Abed et al., 2022). Sources of water pollution are diverse, with pesticides, sewage, and industrial wastewater being among the most prominent water pollutants (Ibrahim et al., 2018; Baddi et al., 2023). The Water Quality Index (WQI) is an essential tool for assessing the quality of surface and groundwater used to determine its suitability for various uses such as irrigation and drinking (Hammash et al, 2022; Ibrahim et al., 2018). The climate of the study area is mainly semi-arid, affected by the Mediterranean climate (Hamamin, 2018). It is characterized by dry and

hot summers, and cold, moderately wet winters. According to the meteorological information supplied by the Iraqi General Organization for Meteorological Information (2013) for Kirkuk meteorological stations for the period (2001 – 2013), the annual mean rainfall ranges from 200 mm within the southern parts to more than 600 mm in the northern parts. Rainfall is considered an important atmospheric parameter in the hydrological system. It is the focus of hydrogeological studies and essential for maintaining water balance and replenishing groundwater (Al-Jumaily and Al-Tamimi, 2025). This study aims to analyze the quality of AlKhasa River surface water, focusing on two main axes: the first is to assess the suitability of this water for agricultural purposes; and the second is to evaluate the level of heavy metal pollution index by using specialized scientific indicators utilizing both parameters (methods) (HPI and IWQI).

## 2. Study Area

AlKhasa River lies in the northern part of Iraq in Kirkuk Province (Fig. 1). The study area is limited, approximately following coordinates: "442000 - 448000" E, "3929840 - 3915875" N (UTM). The recharge areas are mainly represented by the highlands due to rainfall on the (catchment) outcropped formations in north part of the governorate. Rainwater and municipal water are the main sources of the river water.

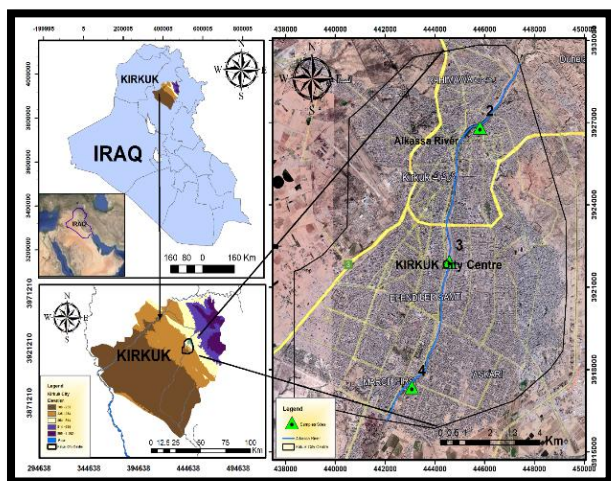


Fig. 1: Map of study area with sample locations

## 3. Geological Setting

The present study is located within the Low Folded Zone extending along the central northern

and northeastern parts of Iraq. From the regional tectonic point of view, the Low Folded Zone forms the central unit of the Unstable Shelf of the outer Platform (Sissakian and Fouad, 2012) of the Nubio-Arabian Platform, characterized by thick sedimentary cover and a well-defined folding system (Buday and Jassim, 1987; Sissakian and Fouad, 2012). This zone forms a series of narrow anticlines of different amplitudes with an NW-SE trend separated by broad synclinal rivers. The rivers form the main groundwater basins, which consist of thick sedimentary cover as geological formations of Late-Miocene until Recent (Sissakian, 1992); they are, from oldest to youngest: Fátha, Injána, Mukdádiyá and Báí Hássán, also Quaternary sediments. It is well drained by the Tigris River and its tributaries, like Duhok, Al-Khosar, Al-Khazir, Al-Gomal, Upper and Lesser Zabs, Al-Adhaim and Diyala River, and they drain a large sector of the zone east of the Tigris River. Numerous ephemeral streams and rivers drain the western sector of the zone; most of them flow towards the Tigris River.

## 4. Materials and Methodology

To assess the water suitability of AlKhasa River in Kirkuk, an intensive water sampling program was implemented in 2023. Sixteen water samples were collected across four main seasons (four samples each) for a comprehensive analysis using the IWQI) and HPI.

Sample collection followed precise scientific protocols using sterile polyethylene bottles according to recommended standards (Abawi and Hassan, 1990; Al-Mutawqi and Al-Mayyahi, 2025). Before sampling, each bottle was repeatedly washed with river water to ensure the absence of external contamination. The samples then underwent a thorough filtration process using 45-micron filters to ensure the absence of suspended impurities. To preserve the samples and prevent any chemical or biological changes, they were acidified with nitric acid until they reached a pH of 2 according to the methods used in recent studies (Abed and Ahmed, 2019; Ibrahim, 2022). The samples were carefully transported to specialized laboratories for the necessary analysis. Laboratory analyses included measuring a comprehensive set of physicochemical parameters (Trace elements, EC, pH, Chloride concentrations (Cl<sup>-</sup>), and Bicarbonate (HCO<sub>3</sub>). Trace elements were

analyzed using ICP-MS at ALS Laboratory. Bicarbonate ion (HCO<sub>3</sub><sup>-</sup>), Sulfate ion (SO<sub>4</sub><sup>-</sup>), and Chloride ion (Cl<sup>-</sup>) were analyzed by the Science and Technology Authority. pH and (EC) measurements were performed directly in-site using advanced, waterproof, portable measuring devices, ensuring accurate readings and representativeness of field conditions.

**Calculation Method of the Water Quality Index (IWQI).**

The water quality index for irrigation purposes is calculated by the five sub-indices (SI) and ranges from (1-5). The method is summarized as follows (Simsek and Gunduz, 2007; Todd and Mays, 2005).

Calculating the first sub-index, which represents the effect of salinity (EC) given in Table 1, using the following equation:

$$SI_1 = w_1 \times r_1 \dots \dots \dots (1)$$

Where: *w* = weight of *SI*<sub>1</sub>; *r* = classification value.

The second indicator is the risk of infiltration and permeability, which is calculated using the values of (EC, SAR) given in Tables 1 and 2. The value of the second indicator is calculated using the equation:

$$SI_2 = w_2 \times r_2 \dots \dots \dots (2)$$

Where: *w* = weight of *SI*<sub>2</sub>; *r* = classification value.

The third group (*SI*<sub>3</sub>) is applied to the toxicity of chloride ions and sodium absorption ratio (Cl, SAR) given in Table 1 as shown in the following equation:

$$SI_3 = \frac{W_s}{n} \sum_{j=1}^2 r_j \dots \dots \dots (3)$$

Where: *j* = number of contributing indicators; *W<sub>s</sub>* = weight; *r* = classification or evaluation value given in Table 1.

The fourth group is represented by toxic trace elements (Table 3) and calculated using equation (4):

$$SI_4 = \frac{W_4}{n} \sum_{k=1}^2 r_k \dots \dots \dots (4)$$

Where: *k* = number of contributing indicators; *n* = total number of trace elements available for analysis; *w* = weight; *r* = ranking for each parameter.

The fifth group is represented by (bicarbonates, pH, HCO<sub>3</sub>), calculated using equation (5).

$$SI_5 = \frac{W_s}{n} \sum_{m=1}^3 r_m \dots \dots \dots (5)$$

Where: *m* = number of contributing indicators; *W<sub>s</sub>* = weight; *r* = ranking of each parameter.

The sum of the previous sub-indices is calculated to get the final value of the internal water quality index (*IWQI*), which is compared with the values in Table (1) that shows the suitability of the studied water resource for irrigation purposes.

$$IWQI = \sum_{i=1}^5 SI_i \dots \dots \dots (6)$$

Where: *i* = number of contributing sub-indices; *SI* = a sub-index risk group.

The *IWQI* deals with multi parameter (physical and chemical variables as major, minor, trace, and the results are compared with Table (2).

**Table 1: IWQI Parameter Rating based on (Spandana et al., 2013; Narany et al., 2016; Kumari and Gunarathna, 2019; Ahmed et al., 2023).**

Class	Weight	Parameter	Range	Rate	Suit
Salinity hazard	5	EC (µS/cm)	< 700	3	High
			700 ≤ EC ≤ 3000	2	Medium
			> 3000	1	Low
EC (µS/cm) Table (2)					
Infiltration and permeability hazard	4	SAR	< 3.0	3	High
			3.0 ≤ SAR ≤ 9.0	2	Medium
			> 9.0	1	Low
Particular ion toxicity	3	Cl	< 140	3	High
			140 ≤ Cl ≤ 350	2	Medium
			350 >	1	Low
Trace element	2	HCO <sub>3</sub>	Table (3)		
			< 90	3	High
			90 ≤ HCO <sub>3</sub> ≤ 500	2	Medium
Miscellaneous effects	1	pH	500 >	1	Low
			7.0 ≤ pH ≤ 8.0	3	High
			6.5 ≤ pH < 7.0 and 8.0 < ≤ 8.5	2	Medium
			≤ 8.5	1	Low

**Table 2: Permeability and Infiltration Risk Classification based on (Simsek and Gunduz, 2007; Spandana et al., 2013; Narany et al., 2016; Kumari and Gunarathna, 2019; Ahmed et al., 2023).**

Rating	Sodium adsorption ratio					Suitability
	< 3.0	3-6	6-12	12-20	> 20	
3	>700	>1200	>1900	>2900	>5000	High
2	700-200	1200-300	1900-500	2900-1300	5000-2900	Medium
1	<200	<300	<500	<1300	<2900	Low

**Table 3: Trace Element Toxicity Classification (Simsek and Gunduz, 2007).**

Parameter (mg/l)	Range	Rating	Suitability
Mercury (mg/l)	Hg < 0.02	3	High
	0.02 ≤ Hg ≤ 0.1	2	Medium
	0.1 > Hg	1	Low
Arsenic (mg/l)	As < 0.1	3	High
	0.1 ≤ As ≤ 2.0	2	Medium
	2.0 > As	1	Low
Cadmium (mg/l)	Cd < 0.01	3	High
	0.01 ≤ Cd ≤ 0.05	2	Medium
	0.05 > Cd	1	Low
Cobalt (mg/l)	Co < 0.05	3	High
	0.05 ≤ Co ≤ 5.0	2	Medium
	5.0 > Co	1	Low
Chromium (mg/l)	Cr < 0.1	3	High
	0.1 ≤ Cr ≤ 1.0	2	Medium
	1.0 > Cr	1	Low
Copper (mg/l)	Cu < 0.2	3	High
	0.2 ≤ Cu ≤ 5.0	2	Medium
	5.0 > Cu	1	Low
Iron (mg/l)	Fe < 5.0	3	High
	5.0 ≤ Fe ≤ 20.0	2	Medium
	20.0 > Fe	1	Low
Nickel (mg/l)	Ni < 0.2	3	High
	0.2 ≤ Ni ≤ 2.0	2	Medium
	2.0 > Ni	1	Low
Lead (mg/l)	Pb < 5.0	3	High
	5.0 ≤ Pb ≤ 10.0	2	Medium
	Pb > 10.0	1	Low
Zinc (mg/l)	Zn < 2	3	High
	2 ≤ Zn ≤ 10.0	2	Medium
	10.0 > Zn	1	Low
Aluminum (mg/l)	Al < 5.0	3	High
	5.0 ≤ Al ≤ 20.0	2	Medium
	Al > 20.0	1	Low
Manganese (mg/l)	Mn < 0.2	3	High
	0.2 ≤ Mn ≤ 10.0	2	Medium
	10.0 > Mn	1	Low
Vanadium (mg/l)	V < 0.1	3	High
	0.1 ≤ V ≤ 1.0	2	Medium
	1.0 > V	1	Low

**Calculation of Heavy Metal Pollution Index (HPI)**

HPI is an effective tool that uses a method to calculate the concentrations of heavy metals completely and extract them as a single value for the purpose of assessing water quality (Ustaogl and Islam, 2020; Ahmed et al., 2024). HPI can be calculated using equation (7) (Mohan et al., 1996).

$$HPI = \frac{\sum_{i=1}^n Qi \times Wi}{\sum_{i=1}^n Wi} \dots\dots\dots (7)$$

Where: Qi = rating scale; Wi = variable weight; n = refers to the number of variables selected

Sub-indexes of HPI are calculated by using flowing equations.

Constant of proportionality (K) is calculated by the following equation; the results are shown in Table (4).

$$K = \frac{1}{\sum_{i=1}^n \frac{1}{Si}} \dots\dots\dots (8)$$

Where: K= constant of proportionality; Si=permissible limit for the i<sup>th</sup> metal; n= number of heavy metals.

Second sub index, weight of parameter ( $W_i$ ), is calculated by equation (9); the results are shown in Table (4):

$$W_i = \frac{K}{\sum Si} \dots \dots \dots (9)$$

$Q_i$  sub index is calculated by equation (10)

$$M_i = \left( \frac{V}{Si} \right) \times 100 \dots \dots \dots (10)$$

**Table 4: Weight of Heavy Metals.**

Heavy Metal	Si	1/Si	K	Wi
As	10	0.1	1.72626	0.17263
Cd	3	0.33333		0.57542
Cr	50	0.02		0.03453
Cu	2000	0.0005		0.00086
Fe	300	0.00333		0.00575
Ni	70	0.01429		0.02466
Pb	10	0.1		0.17263
Zn	3000	0.00033		0.00058
Al	200	0.005		0.00863
Mn	400	0.0025		0.00432
Sum		0.57929		1

**5. Results**

The results of surface water (SW) physicochemical variables are shown in Tables 8 and 9, displaying the lists of the trace elements. The (IWQI) values show that all samples taken from the various study stations recorded values above 37, indicating that the water quality in the region meets high standards and is considered suitable for agricultural and irrigation uses compared with Table (5) and Figure (2). These results reflect that the water conditions are suitable for agricultural activities in the region with no significant risks to crops or soil. The (HPI) results show a clear seasonal variation in contamination levels: In winter, most stations recorded values ranging from (61.777 to 90.276), placing them within the (poor to very poor) category in terms of heavy metal pollution. It is worth noting that Station (1) is an exception to this rule, recording a (good) rating. In other seasons: All stations across the seasons (except winter) recorded values ranging from 6.591 to 18.368, placing them within the "excellent" category in terms of water purity from heavy metals. However, Station (1) is excluded in the spring and fall seasons, where it recorded a "good" rating, as shown in Table (7) and Figure (3). The results show a clear difference in pollution levels between seasons, with a significant increase in pollution values during the winter. This difference can be attributed to several factors,

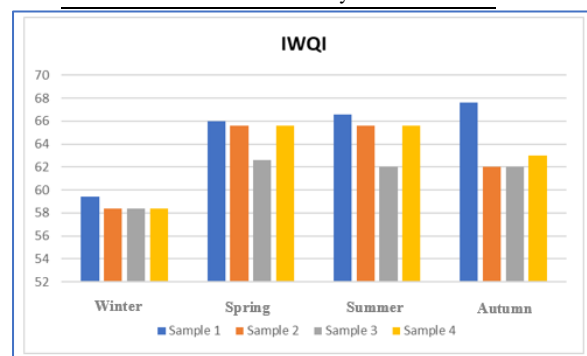
including increased rates of surface runoff during this season, which carries various pollutants, while these rates decrease in other seasons, leading to a significant improvement in water quality. All values are compared with Table 6.

**Table 5: Classifying Water Quality Index for Irrigation (IWQI) based on (Kumari and Gunarathna, 2019).**

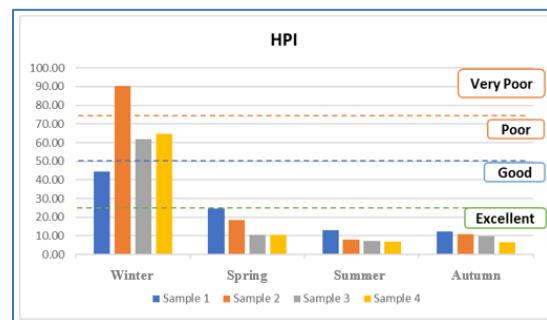
Water Quality Index	Suitability for irrigation
> 37	High
22 - 37	Medium
< 22	Low

**Table 6: HPI Category based on (Sheykhi and Moore, 2012).**

HPI	Degree of Pollution
0 – 25	Excellent
25 – 50	Good
51 – 75	Poor
> 76	Very Poor



**Fig 2: IWQI Values of the study area.**



**Fig 3: HPI Values of the Study Area.**

**6. Discussion**

Using IWQI, the results show variations in quality levels between sampling stations. Station (1) emerged as the best site of water suitability for Irrigation use. This is attributed to the fact that its water source comes directly from AlKhasa Dam before being exposed to urban pollution inside the city. The other stations also recorded results indicating their suitability for irrigation, but to a lesser extent than Station (1), indicating their gradual exposure to pollutants as the river flows through populated areas.

**Table 7: Results of HPI values of the Study.**

Season	Parameter	HPI	Degree of Pollution
Winter 2023	Sample 1	44.58	Good
	Sample 2	90.28	Very Poor (unsuitable for drinking)
	Sample 3	61.78	Poor
	Sample 4	64.82	Poor
Spring 2023	Sample 1	24.51	Good
	Sample 2	18.37	Excellent
	Sample 3	10.58	Excellent
	Sample 4	10.48	Excellent
Summer 2023	Sample 1	12.84	Excellent
	Sample 2	8.08	Excellent
	Sample 3	7.41	Excellent
	Sample 4	6.84	Excellent
Autum2023	Sample 1	12.30	Excellent
	Sample 2	10.80	Excellent
	Sample 3	9.83	Excellent
	Sample 4	6.59	Excellent

**Table 8: Surface water chemical and physical variables.**

Sample	pH	Cl	HCO <sub>3</sub> <sup>-2</sup>	TDS	EC	SAR	Season
1	8.2	25.6	110	372	531	0.476	Winter 2023
2	7.9	79.2	178.04	823	1029	0.960	
3	7.7	126.3	148	954	1193	1.014	
4	7.6	71	139.66	838	1048	1.002	
1	8	30.4	166.8	313	523	0.832	Spring 2023
2	7.5	121	198	844	1055	1.045	
3	7.4	157	172	808	1011	0.913	
4	7.2	81	180.52	595	848	0.971	
1	7.25	23.2	195	312	520	1.094	Summer 2023
2	7.13	80	286	626	1043	0.811	
3	7.24	205	310	1045	1742	0.996	
4	7.23	74.4	318	510	850	0.962	
1	7.1	92	67	381	534	0.693	Autum 2023
2	6.71	177.26	115	620	868	0.852	
3	6.81	216	92	1060	1484	1.262	
4	6.6	233	74.4	980	1372	1.343	

**Table 9: Trace elements in surface water.**

Hg	As	Cd	Co	Cr	Cu	Fe	Ni	Pb	Zn	Al	Mn	V	Season
B.D.L	1.25	1.57	B.D.L	1.42	B.D.L	24.71	1.66	7	B.D.L	1.73	13.46	B.D.L	Winter Season
B.D.L	4.43	3.16	B.D.L	1.45	B.D.L	25.15	6.89	12.51	B.D.L	2.15	20.37	B.D.L	
B.D.L	2.82	2.52	B.D.L	1.75	B.D.L	28.48	6.31	4.72	B.D.L	1.97	17.45	B.D.L	
B.D.L	1.67	2.75	B.D.L	2.56	B.D.L	27.42	8.46	5	B.D.L	1.58	18.83	B.D.L	
B.D.L	2.29	0.02	0.219	25.7	21.8	346	4.9	10.05	26.7	42	24.4	5.03	Spring Season
B.D.L	2.73	0.02	0.507	11.8	18	202	11.1	6.61	40.2	53	34.3	5.25	
B.D.L	1.9	0.012	0.32	4.4	3.6	143	5.8	3.52	26.7	28	81.8	4.66	
B.D.L	2.16	0.012	0.305	4.4	4.4	158	4.7	3.19	31.6	37	76	4.38	
B.D.L	3.38	0.029	0.355	44.1	8.3	401	6.9	1.25	32.1	38	66.8	5.46	Summer Season
B.D.L	3.01	0.019	0.363	18.6	1.4	180	6.7	0.34	22.5	9	25.1	4.24	
B.D.L	1.43	0.032	0.906	18.1	3.8	265	5.3	1.06	42.1	57	286	1.6	
B.D.L	2.3	0.03	0.508	6.9	3.4	104	3.7	0.67	38.6	33	176.5	1.99	
B.D.L	3.49	0.138	0.616	10.3	3.4	116	6.2	1.15	57.3	106	32.3	6.3	Autum Season
B.D.L	3.21	0.031	3.02	12.4	3.3	215	14.1	1.01	130.5	147	478	10.55	
B.D.L	1.65	0.052	0.682	31.5	6.6	422	10.4	1.1	56	75	376	3.04	
B.D.L	1.47	0.035	0.599	5.3	4	192	6.1	0.99	50.6	107	242	2.33	

B.D.L = Below Detection Limit

The (HPI) results reveal a clear variation in pollution levels between the different stations. Stations (1 and 2) topped the list of sites most affected by heavy metal contamination. It should be noted that this indicator focuses exclusively on measuring heavy metal concentrations without considering other physical or chemical variables. The high level of pollution at Station (1) is due to geological and structural factors. The water in this area is affected by its sources in the Chamchamal area, known for containing high levels of some trace elements and iron, as confirmed by Al-Jumaily et al. (2020). The risk level at Station (2) increases due to urban factors, as its water receives additional flows from blacksmith shops and industrial facilities located in the Imam Qasim area, after having been already contaminated by the water from Station (1). In contrast, the other stations show lower levels of heavy metal pollution. This is attributed to the dilution factor resulting from the mixing of surface water with rainwater and domestic runoff, which contributes to reducing pollutant concentrations. These results provide a clear picture of the pollution dynamics in the river and the influence of natural and human factors on the distribution of pollutants along the watercourse. The variation in result values from one season to another is due to the influence of human activities and natural factors, as AlKhasa River is a seasonal river and depends mainly on domestic water.

## 7. Conclusion

This study reached a set of important results by applying two main indices to assess the water quality (WQ) of AlKhasa River (the Irrigation Water Quality Index IWQI and the Heavy Metal Pollution Severity Index HPI). The results reveal the following facts:

Using (IWQI), the analyses show that all samples taken from the various study stations have high-quality specifications, classified as "high" in terms of suitability for irrigation purposes. This positive result means that the surface water in the area meets the basic requirements for agricultural use with minimal risk to crops or soil.

Regarding (HPI), the results show clear seasonal and spatial variation. In most seasons, all stations record "excellent" values in terms of low levels of heavy metal pollution. During the winter,

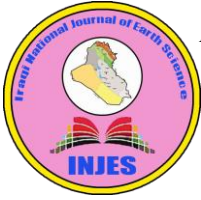
a significant deterioration in water quality is observed: Station (1) is rated "good," Stations (3 and 4) are rated "poor," and Station (2) is rated "very poor," indicating a potential hazard to health and the environment in this particular area.

These results provide an important database for decision-makers in the field of water resource management and environmental protection in the region.


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## تقييم المياه السطحية لنهر الخاصة في مدينة كركوك باستخدام مؤشر جودة مياه الري ومؤشر التلوث بالمعادن الثقيلة

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### الملخص

تهدف هذه الدراسة إلى تقييم مدى ملاءمة المياه السطحية الجارية في وادي الخاصة الواقع ضمن مدينة كركوك لأغراض الري. وقد طبقت هذه الدراسة مؤشر جودة مياه الري (IWQI) ومؤشر تلوث المعادن الثقيلة (HPI) لتحليل التغيرات الموسمية في مستويات التلوث. ولتحقيق هذا الهدف، جُمعت ست عشرة عينة من المياه السطحية من النهر على مدار عام واحد هو 2023، موزعة على أربعة فصول (أربع عينات لكل موسم)، لتتبع التقلبات في جودة المياه وتحديد خصائصها على مدار العام. واعتمدت الدراسة على مؤشرين رئيسيين: مؤشر جودة مياه الري (IWQI) ومؤشر تلوث المعادن الثقيلة (HPI). وقد تم استبعاد مؤشر جودة مياه الشرب نظرًا لطبيعة المياه في الوادي، والتي تتكون من خليط من مياه الصرف الصحي ومياه الأمطار، مما يجعلها غير صالحة للتقييم وفقًا لمعايير مياه الشرب. أظهرت نتائج مؤشر جودة مياه الري (IWQI) أن جميع العينات المحللة كانت عالية الجودة ومُصنفة على أنها "مناسبة جدًا" للاستخدام في الري، حيث تجاوزت جميع القيم المسجلة (37)، مما يؤكد ملاءمتها لهذا الغرض. أما بالنسبة لمؤشر تلوث المعادن الثقيلة (HPI)، فقد أظهرت النتائج تباينًا موسميًا كبيرًا في مستويات التلوث. ففي فصل الشتاء، تراوحت قيم المؤشر ما بين (61.777 و 90.276)، مما وضع معظم محطات أخذ العينات في فئة "من سيئ إلى سيئ جدًا" من حيث التلوث، باستثناء المحطة (1) التي سجلت مستوى "جيد". في المقابل، سجلت جميع المحطات في المواسم الأخرى (الصيف والخريف والربيع) مستويات "ممتازة" من حيث جودة المياه، حيث تراوحت قيم المؤشر ما بين (6.591 و 18.368)، باستثناء المحطة (1) في فصلي الربيع والخريف، والتي سجلت تصنيف "جيد". تُظهر هذه النتائج أن تلوث المعادن الثقيلة يختلف اختلافًا كبيرًا بين المواسم، حيث تكون المستويات أعلى بكثير خلال فصل الشتاء مقارنة بالمواسم الأخرى.

### الكلمات المفتاحية:

المياه السطحية، مؤشر جودة مياه الري، مؤشر تلوث المعادن الثقيلة، التلوث، نهر الخاصة.

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