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APPLICATION OF POLLUTION INDICES FOR HEAVY METAL CONTAMINATION ASSESSMENT IN SURFACE WATER OF DUHOK DAM (KURDISTAN REGION, IRAQ)

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ABSTRACT

Continuous monitoring and assessment of water sources in term of heavy metal is crucial to grantee their suitability for any purposes including human consumption. Accordingly, this study was conducted to assess surface water pollution of Duhok Dam in Kurdistan region of Iraq, in term of metal pollution indices. Surface water samples were collected from 6 different sites around the dam during dry (July to October, 2018) and wet (December to April 2019) seasons, and analyzed for heavy metals concentration including Chromium (Cr), Manganese (Mn), Iron (Fe), Copper (Cu), Zinc (Zn), lead (Pb), and Cadmium (Cd) using Atomic Absorption Spectrophotometer. Then, heavy metal pollution index (HPI), degree of contamination (Cd) and heavy metal evaluation index (HEI) was calculated for assessing overall quality of the water with regard to the total content of heavy metals. Results of individual parameters showed that, except Cd, the concentration of heavy metals at all the studied sites were lower than prescribed limits according to Iraqi's (IQS:417, 2001) and WHO (2017) standards. However, the results was also showed that the concentrations of Cd in most of the studied sites were higher than the permissible limits (3μg/L) depending on the recommended standards, indicating that there is a leaching of this metal into the water dam. Based on metal pollution indices values, despite of the existence of higher value of HPI in one situation, water samples from all studied sites were below the critical values. Concerning the seasonal variation, the concentrations of heavy metals and metal indices values were fluctuated throughout the seasons and different sites. Depending on these results, it can be concluded that the dam water can be used as safe water for drinking. However, higher concentration of Cd in some water samples could have negatives impacts on human health in long-term usage. Therefore, it can be suggested that simple treatments such as granular activated carbon filtration of the study water before use is advisable for granting safe water supply to the citizens of this area.

KEYWORDS: Water Sources, Water Pollution, Heavy Metals, Pollution Indices, Duhok Dam

1. INTRODUCTION

Dams have been considered as the most significant human interventions in the water cycle which supply large amount of water for variety of human uses including drinking water supply, agriculture, recreation (Mohhamed and Bamarni, 2019). Dams can also be utilized for other purposes such hydroelectric power generation, fishing, decreasing the risk of flood and drought. However, as a result of population growth, agricultural practices, and urbanization, the quality of dams water is being threatened by pollution, particularly by heavy metal contamination, although the water quality of these reservoirs are also affected by the natural contributions such as precipitation rate, weathering processes and soil erosion (Khatri and Tyagi, 2015; Issaka and Ashraf, 2017). Thus, information of an area's water resources and their suitability for any purposes is mandatory for spatial planning and sustainable development.

Metals refers to any metal and metalloid element that has a relatively high density ranging from 3.5 to 7g/cm^3 and is toxic or poisonous at low concentrations, although a few number such as Fe, Cu and Zn is beneficial to both to human and animal body in very trace amounts (Gautam *et al.*, 2014). Heavy metals are not only poisonous to human, but also have toxic effects on animals, fisheries and plants (Gautam *et al.,* 2014). The main sources of heavy metal pollution in aquatic ecosystem are natural sources and anthropogenic activities (Bhardwaj *et al.,* 2017). The main natural sources of metals in waters are chemical weathering of minerals, soil erosion and soil leaching (Abdullah, 2013). The anthropogenic sources are associated mainly with industrial and domestic effluents, urban storm, water runoff, landfill leachate, mining of coal and ore, atmospheric sources and inputs rural areas (Zarazua et al. 2006; Abdullah, 2013). However, high concentrations of metals in aqueous environments led to serious problems concerning the human, animal and plant health (Zvinowanda et al. 2009). Heavy metal monitoring in dams, therefore, need to be conducted continuously and periodically to insure clean and safe water supply for both human and aquatic life.

A necessary and an effective mean of assessing heavy metal pollution is the use of metal pollution indices (Reza and Singh, 2010; Prasad and Mondal, 2008; Prasad and Kumari, 2008). These indices are considered effective tools for water quality assessment that impart information on the quality of water to the concerned citizens and policymakers (Yisa *et al.*, 2012) and henceforth it has been connected for both surface and groundwater quality evaluation all over the world (Bora and Goswami, 2017). Pollution indices are simple, useful, and easy-to understand tools for water quality executives, environmental managers, decision makers, and potential users of a given water system (Herojeet *et al.*, 2015). Accordingly, numerous water quality and pollution indices have been formulated and approved around the world, the differences among them being the statistical incorporation and translation of parameter values. Some of these indices are heavy metal pollution index (HPI), the contamination index (CI), and the heavy metal evaluation index (HEI), (Brown *et al.*, 1970; Backman *et al.*, 1998; Reza and Singh, 2010; Edet and Offiong, 2002; Shigut *et al.*, 2017).

The importance of identifying and clearing heavy metals in water of Duhok Dam cannot be overstated, as the water in this dam are used for many purposes including: supplying water to the city for domestic use, as a drinking water source, agricultural irrigation purposes and recreation. Thus, the quality of Duhok's water dam must be monitor regularly in order to check its suitability for any purposes. However, some studies have been conducted on water quality of Duhok Dam to assess the dam's water quality for varies purposes and in most of these studies only major elements have been considered, but, trace chemical elements are not usually analyzed. In addition, to the best of our knowledge, no study has been conducted on pollution indices to assess the dam's water pollution by heavy metal, so there is the need to have some kind of indication about the concentration of heavy metals and their variation ranges in order to better assess the water quality. The present study was therefore conducted to asses surface water contamination of Duhok water dam with heavy metals using heavy metal pollution indices.

2. MATERIAL AND METHODS

1.1. Study area

The study was conducted at designated sampling points representative of the Duhok water Dam (Figure 1).The Dohuk dam is an embankment dam located in north part of Duhok City, Kurdistan region, Iraq. It is about 2Km away from Duhok city center, bounded by the coordinates 36˚51'20"N, 37˚01'00"N, 42˚50'30"E and 43˚05'50"E. The dam was completed in 1988 with the purposes of water supply to the Duhok city for domestic and irrigation uses in addition to recreation. The dam has a bell-mouth spillway with a maximum discharge of 81m^3/s. The depth of dam is about 60m having an area of 6.8 Km^2 (1.7Km width, 4Km length), and with storage capacity of approximately 52 million m^3 of water (Mohammed, 2010; Shekha, *et al.,* 2013; Al-Barzingy, 2018). The water of the dam mainly comes from rain, snow melts, springs from shrouding maintains and the main tributaries of Sunder and Gurmava which on their joining make up Duhok river. The geology of the area consists of clay marl, dolomite, poly clay limestone and sandstone (Toma, 2013). The climate characterized by a dry and hot summer and rainy winter. However, cold weather prevails during the winter and snow falls on the high mountains. Major rainfall storms occur from October to May, the other months of the year are relatively dry (Mohammed, 2010). The long-term mean annual rainfall of the region is about 535mm and mean annual temperature of 19.2°C. The annual minimum temperature, annual maximum temperature and total year precipitation depth of Duhok Station for the considered period is about 14.5, 27.6, and 900mm respectively (data recorded from 1 June 2018 to 1 April 2019).

1.2. Collection and preservation of water samples

The sampling process was conducted on seasonal basis, during the dry season (July to October, 2018), when the area had not received rainfall for some months and during the wet season (December to April 2019),when the area

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had received rainfall large enough to cause runoff). Samples were collected in different seasons in view of the fact that the seasons affect the level and fate of the contaminants in the dam and rivers getting into the dam to a great extent (Bhardwaj *et al.*, 2017). In this study, water samples were collected from six sites (S1, S2, S3, S4, S5, and S6) along the bank of the dam (Figure 1) to represent the quality of water in the studied dam as much as possible. The name and geographic coordinates of the investigated springs are presented in Table 1.

During each season, 4 water samples (at 15 days intervals) were taken from 10 to 15 cm below the surface water using stopper fitted polyethylene bottles (capacity 500mL). Prior collection, bottles have been triple-rinsed with distilled water and acidified with 1mL of HNO_3 (50%) to a pH below 2 to minimize the precipitation and adsorption of heavy metals as per standard procedures (APHA, 2005). The collected water samples were then transporting to the laboratory and refrigerated at 4°C until analysis.

1.1. Sample Digestion and analysis

The digestion procedure for dam water was applied (APHA, 2015) by transferring a measured volume (50mL) of well mixed acid preserved water sample to a flask (100mL capacity). Then 5 mL of conc. HNO_3 were added into the flask. The mixture was digested on a hot plate and in a fume hood for about 30 minutes until a clear solution was seen and volume reached to approximately 15-20mL. The digested solution was then transferred to 100mL volumetric flask and diluted with distilled water, and then the mixture made up to 100 mL mark. The mixture was filtered with Watman No. 41 filter paper (0.45-µm pore size) and again the samples were stored in refrigerator at 4°C until analysis. A portion of the final solution was taken and analyzed for heavy metals includes: Chromium (Cr), Manganese (Mn), Iron (Fe), Cupper (Cu), Zink (Zn), lead (Pb), and Cadmium (Cd) using GBC Atomic Absorption Spectrophotometer (A.A.S.), Model (932 AA) made in Australia.

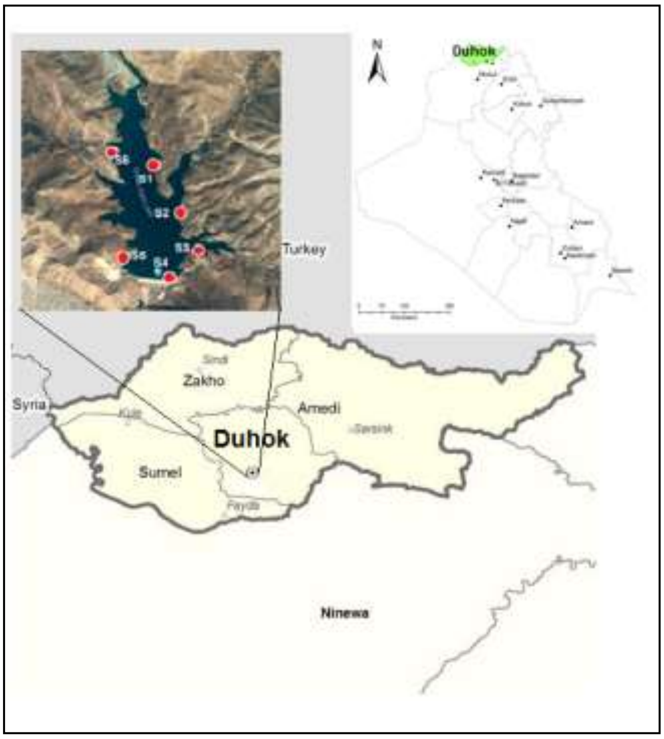

Fig. (1): Map of Iraq with a Satellite image of the study area illustrating the sampling sites.

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Table (1):- The site codes and geographic coordinates of the collected water samples.

Sampling site codes	Latitude	Longitude
S1	36°53′38.86″N	43°00′16.68″E
S2	36°53'08.6"N	43°00'30.4"E
S3	36°52'47.9"N	43°00'41.9"E
S4	36°52'33.4"N	43°00'22.2"E
S5	36°52'45.5″N	42°59′56.05″E
S6	36°53′42.13″N	42°59′48.95″E

1.3. Pollution Evaluation methods and Calculations

Generally, pollution indices are applied to estimate the pollution of the water samples under consideration. The indices used in this study, were heavy metal pollution index (HPI), degree of contamination (Cd) and heavy metal evaluation index (HEI). These indices are used to evaluate the quality of water for drinking. The HPI and HEI methods provide an overall quality of the water with regard to heavy metals (Brraich and Jangu, 2015).

1.3.1. Heavy metal pollution index (HPI)

Heavy metal pollution index (HPI) of all water samples was assessed by applying the weighted arithmetic index method employed by (Brown *et al.,* 1970), after slight modification has been made. Heavy metal pollution index (HPI) is a technique of rating that provides the composite influence of individual heavy metal on the overall quality of water. In this study, seven important heavy metals were chosen for HPI calculation. Iraqi Standards (IQS:417, 2001) and WHO (2017) standards were used to study the quality of water samples. It has been found that Iraqi's standards were mostly similar to the WHO standards, thus, in most cases, Iraqi standards (IQS:417, 2001, Maximum permissible limits) were used. The calculation of HPI involves the following steps:

In the first step: each of the selected heavy metals has been assigned a weight (Wi) depending on its relative importance in the overall quality of water. The rating is a value between zero and one, reflecting the relative importance of individual quality considerations and reciprocally proportional to the recommended standard (Si) for each metals (Reza and Singh, 2010; Prasad and Mondal, 2008; Prasad and Kumari, 2008). (Table 3). The unit weight (W_i) has been found out using the formula:

$$Wi = K/S_i$$

Where W_i is the unit weigh and Si is the recommended standard for an ^{i}th parameter, while K is the constant of proportionality. In the present study the K value was considered (1), it also can be calculated using the following equation:

$$K = 1/\Sigma(1/S_n)$$

Table (2):- Recommended Standards used for indices computation and unit weight of individual parameters.

		(WHO, 2017)	Iraqi standards (IQS: 417, 2001)	
Heavy metals	Unit	Drinking water (Gv)[a]	(MPL)[b] (Si)	Units weight (Wi)
Cr	µg/L	50	50[c]	0.020
Mn	µg/L	400	100[c]	0.010
Fe	µg/L	0	300[c]	0.003
Cu	µg/L	2000	1000[c]	0.001
Zn	µg/L	-	3000[c]	0.0003

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Pb	µg/L	10	10[c]	0.100
Cd	µg/L	3	3[c]	0.333
				ΣWi = 0.468

(Gv)[a] = Guideline value; (MPL)[b] = Maximum permissible limit (IQS: 417, 2001). [c] depended standards.

In the second step: a quality rating score (Q_i) or sub-index for all the parameter was calculated by dividing the concentration of each parameter by its respective standard, the result was then multiplied by 100 as follows:

$$Q_i = M_n/S_i \times 100$$

Where M_n is the monitored value of heavy metal of ^{i}th parameter, S_i is the recommended standard or permissible limit for the ^{i}th water quality parameter.

If quality rating Q_i = 0 means complete absence of pollutants within water sample, While $0 < Q_i < 100$ implies that the pollutants are within the prescribed standard. When $Q_i > 100$ implies that the pollutants are above the standards. Hence the higher the value of Q_i is, the more contaminated is the water.

Finally: the overall HPI for each sample was calculated with the following equation (Mohan *et al.*, 1996):

$$HPI = \frac{\sum Q_i W_i}{\sum W_i}$$

Where Q_i referred to the quality rating of nth water quality parameter, W_i is the unit weight of ^{i}th water quality parameter. Generally, the critical pollution index of HPI value for drinking water is 100 (Prasad and Bose, 2001).

1.3.2. The contamination index (C_d)

C_d summarizes the combined effects or degree of contamination of several parameters considered potentially harmful to domestic water (Backman *et al.*, 1998). C_d is a sum of the contamination factors of the individual parameters that exceed their respective permissible values, as presented in the following equation:

$$C_d = \sum_{i=1}^{n} C_{fi}$$

$$C_{fi} = \frac{C_{Ai}}{C_{Ni}} - 1$$

where:

C_{fi} = contamination factor for the ^{i}th component

C_{Ai} = analytical value for the ^{i}th component

C_{Ni} = upper permissible concentration of the ^{i}th component (N denotes the 'normative). In present study, C_{Ni} is taken as Maximum permissible limits (MPL), Table 2.

The C_d values, which are reflecting the contamination level (Backman *et al.*, 1998; Edet and Offiong 2002), are classified in three categories as follows: low (C_d < 1), medium ($1 < C_d < 3$) and high ($C_d > 3$).

1.3.3. Heavy metal evaluation index (HEI)

Similar to HPI, HEI assigns an overall water quality with respect to heavy metals (Edet and Offiong, 2002). HEI describes water quality condition in response to anthropogenic heavy metals and is calculated using the following equation:

$$HEI = \sum_{i=0}^{n} \frac{H_C}{H_{max}}$$

Where, H_c and H_{mac} are the monitored value and maximum admissible concentration (MAC) of the ^{i}th parameter, respectively. In the current research, MPL is considered as MAC according to Iraqi standards. According to the approach of Edet and Offiong (2002), *HEI* are grouped into three categories as follows: low (*HEI* < 10), medium (10 < *HEI* < 20), and high (*HEI* >20).

1.4. Statistical Analysis

Descriptive statistics such as mean, standard deviation were calculated to describe the variation of each parameter. One sample T-test was used to determine if there were significant variations (at 95% confidence level) in heavy metal values and recommended standards. Accordingly, right (upper) tailed T-test was used to examine if the measured values are greater than standards values. Paired T-test was performed to determine if there are significant variations (at 95% confidence level) in the selected parameters between seasons. Prior analysis, data were evaluated for normal distribution using the Anderson-Darling normality test (if P-value < 0.05 data considered non-normal). Long Root square transformation was used where data were not normally distributed. All Statistical analysis was performed using the Minitab software package 17.

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3. RESULT AND DISCUSSION

In present study, the collected water samples from Duhok dam were analyzed for heavy metal contamination using 7 heavy metal including Cr, Mn, Fe, Cu, Zn, Pb, and Cd. The summary [Mean ± standard deviation (SD)] found by descriptive statistics, one sample T-test results of analyzed metals and standards, and paired T-test analysis results of season variation determination at each 6 studies points are shown in Table 3. Overall values of heavy metal pollution indices are presented in Table 4.

1.5. Sidewise and seasonal distribution of Heavy metal

The analyzed results shown that heavy metals concentration (Cr, Mn, Fe, Cu, Zn, Pb, and Cd) were detected in all water samples taken from different sites. In general, it was noted that the concentration of heavy metal in all studied sites were within permissible limit per Iraqi (IQS:417, 2001) and WHO (2017) standards for drinking water, except Cd in some cases.

Cr concentration in water samples during both dry and wet seasons were ranged from 3.33 to 7.33µg/L and 0.63 to 4.98µg/L respectively. The maximum concentration of Cr were found in samples collected at site 7 during dry season, while the minimum concentration were observed in samples collected in same site during wet season. The results were revealed that the values of Cr in all water samples were below the permissible limit (50 µg/L) for drinking water according to proposed standards. Seasonally, the values of Cr in almost all studied sites were significantly higher ($P < 0.01$) during the dry season than during the wet season. The lower trends of Cr in wet season may reflect the dilution of dam by rainwater as the studied area in general, receive considerably large amount of rainfall during this season. In addition, the increase in temperature and high rate of evaporation during the dry season, could resulting in increasing the concentrations of this metal in the dam water.

Iron (Fe) and Manganese (Mn) are essential elements needed by body of human at low concentration as they play major roles in the hemoglobin synthesis and functioning of cells (Gautam *et al.*, 2014). However, in present study, the concentration of iron varied from 5.28 to 10.38µg/L during dry season and from 23.93 to 194.37µg/L during wet season. The relatively higher concentrations of Fe were found in samples collected at sites 1, 2 and 6 during both dry and wet season. The higher values of Fe at this site could be explained that these sites locate at inlet, where river firstly entering the dam, containing higher amount Fe derived from erosion, agricultural activates, and landfill of the surrounding villages. Concerning the season variation, the Fe values in all sampling sites were significantly higher ($P < 0.01$) during wet season than during dry season. This could be explained by many reasons such as dissolution of rocks into the water system, the domestic sewage water and runoff from extensive farmed areas, and leachate coming from the landfills of surrounding villages. On the other hand, Mn concentrations were also varied from 5.2 to 7.38µg/L during dry season and from 3.08 to 6.43µg/L during wet season. The concentrations of Mn were also differ according to different sites and higher concentrations were observed at sites 4 and 5 and lower value was observed at site 1. Opposite to Fe values, all the Mn values were found to be significantly greater during dry season than during wet season, with the exception of site 6. Again, the lower concentrations during winter season may be due to dilution of Mn by rain water. Although the concentrations of Fe were a bet high in some case, Fe and Mn values in analyzed samples were generally low and far below the prescribed limit (100 and 300µg/L for both Mn and Fe respectively) according to the depended standards (Table 2).

The concentration of Cu in the study area varied between 1.4 and 191.58µg/L. The higher value of Cu was observed at site 3 during wet season, while lower values were detected at site 6 during both seasons. According to limits prescribed by both WHO (2017) and Iraqi's standards (IQS:417, 2001), all water samples were far below the maximum permissible limit (1000µg/L). With regard to the seasonal variation, it was found that the Cu concentration in all sampling sites were significantly greater ($P < 0.01$) during wet season compared to dry season. The higher values of Cu may be due to runoff from extensive farmed areas, leachate coming from the landfill and domestic sewage water of the surrounding villages.

Zinc (Zn) is also an essential element in our diet. Too much zinc, however, can also be damaging to health. Although no health-based guideline value has been set for these parameters by WHO (2017), zinc toxicity in large

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amounts causes nausea and vomiting in children (Gautam *et al.,* 2014). The results of current study showed that the Zn concentration in water samples ranged from 4.1to 6.13 μg/L during dry season and from 2.93 to 26.85 μg/L during wet season. It was noted that during both seasons the minimum values of Zn were found at site 4 and maximum values of Zn were found at site 5. Concerning the variation of Zn between seasons, it was observed that Zn concentration in almost all sites were significantly higher ($P < 0.01$) in winter than in summer, except site 4. Higher concentrations of Zn detected during wet season could be due to (as mentioned previously) agricultural drainage water containing fertilizers and pesticides and leachate coming from the landfill of the nearby villages. Comparing the analyzed values of Zn to standards, the concentrations of Zn in all water samples were far below the permissible limits (3000μg/L) set by Iraq's standards (IQS:417, 2001).

Lead (Pb) is both a toxic and non-essential metal having no nutritional value to living organisms (Gautam *et al.,* 2014; WHO, 2017). In present study, the concentration of Pb were ranged from 0.58 to 6.08μg/L during dry season and from 0.55 to 5.35 μg/L during wet season. It can be noticed that the concentrations of Pb were relativity high especially at sites 2, 4, and 5, but sill these values are below the maximum permissible limit (10μg/L) recommended by both Iraqi's (IQS:417, 2001) and WHO (2017) standards. This higher values of Pb may resulted from increased urban activity around the dam. It was also found that, except site 3, the concentrations of Pb in most of the analyzed water samples were significantly higher during dry season compared to wet season. Higher trend of Pb during summer were found by other researchers such as Ndeda and Manohar (2014) who stated that "the rainy (wet) season caused a dilution factor in the water body, therefore, low concentrations of these heavy metals were recorded in the dam's water". Furthermore, these greater trends of Pb in dry season may be attributed (as discussed previously) to the high evaporation rate of surface water followed by high temperature and subsequent outflow of reservoir water leading to the accumulation of the heavy metals in dam water (Bhardwaj *et al.,* 2017).

Surprisingly, it has been found that the Cd concentration in most of the studied sties were significantly ($P < 0.05$) exceeded the maximum permitted limits (3μg/L) provided by both Iraqi's (IQS:417, 2001) and WHO (2017) standards. The concentrations of Cd were ranged from 2.45 to 3.78μg/L during dry season and from 2.40 to 3.55μg/L during wet seasons. This higher values of Cd may be due to several activates happening near or around the dam including agriculture, construction works, human waste, sewage and garbage. Furthermore, This also may be due to large quantities of solid and liquid waste disposed in the dam from the tourists which has been of concern to the citizens and authorities as well. Cadmium (Cd) classified as toxic trace element appears to accumulate with age, especially in the kidney and it is considered as an agent to cause cancer and cardiovascular diseases (Priti *et al.,* 2016). Depending on the results of Cd and Pb, it can be claimed that the studied water is unsafe for drinking purposes, therefore, effective measures need to be taken to lower the concentration of these two metal in dam water. With regards to Cd seasonal variation, except site 6, the concentrations Cd in samples collected during dry season were significantly higher ($P < 0.05$) than in those collected during wet season. These findings are consistent with that of Hawrami and Mezuri (2014). As discussed previously, This may be due to evaporation during hot and dry season and dilution during rainfall.

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Table (3):- Mean ± SD values of studied heavy metal at each site and season, one sample T-test for determining differences between metals and standards values together with Paired T-test analysis for determining seasonal variation in heavy metals.

	S1			S2			S3		
Heavy metals	Dry season	Wet season	Differences	Dry season	Wet season	Differences	Dry season	Wet season	Differences
Cr	3.33±0.13	3.13±0.10	0.21	7.33±0.13	0.63±0.07	6.70**	4.5±0.10	2.43±0.10	2.08**
Mn	6.23±0.21	3.08±0.10	3.15**	7.08±0.10	5.03±0.17	2.05**	6.95±0.13	6.43±0.10	0.53**
Fe	10.38±0.15	194.37±1.3	-184**	9.35±0.17	123.35±9.64	-114.0**	8.1±0.08	23.93±0.10	-15.83**
Cu	11.13±0.15	145.5±2.1	-134.38**	9.05±.0.13	191.58±0.79	-182.5**	9.9±0.18	168.32±0.10	-158.42**
Zn	5.52±0.01	22.45±0.58	-16.94**	5.45±0.06	21.35±0.62	-15.90**	5.05±0.06	10.98±0.17	-5.93**
Pb	4.1±0.08	2.53±0.17	1.58**	5.08±0.3	1.43±0.13	3.65**	0.58±0.09	3.5±0.08	-2.93**
Cd	3.63±0.13*	2.88±0.15	0.75**	2.95±0.13	2.40±0.17	0.55**	3.43±0.1*	2.85±0.19*	0.58*
	S4			S5			S6		
Heavy metals	Dry season	Wet season	Differences	Dry season	Wet season	Differences	Dry season	Wet season	Differences
Cr	4.93±0.15	3.48±0.10	1.45**	4.93±0.15	4.98±0.13	-0.05	4.3±0.14	4.45±0.10	-0.15
Mn	7.38±0.19	5.45±0.13	1.93**	7.38±0.10	6.28±0.17	1.10**	5.2±0.22	6.3±0.15	-1.23**
Fe	5.28±0.21	61.75±0.35	-56.48**	8.13±0.13	46.2±0.73	-38.1**	9.63±0.12	83.58±0.48	-73.95**
Cu	12.4±0.08	154.54±0.43	-142.14**	9.53±0.17	186.1±0.56	-176.6**	1.4±0.19	2.08±0.10	-0.68*
Zn	4.1±0.10	2.93±0.15	1.2**	6.13±0.08	26.85±0.24	-20.73**	5.25±0.3	16.165±0.38	-10.92**
Pb	6.08±0.10	3.43±0.10	2.65**	5.42±3.1	5.35±0.24	0.07	0.6±0.08	0.55±0.06	0.05
Cd	2.75±0.17	2.98±0.13	-0.20	3.78±0.17*	3.53±0.17*	0.25	2.45±0.13	3.55±0.06*	-1.10**

The concentration of all heavy metals are in µg/L.
* on heavy metals values in Dry and Wet season column = measured values significantly greater than recommended standard value.
* on values in differences column = significant difference exist in values between the studied season at p - value < 0.05.
** on values in differences column = significant difference exist in values between the studied season at p - value < 0.01.

1.6. Metal pollution indices

In current study, the mean concentration values of the selected metals (Cr, Fe, Mn, Zn, Cu, Pb and Cd) were used in order to calculate pollution indices for each sampling point (Prasad and Mondal, 2008). This helps us to assess the surface water quality in each sampling points, which can be used to compare the index of each sample. The summaries pollution indices (HPI, Cd and HEI) values of water sampling sites for each season are presented in Table 4. Heavy metal pollution indices is one of the widely indices for assessing water quality evolution because it shows the composite influence of individual heavy metal on the overall quality of water (Reza and Singh, 2010). During dry season the range and mean of HPI were 59.95 to 101.93 and 83.51, while during winter the range and mean of HPI were 60.53 to 95.95 and 82.53 respectively. These results of HPI shown that, except site 5 during dry season, all the water samples were below the critical pollution index value of 100, and are not critically polluted with respect to heavy metals. However, it was also observed that, the values of HPI were close to the critical value as the average values were (83.51 and 82.53 for dry and wet season respectively), and these values may increase in the future if effective measures were not taken to reduce the load of heavy metal getting into dam. These slightly higher values of HPI at different sites could be due to the higher values of Cd and Pb detected at these sites. Since the units weight (Wi) given to other metal (Cr, Fe, Cu, Mn and Zn) were very less, these metals did not contribute much to the evaluation of HPI of the dam water, but Cd and Pb have been given high units weight and have much contribution (Ewaid, 2017) (Table 2 and 3). Concerning the contamination index (C_d), the highest value was observed in water sample collected at site 5 (- 4.78) during wet season, while the lowest value was observed from water sample collected at site 6 (-5.95) during dry season. Depending on these results and average values of C_d (-5.38 during dry season and -5.15 during wet season), the studied water dam was found to have low degree of contamination ($C_d < 1$) according to (Backman *et al.*, 1998; Edet and Offiong 2002) classifications. Depending on the average values of HEI during both dry and wet season (1.62 and 1.86 respectively) and values of this index for each sampling site, the studied water samples were belong to the low heavy metals level (HEI < 10) according to (Edet and Offiong, 2002) classification. The values of HEI were varied from 1.05 to 2.01 during dry season and from 1.62 to 2.22 during wet season.

On the other hand, the seasonal variation shown that the values of selected indices were fluctuated at different sites. The values of indices in some situations were higher during dry season, this could be due to (as mentioned previously) dilution, temperature and evaporation factors, while the higher indices values during wet season could be due to various reason including agricultural drainage water containing fertilizers and pesticides, leachate coming from the landfill of the nearby villages, solid and liquid waste disposal from tourist and urban activities around the dam.

Table (4):- Overall heavy metal pollution indices for all studied sites during dry and wet seasons.

	HPI		Cd		HEI	
Sites	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season
S1	95.39	74.60	-5.21	-4.89	1.79	2.11
S2	81.69	60.53	-5.25	-5.38	1.75	1.62
S3	83.23	75.58	-5.60	-5.34	1.40	1.66
S4	78.88	78.67	-5.27	-5.18	1.73	1.82
S5	101.93	95.95	-4.99	-4.78	2.01	2.22
S6	59.95	86.17	-5.95	-5.32	1.05	1.68
Mean	83.51	82.53	-5.38	-5.15	1.62	1.86

4. CONCLUSION

In this study, metal pollution indices was used to assess water quality contamination by heavy metal pollution and its suitability for drinking and domestic purposes. However, based on individual heavy metal parameters, except Cd in some cases, the concentration of all the selected metals during both dry and wet season were below prescribed limits according to Iraqi's (IQS:417, 2001) and WHO (2017) standards. The higher concentration of Cd in some sites indicates that there is a leaching of this metal from the anthropogenic activity such as agriculture surrounding the dam or discharge of the waste materials, which contains a high level of Cd.

The calculations of metal pollution indices revealed that, in general, the water samples collected from all the studied sites during both season were below the contamination levels, although the value of HPI was slightly higher than critical pollution range at site 5 during dry season. Moreover, depending on average values of these indices (HPI, C_d and HEI), the water of Duhok dam was not contaminated and safe enough to be utilized by human for any purposes including drinking. In present study, fluctuations in concentration of various heavy metals and metal indices values have also been observed in different seasons at different sites, but in almost all cases the values were below permissible limits and contamination levels.

Depending on the results of present study, it can be concluded that the current concentration of studied heavy metal could have no noticeable negative impacts on human health, but it could have negative impacts on human health in long-term usage as some sites have higher contents of Cd. Therefore, it can be recommended that a simple physical treatment notably by filtration such Granular activated carbon filtration of the study spring water are desirable to reduce heavy metals loads and consequently to ensure spotless and secure water supply. It is also mandatory to regularly monitor the Duhok water dam in order to detect any changes that may happen in water quality parameters. Furthermore, the government and authorities should provide effective management programs such as control the overuse of fertilizer and other agriculture inputs in farms around the dam, manage the wastewater and waste disposal of the surrounding village, control erosion by re-vegetation and construction of check dams, and distribution of trash bins around the dam for tourists in order to eliminate the concentration of heavy metals entering the dam water body.

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REFERENCES

– Abdullah E.J., Quality assessment for Shatt Al-Arab River using heavy metal pollution index and metal index. *Journal of Environment and Earth Science*, *3*(5) (2013),114-120.
– Al-Barzingy Y.O.M., Water quality assessment for Duhok reservoir. *ZANCO Journal of Pure and Applied Sciences*, *30*(6) (2018) 66-71. DOI: https://doi.org/10.21271/ZJPAS.30.6.6
– APHA, Standard methods for the examination of water and waste water. American Public Health Association, Washington DC, (2005).
– Backman B., Bodiš D., Lahermo P., Rapant S. and Tarvainen T., Application of a groundwater contamination index in Finland and Slovakia. *Environmental Geology*, *36*(1-2) (1998), 55-64. https://doi.org/10.1007/s002540050320
– Bhardwaj R., Gupta A. and Garg J.K., Evaluation of heavy metal contamination using environmetrics and indexing approach for River Yamuna, Delhi stretch, India. *Water Science*, *31*(1) (2017), 52-66. https://doi.org/10.1016/j.wsj.2017.02.002
– Bora M. and Goswami D.C., Water quality assessment in terms of water quality index (WQI): case study of the Kolong River, Assam, India. *Applied Water Science*, *7*(6) (2017), 3125-3135.
– Brown R.M. McClelland N.I. Deininger R.A. and Tozer R.G., A Water Quality Index- Do We Dare, (1970). https://doi.org/10.1007/s13201-016-0451-y
– Brraich O.S. and Jangu S., Evaluation of water quality pollution indices for heavy metal contamination monitoring in the water of Harike Wetland (Ramsar Site), India. *International Journal of Scientific and Research Publications*, *5*(2) (2015), 1-6.
– Drinking-Water Standard, (IQS:417), *Central Organization for Quality Control and Standardization, Council of Ministers, Republic of Iraq*, (2001).

- Duman F., Sezen G. and Tug G.N., Seasonal changes of some heavy metal concentrations in Sapanca Lake water, Turkey. *Uluslararası Doğa ve Mühendislik Bilimleri Dergisi*, (3) (2007), 25-28.
- Edet A.E. and Offiong O.E., Evaluation of water quality pollution indices for heavy metal contamination monitoring. A study case from Akpabuyo-Odukpani area, Lower Cross River Basin (southeastern Nigeria). *GeoJournal*, *57*(4) (2002), 295-304. DOI: https://doi.org/10.1023/B:GEJO.0000007250.92458.de
- Ewaid S.H., Water quality evaluation of Al-Gharraf river by two water quality indices. *Applied Water Science*, *7*(7) (2017), 3759-3765.DOI: https://doi.org/10.1007/s13201-016-0523-z
- Gautam R.K., Sharma S.K., Mahiya S. and Chattopadhyaya M.C., Contamination of heavy metals in aquatic media: transport, toxicity and technologies for remediation. *Heavy metals in water: Presence, removal and safety*, (2014), 1-24.DOI:10.1039/9781782620174-00001
- Hawrami K. and Mezuri H., Assessing Risks to Human Health from Potentially Toxic Elements in Drinking Water of Duhok Province/Kurdistan Region of Iraq. *Journal of Environment Pollution and Human Health*, *2*(2) (2014), 44-51.DOI:10.12691/jephh-2-2-2
- Herojeet R., Rishi M.S. and Kishore N., Integrated approach of heavy metal pollution indices and complexity quantification using chemometric models in the Sirsa Basin, Nalagarh valley, Himachal Pradesh, India. *Chinese Journal of Geochemistry*, *34*(4) (2015), 620-633. https://doi.org/10.1007/s11631-015-0075-1
- IQS, (Iraqi drinking water standard:417), Central Organization for Quality Control and Standardization, Council of Ministers, Republic of Iraq, (2001).
- Issaka S. and Ashraf M.A., Impact of soil erosion and degradation on water quality: a review. *Geology, Ecology, and Landscapes*, *1*(1) (2017), 1-11. https://doi.org/10.1080/24749508.2017.1301053
- Khatri N. and Tyagi S., Influences of natural and anthropogenic factors on surface and groundwater quality in rural and urban areas. *Frontiers in Life Science*, *8*(1) (2015), 23-39. https://doi.org/10.1080/21553769.2014.933716
- Mohammed R., The impact of the man activity in duhok dam watershed on the future of Duhok Dam Lake North-Iraq. In *1st International Applied Geological Congress, Department of Geology, Islamic Azad University-Mashad Branch, Iran*, (2010), 26-28).
- Mohan S.V., Nithila P. and Reddy S.J., Estimation of heavy metals in drinking water and development of heavy metal pollution index. *Journal of Environmental Science & Health Part A*, *31*(2) (1996), 283-289. https://doi.org/10.1080/10934529609376357
- Mohhamed N.I. and Bamarni K.A., Water quality monitoring of Duhok Dam (Kurdistan Region of Iraq). *ZANCO Journal of Pure and Applied Sciences*, *31*(1) (2019), 7-16. DOI:https://doi.org/10.21271/ZJPAS.31.1.2
- Ndeda L.A. and Manohar S., Determination of heavy metals in Nairobi dam water,(Kenya). *IOSR Journal of Environmental Science, Toxicology and Food Technology*, *8*(5) (2014), 68-73. DOI:10.9790/2402-08546873
- Prasad B. and Bose J., Evaluation of the heavy metal pollution index for surface and spring water near a limestone mining area of the lower Himalayas. *Environmental Geology*, *41*(1-2) (2001), 183-188. https://doi.org/10.1007/s002540100380
- Prasad B. and Kumari S., Heavy metal pollution index of ground water of an abandoned open cast mine filled of the water quality of River Adyar, India. *Bulletin of Environmental Contamination and Toxicology*, *82*(2) (2008), 211-217. DOI:10.1007/s10230-008-0050-8
- Prasad B. and Mondal K.K., The impact of filling an abandoned open cast mine with fly ash on ground water quality: a case study. *Mine Water and the Environment*, *27*(1) (2008), 40-45. https://doi.org/10.1007/s10230-007-0021-5
- Priti P. and Paul B., Assessment of Heavy Metal Pollution in Water Resources and their Impacts: A Review. *Journal of Basic and Applied Engineering Research*, *3*(8) (2016), 671-675.
- Reza R. and Singh G., Heavy metal contamination and its indexing approach for river water. *International Journal of Environmental Science & Technology*, *7*(4) (2010), 785-792. https://doi.org/10.1007/BF03326187
- Shekha Y.A., Ismael H.M. and Ahmed A.A., Bacteriological and mycological assessment for water quality of Duhok reservoir, Iraq. *Jordan Journal of Biological Sciences*, *147*(916) (2013), 1-8.DOI:10.12816/0001630
- Shigut D.A., Liknew G., Irge D.D. and Ahmad T., Assessment of physico-chemical quality of borehole and spring water sources supplied to Robe Town, Oromia region, Ethiopia. *Applied*

Water Science, *7*(1) (2017), 155-164. https://doi.org/10.1007/s13201-016-0502-4

– Toma J.J., Limnological study of Dokan, Derbendikhan and Duhok lakes, Kurdistan region of Iraq. *Open Journal of Ecology*, *3*(1) (2013), 23-29.DOI:10.4236/oje.2013.31003

– Uzairu A., Okunola O.J., Wakawa R.J. and Adewusi S.G., Bioavailability studies of metals in surface water of River Challawa, Nigeria. *Journal of Applied Chemistry*, 2014(2014), Article ID 648453, 9p. http://dx.doi.org/10.1155/2014/648453

– Yisa J., Jimoh T.O. and Oyibo O.M., Underground water assessment using water quality index. *Leonardo Journal of Sciences*, *21* (2012), 33-42.

– Zarazua G., Ávila-Pérez P., Tejeda S., Barcelo-Quintal I. and Martínez T., Analysis of total and dissolved heavy metals in surface water of a Mexican polluted river by total reflection X-ray fluorescence spectrometry. *Spectrochimica Acta Part B: Atomic Spectroscopy*, *61*(10-11) (2006), 1180-1184. https://doi.org/10.1016/j.sab.2006.06.010

– Zvinowanda C.M., Okonkwo J.O., Shabalala P.N. and Agyei N.M., A novel adsorbent for heavy metal remediation in aqueous environments. *International Journal of Environmental Science & Technology*, *6*(3) (2009), 425-434. https://doi.org/10.1007/BF03326081

بكارهێنانا نیشانێن پیساتیێ بو هەل سەنگاندنا بیساتیا ئاڤا سەرڤەیی یا سكرێ دهوكێ ب كانزاییێن گران (هەرێما كوردستانا عراقێ)

پوختە

بەردوام چاڤدێری كرن و هەل سەنگاندنا سەرچاوێت ئاڤێ ل زاراڤێ كانزاییێن قورس زورا گرنگە بو گەرانتیكرنا گونجیا ئاڤا وان بو هەرمەبەستەكێ هەروك ب كارهێنانا وان بو ڤەخارنێ ژلایێ مروڤی ڤە. ژ بەر ڤێ چەندێ، ئەڤ ڤەگولینە هاتە ئەنچامدان بو هەل سەنگاندنا پیسبونا ئاڤا سەرفەیێ یا سكرێ دهوكی ل هەرێما كوردستانا عراقێ ب زارافێ نیشانێن پیساتیا كنزاییێن گران. نمونێن ئاڤا سەرفەیێ هاتن كومكرن ژ ٦ شوێنێت چێواز ل دەورو بەرێت كەنارێ سكرێ دهوكێ ل ورزێت هشك (تەمووز بو تشرینا ئێكێ، ٢٠١٨) و تەر (كانونا ئێكێ بو نیسانێ، ٢٠١٩)، و ئەڤ نمونە هاتن شلوڤەكرن بو چەندیا كانزاییێن گران وەكی كرومی **(Cr)**، مەنگەنیسی **(Mn)**، ئاسنی **(Fe)**، سفری **(Cu)**، زنكی **(Zn)**، رساسی **(Pb)**، و كادمییومی **(Cd)** ب كارئینانا ئامیرێ **Atomic Absorption Spectrophotometer**. ل دیڤدا، نیشانا پیس بوونا كانزاییێن گران **(HPI)**، بلا بیس بوونێ **(Cd)**، و نیشانا هەل سەنگاندنا كانزایی گران **(HEI)** هاتن ژمێریاری كرن بو هەل سەنگاندنا چوری یا ئاڤێ ب گشتی سەبارەت ب رێژا گشتی یا كانزاییێن گران.ئەنچامێن هوكارینَ تاك دیاركر، ژبلی كانزایێ **Cd**، ل هەمی چهێن هاتین شلوڤەكرن، چراتیا هەمیی كانزایی ب شێوەكێ گشتی كێمتربوون ژ ریژا سنوردار ب گوێرەی پیڤەرێن عراقی **(IQS:417, 2001)** و رێكخراوا جیهانی یا ساخلەمیێ **(WHO,2017)** . هەروسا، ژ لایەكی دیفە ئەنچامان دیاركر كو ل هەمی جهێن هاتینە شلوڤەكرن ریژا كانزایێ **Cd** بتر بو ژرێژا سنوردار **(٣ میكروكرام/لتر)** بشت بەستن ب پیڤەرێن هاتینە بكائینان، ئەف چەندە نیشا ددەت كو دزینا فی كانزای یا هەی بو ناف ئاڤا سكری. ل سەر بنەمایی ژمارا نیشانێن پیس بوونێ، سەرەرای هەبەنا ژمارا بلند یا نیشانا پیس بوونا كانزاییێن گران **(HPI)** ل جهەكی بنتێ، ژمارا نیشانێن پیس بوونێ یێن هەمی نمونێن ئاڤێ ل هەمی جهێن هاتین شلوڤەكرن كێمتر بوو ژ ژمارا هەستیار. دەربارەی جیاواریا وەرزی، رێژا كانزاییێن گران و ژمارا نیشانێَن پیس بوونێ د چێوازیا وەرزا و جهێن نمونا. بشت بەستن ب فان ئەنچاما، ئەم دشێین بگەهینە ئەنچامەكی كو ئافا سكری یا كونچایە و یا ب سلامە تە بو ڤەخارنێ. ل گەل ئەڤێژی دا، چێت بیت رێژا بلند یا **Cd** د هندەك نمونادا ببتە ئەگەرێ كاریگەرییێن نەرێنی ل سەر ساخلەمیا مروفی ب كار ئینانا درێژخانە. لەورا، د هێتە پێشنیار كرن چارەسەرێن سفك وەكی فلتەركرنا ئاڤی برێكا كاربونی بەری فەخارنێ گەلەك یا گرنكە بو گەرەنتیكرنا باقشی و ساخلەمیا ئاڤێ بو هاووەلاتییێن ڤێ دەڤەرێ.

تطبيق مؤشرات التلوث لتقييم تلوث المعادن الثقيلة في المياه السطحية لسد دهوك (**إقليم كردستان العراق**)

الخلاصة

يعد المتابعة والتقييم المستمر لمصادر المياه من حيث المعدن الثقيل أمرًا بالغ الأهمية لمنح صلاحيتها لأي غرض بما في ذلك الاستهلاك البشري. وفقًا لذلك، أجريت هذه الدراسة لتقييم تلوث المياه السطحية لسد دهوك في إقليم كردستان العراق، من حيث مؤشرات تلوث المعادن. تم جمع عينات من المياه السطحية من ٦ مواقع مختلفة حول السد خلال الفصول الجافة (من تموز إلى تشرين اللأول ٢٠١٨) والرطبة (من كانون الأول إلى نيسان ٢٠١٩) ، وتم تحليلها لتراكيز المعادن الثقيلة بما في ذلك الكروم **(Cr)** والمنغنيز **(Mn)** والحديد **(Fe)** ، النحاس **(Cu)** ، الزنك **(Zn)** ، الرصاص **(Pb)** ، والكادميوم **(Cd)** باستخدام جهاز الامتصاص الذري. تم حساب مؤشر تلوث المعادن الثقيلة **(HPI)** ، ودرجة التلوث **(Cd)** ومؤشر تقييم المعادن الثقيلة **(HEI)** لتقييم الجودة الكلية للمياه فيما يتعلق بالمحتوى الكلي للمعادن الثقيلة. أظهرت نتائج المعلمات الفردية أنه ، باستثناء الكادميوم في بعض المواقع ، كان تركيز المعادن الثقيلة في جميع المواقع التي خضعت للدراسة أقل من المقايس وفقًا للمعايير العراقية **(IQS:417, 2001)** والعالمية **(WHO, 2017)**. أظهرت النتائج أيضًا أن تراكيز الكادميوم في معظم عينات المياه كانت أعلى من الحدود المسموح بها (٣ ميكروغرام/لتر) وفقًا للمعايير الموصى بها ، مما يشير إلى وجود ترشيح لهذا المعدن في سد الماء استنادًا إلى قيم مؤشرات التلوث المعدني، على الرغم من وجود قيمة أعلى لـ **HPI** في حالة واحدة كانت عينات المياه من جميع المواقع التي خضعت للدراسة أقل من القيم الحرجة. فيما يتعلق بالاختلاف الموسمي، فقد تفاوتت تراكيز المعادن الثقيلة وقيم مؤشرات المعادن طوال الفصول والمواقع المختلفة. إعتمادًا على هذه النتائج ، يمكن الاستنتاج أن مياه السد يمكن استخدامها كمياه آمنة للشرب. ومع ذلك ، قد يكون لتركيزات عالية من الكادميوم في بعض عينات المياه آثار سلبية على صحة الإنسان في الاستخدام طويل الأمد. لذلك ، يمكن اقتراح أنه من المستحسن استخدام بعض المعالجات البسيطة مثل ترشيح الكربون الحبيبي المنشط لمياه الدراسة قبل الاستخدام لتزويد مياه آمنة تزويد لمواطني هذه المنطقة.