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Assessment the Environmental Reality of Duhok Valley Water on the Water Quality of Mosul Dam Lake by Using Water Quality Index (WQI)

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Abstract

The water quality of the Duhok Valley stream was studied as one of the sources of pollution for the water of Mosul Dam Lake, which is located on the Tigris river.The necessary environmental tests were conducted for the water samples taken from different locations in the valley to investigate the degree of pollution of its water using the water quality index (WQI), and the extent of the impact of self-purification processes in improving the water quality before it reaches the dam lake. The results indicated that the water quality of Duhok Dam site (S1) was of medium water quality(68.7), while the rest sites of the valley were of poor quality, as the water quality index ranged between (26.8 to 39.4) and this deterioration in quality is due to the huge amount of the wastewater drained into it, which led to an increase in the organic load, phosphate and EC_{25} to reach (66.0) ppm , (25.0) ppm and (1135) uS. cm^{-1}, with a lack of dissolved oxygen in the water in some locations and for some periods, and no noticeable improvement was observed in the water of the valley before it reached the Mosul Dam lake except for dissolved oxygen, sulphate and chloride ions. The study summarized that the quality of the studied water according to WQI was of the category of bad quality water, which increases the possibility of a negative impact on the water quality of Mosul Dam lake.

*Keywords:*WQI;Duhok valley;Wastewater;Water Quality;Organic load.

1. Introduction

Aquatic ecosystems face many challenges as a result of industrial, agricultural and civilized development as well as climatic changes and the scarcity of rainfall, which prompted world opinion and specialists to warn of the consequences that may occur in your aquatic ecosystems, if the necessary measures are not taken to follow up and reduce pollution problems. The increase and continuation of wastewater dumping into valleys and its transfer to water resources may threaten the occurrence of crises and disasters for aquatic ecosystems, as is the case for Duhok valley, which transfers polluted water to the Mosul Dam lake, which contains various pathogens such as bacteria, viruses, parasites, etc. [1,2]. Also, the high levels of organic load resulting from wastewater disposal may lead to the depletion of dissolved oxygen in the water and create anaerobic conditions and the production of many toxic substances and odour triggers such as H_2S, HS^-, S^{-2}, amines, ammonia and methane, which cause the deterioration of the aquatic ecosystem, but their arrival in the well-ventilated Mosul Dam lake leads to the biological oxidation of ammonia to nitrite and then to nitrate by the process of nitrification and harmful forms of sulfur to sulfate ions[3,4,5]. The transfer of the remains and small parts of plastic materials from wastewater to water sources, whether the water of the valley or the waters of the Mosul Dam lake, and they are often floating on the surface

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water may deceive birds, fish and aquatic organisms into swallowing them without thinking that they are eggs of aquatic animals that may collect in the digestive system causing the slow death of it, and what increases its danger is its inability to decompose and its survival as a source of danger to aquatic life[3], the high levels of plant nutrients ($PO4^{-3}$ and $NO3^{-1}$) in the aquatic environment may cause eutrophication and increase the numbers of algae, especially blue-green algae, and this problem is reinforced by the phenomenon of climate change and high temperatures, which negatively affects the aquatic environment due to its production of toxins such as neurotoxins and inflammation Liver, skin toxins and carcinogens etc. that can accumulate and biomagnified in the bodies of fish and aquatic organisms and transfer them to the human final consumer in the food chain as well as reduce biological diversity and reduce the concentration of dissolved oxygen in the water[6,7,8]The decrease in water transparency as a result of the high concentration of suspended substances and the products of anaerobic decomposition processes will impede the penetration of light into the water column and thus affect the photosynthesis processes of plants and aquatic algae, which are a food source for many aquatic organisms (herbivores) and reduce the oxygen supply of water, as well as their negative effects on the life cycles of fish and aquatic organisms and gas exchange processes due to the damages that occur to the gills, It also interferes with the filter-feeding mechanism of invertebrates [3,9]. As for the low pH values of the aquatic environment, it leads to mass death of fish and aquatic organisms as a result of the increased release of toxic metal ions, especially aluminum ions, and its release into the water, causing the formation of a mucous layer on the gills that impedes gas exchange processes and the inability of eggs to hatch and young fish to survive in acidic environments [10], also, fluctuations in pH values have a great effect on toxicity, for example, the toxicity of ammonia at pH = 8 is ten times more than its toxicity at pH = 7.0. Finally, dissolved oxygen in water has a vital role in the aquatic ecosystem, but the depletion of dissolved oxygen due to the increase in organic pollution will lead to the disappearance of many organisms and their replacement with less oxygen-requiring species as well its relationship to toxicity and mortality. The lethal concentration of detergents (LAS) for Lepomismaroshirus is 0.4 ppm when the concentration of dissolved oxygen in water is 2.0 ppm, while the lethal concentration becomes 2.2 ppm when the dissolved oxygen concentration is 7.5 ppm [11]. Although there are few studies on wastewater in Duhok valley compared to studies conducted on types of Iraqi water sources, they did not address the use of mathematical models to assess water quality for various purposes, including the study of Al-Saffawi et al.[12] for the characteristics Physical, chemical and microbial assessment of water quality. Duhok valley, where they mentioned the deterioration of water quality due to the high organic load and low concentration of oxygen, and the study of Hassan and Al-Barwari [13] included an assessment of the waters of Duhok valley, where water samples were taken along the valley for different seasons. The result indicated a lack of dissolved oxygen and an increase in the organic load concentration in varying proportions. Also, Omer et al,[14] conducted their study to assess the qualitative characteristics of water for different periods of the year. They reached some results that indicated that the oxygen concentration in the water did not drop below 5 ppm, and later, Mohamed and Bemrani [15] investigated the ions in the water of Duhok dam lake, the observed results showed an increase in the concentration of dissolved solids, as well as a high conductivity of water. Therefore, the current study aims to assess the environmental reality of the waters of Duhok valley and the expected effects on the waters of the Mosul Dam lake.

2. Materials and Methods

Duhok valley is one of the natural valleys that penetrates Duhok city, transporting most of its wastewater through its long course to the Mosul Dam lake, which is located on the Tigris River, north of the city of Mosul. Because of the large expansion of the city with the increase in the population, it led to an increase in the amount of wastewater introduced to it, causing significant effects on water resources. Fields and farms are also spread on both sides of the valley even after leaving the city and reaching the lake that is used to drink livestock and poultry for farmers, especially after leaving the city. Table 1 and Figure 1 illustrated the locations of sampling sites of the valley under study.

Table 1: The Altitudes, latitudes and longitudes of sampling sites for the waters of Duhok valley, northern Iraq

Sites		Altitude	Longitudes (E)	Latitudes (N)	Notes
S1	Duhok dam	607 m	40°00’09"	36°87’74"	The transparency of the valley's water decreased with foul odors in some periods
S2	Near D.P.C.*	551 m	43°00’23"	36°86’78"	
S3	Khashman Spring**	523 m	42°99’38"	36.85’39"	
S4	Shindokha Bridge	499 m	42°96’79"	36°85’19"	
S5	Aloka bridge	434 m	42°91’08"	36°84’05"	
S6	Bakhotmy	364 m	42°85’38"	36°80’86"	

**Near the Duhok Provincial Council., ** Near Duhok Stadium*

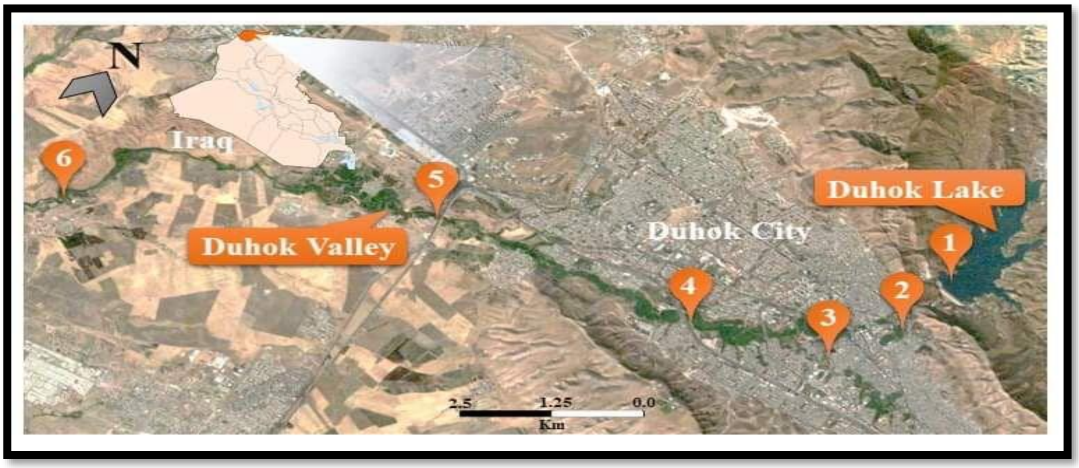

Figure 1: Map of the study area showed the study station

2.1 Methodology

Water samples were collected in clean polyethene bottles, and special glass bottles for the examinations of dissolved oxygen and the biochemical oxygen demand (BOD_5), with one sample per month for each site, initiating from February 2021 until January 2022, and the samples were kept in a refrigerated container away from light until reaching the laboratories of the Faculty of Science at the Universities of Zakho and Duhok, the approved standard methods for its analysis were also used [16,17] as the pH was measured with a PH-meter after regulating it with multiple buffer solutions (pH: 4, 7, 9), Electrical conductivity with a conductivity meter with adjusting values to EC_{25}, Dissolved oxygen in water by azide modification M. Organic load(BOD_5) by incubating at a temperature of 25 °C for five days, Total alkalinity by titration with Na_2EDTA standard solution (0.02 N), Chloride ions by titration with silver nitrate standard solution (0.0141 N), phosphate by stannous chloride M. and sulfate by the turbidimetric method. The temperature of water in all sites was measured by immersing the thermometer to a depth of 10 cm in water and recording the temperature of the water.

2.2 Estimation of water quality index (WQI)

The use of mathematical models to evaluate water quality is one of the important means of evaluation, as it gives one value that expresses the quality of water, which is the result of different interventions between the quality standards used and the huge amount of data that confuses the reader and is understood by the specialist and the non-specialist, as the results of the models in providing data and information for future studies. The first mathematical model was proposed in the sixties of the last decade by Horton. Over time, a number of weighted mathematical models were developed such as CCMEWQI, NSFWQI, OWQI and WPij etc. [18, 19, 5, 20]. In the current study, the WQI value was calculated using the weighted mathematical model using the following equation (1), which was referred to by each of [21.22, 23]:

$$WQI = K\left[\frac{\sum_{i=1}^{n} Pi \times Wi}{Pi}\right]$$

Where, n: represents the number of parameters, Wi: is the Normalization values for each parameter (%), and Pi is the weight given to each parameter according to its importance, ranging from (1 to 5). K:

is a constant (0.25., 0.5., 0.75 and 1.0) according to the degree of visible pollution by smell, color and transparency. Water quality is classified according to WQI values into five categories as follows: 0 to 25 indicates very Bad water; 26 to 50 is Bad water quality, 51 to 70 of Medium water quality, 71 to 90 of good water quality and 91 to 100 of excellent quality.

3. Results & Discussions:

The results of the Water Quality Index (WQI) values for the waters of Duhok valley, which are shown in Table 2,3, indicate that the water quality values of the site (S1) represented by the waters of the Duhok dam lake amounted to (68.7), thus it is classified as a medium-quality water category, and this relative decrease in quality is due to a decrease of Normalization values (Ci) for each of the parameters (T.A, T.H., BOD_5,PO_4^{-3}, SO_4^{-2} and Cl^-, which arrived at (65, 60, 70, 0.0, 60 and 80) consecutively, What confirms this is the results of the analysis shown in Table 4, where it is noted that the concentrations of the parameters are relatively high reaching (368, 500, 6.7, 10.0, 198, 77.9) ppm consecutively, this is due to the presence of sulfur springs around the lake of the Duhok Dam, as well as the discharge of untreated wastewater from nearby villages into the lake.

As for the rest of the studied sites on the valley, the results are shown in Table 3 indicate the relative decline in the values of the water quality index (WQI), which fluctuated between (26.8 to 39.4), where the water was classified in the category of Bad quality water. This deterioration in quality is mainly due to the low values of Normalization (Ci) for each of the total alkalinity, total hardness, dissolved oxygen (DO), the biochemical oxygen demand (BOD_5), phosphate and sulfate ions that ranged between (50 to 65), (45 to 650), (10 to 70), (0.0 to 0.0), (0.0 to 0.0 to 0.0) and (19 to 60) consecutively, which reflected on the decrease in the values of (PiCi), and thus led to the decrease in the values of the quality index of water, and this confirms the concentrations of these parameters shown in Table 4, as it is noted that the relatively high levels of total alkalinity reached (492) ppm.

In general, the main cause of total alkalinity in the studied water is due to the bicarbonate ions because the pH values did not exceed (8.16) [24], these causes reach the water as a result of dissolving carbon dioxide in the water, forming carbonic acid H_2CO_3[25-26] which reacts with carbonate compounds (such as calcite and dolomite) in bottom sediments and suspended matter to produce bicarbonate dissolved in water, which increases the alkalinity of water, as in the following equations(1-4)[19,27].

Table 2: Parameter weight (Pi), Normalization values (Ci), water quality index (WQI) values and water Status of the studied sites for the waters of Duhok valley

Sites		S1		S2		S3		S4		S5		S6	
Parameter	Pi	C_1	P_iC_1	C_2	P_iC_2	C_3	P_iC_3	C_4	P_iC_4	C_5	P_iC_5	C_6	P_iC_6
T °C	2	90	180	90	180	70	140	80	160	80	160	90	180
pH	3	90	270	90	270	90	270	90	270	90	270	90	270
EC_{25}	2	90	180	80	160	80	160	90	445	45	90	37	74
T. A	3	65	195	65	195	55	165	55	165	50	150	56	168
T. H	2	60	120	50	100	60	120	53	106	50.3	101	45	90
DO	4	90	360	70	280	10	40	10	40	52	208	65	260
BOD_5	4	70	280	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PO_4^{-3}	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SO_4^{-2}	2	60	120	50	100	45	90	19	38	25	50	55	110
Cl^-	1	80	80	80	80	70	70	61	61	62	62	68	68
∑	26		1785		1365		10.55		930		1091		1220
WQI		68.7		39.4		30.4		26.8		31.5		35.2	
Status		Medium		Bad		Bad		Bad		Bad		Bad	

Table 3: Calculated WQI and their classification of the stations

Sits	S1	S2	S3	S4	S5	S6
WQI Value	68.7	39.4	30.4	26.8	31.5	35.2
Status	Medium	Bad	Bad	Bad	Bad	Bad

Table 4: range, rate and standard deviation (Sd) of the results of the analysis of the waters of Duhok valley (ppm).

Parameter Sites		T°C	pH	EC_{25}	T. A	T.H	DO	BOD_5	PO_4^{-3}	$SO_4^{=}$	Cl^-
S1	Min	18.4	7.67	671	160	253	5.60	1.85	5.40	124	53.9
	Max	25.0	8.16	794	368	500	10.4	6.70	10.0	198	77.9
	Mean	22.0	7.79	727	230	400	7.40	4.05	7.49	149	66.5
	± Sd	2.68	0.14	43.6	59.3	48.8	1.38	1.53	1.79	20.4	6.43
S2	Min	19.0	7.32	812	172	348	4.00	37.6	6.20	89.0	66.9
	Max	22.0	7.88	1045	284	492	٧,٢٠	59.2	12.4	273	85.9
	Mean	20.3	7.64	918	230	431	5.60	49.8	9.43	193	74.8
	± Sd	0.92	0.18	60.5	30.7	40.9	0.92	6,92	2.01	58.2	6.05
S3	Min	19.1	7.24	795	328	300	0.00	36.1	15.0	101	75.9
	Max	28.6	7.61	1016	404	400	6.20	60.0	20.0	190	120
	Mean	24.9	7.38	877	360	344	1.00	47.6	17.8	147	102
	± Sd	3.05	0.09	71.6	21.4	33.4	2.24	7.65	1.69	26.1	14.9
S4	Min	19.0	7.21	825	284	336	0.00	29.0	15.9	169	75.9
	Max	28.0	7.86	981	392	396	6.10	66.0	25.0	240	130
	Mean	24.4	7.32	877	344	372	1.00	51.3	20.6	205	92.9
	± Sd	2.32	0.17	47.8	33.8	17.0	1.85	10.3	2.96	21.2	14.2
S5	Min	22.0	7.25	856	328	304	1.20	28.7	9.70	79.0	75.9
	Max	25.0	7.58	943	492	484	7.20	63.7	15.2	107	108
	Mean	23.9	7.45	894	399	397	4.20	47.8	12.3	90.8	87.9
	± Sd	0.92	0.11	23.5	52.1	43.3	1.85	10.2	1.76	8.68	12.5
S6	Min	18.4	7.18	899	318	368	1.60	27.0	17.0	98.0	61.9
	Max	28.0	7.85	1135	444	564	11.2	54.2	24.0	126	83.9
	Mean	22.0	7.66	1016	339	453	5.50	45.2	20.2	117	73.5
	± Sd	3.25	0.17	98.1	77.7	62.5	2,93	8.08	2.19	10.2	6.83

$$CO_2 + H_2O \longrightarrow H_2CO_3 \quad (1)$$
$$Organic + O_2 \xrightarrow{Microorganism} Organic\ Acid + H_2CHO_3 \quad (2)$$
$$CaCO_3 + H_2CO_3 \longrightarrow Ca(HCO_3)_2 \quad (3)$$
$$CaMg(CO_3)_2 + 2H_2CO_3 \longrightarrow Ca(HCO_3)_2 + Mg(HCO_3)_2 \quad (4)$$

For the same reasons above, the concentrations of total hardness increased to reach (564) ppm at site S6.It is also noted from table (3), that the dissolved oxygen decreases with the course of the valley to be absent in some periods, especially in the two sites (S3, S4) due to the frequent discharge of wastewater rich in organic matter and protein and the creation of anaerobic conditions, which reduces the transparency of the water and the emission of irritating odors as shown by the following equations(5-6)[28-29].

$$2(CH_2O) + H_3O^+ + SO_4^{-2} \longrightarrow HS^- + 2CO_2 + 3H_2O \quad (5)$$
$$4C_3H_7O_2NS + 8H_2O \longrightarrow 4CH_3COOH + 4NH_3 + 4H_2S + 4CO_2 + 8H^+ \quad (6)$$
$$4CH_3COOH + 8H^+ \longrightarrow 5CH_4 + 3CO_2 + 2H_2O \quad (7)$$

After that, the concentration returns to a relative height with the path of the valley, bringing the average to (5.5) ppm at the site (S6) due to self-purification processes[30-32], this confirms the high levels of organic load, bringing the average concentration of BOD to (63.7) at the site (S5).The same applies to phosphate ions, which ranged between (5.4 to 24.0) ppm, and this increase in concentration is due to the frequent dumping of civil and agricultural wastewater rich in detergents containing the tri-polyphosphate ion, which hydrolyses to release phosphate ions as in the following equation(8-9)[33]:

$$P_3O_{10}^{-5} + 2H_2O \longrightarrow 4H^+ + 3PO_4^{-3} \quad (8)$$
$$2PO_4^{-3} + 3Ca^{+2} \longrightarrow Ca_3(PO_4)_2 \quad (9)$$

Despite the importance of phosphate to living organisms, its high concentration causes harmful effects on the aquatic ecosystem [34-35]. The same is the case with sulfate ions, which amounted to (273) ppm. This is attributed to the processes of biodegradation of protein materials in anaerobic conditions, which oxidize to sulfate ions when the aeration conditions of the aquatic environment improve, as in the following equations (10-14) [36]:

$$2CaSO4 + 3(CH_2O) \longrightarrow 2CaCO_3 + 2S + CO_2 + 3H_2O \quad (10)$$
$$S^{-2} + 2H^+ \longrightarrow H_2S \quad (11)$$
$$2H_2S + 3O_2 \longrightarrow 2SO_2 + 2H_2O \quad (12)$$
$$2SO2 + 2H2O \longrightarrow 2H_2SO_3 \quad (13)$$
$$2H_2SO_3 + O_2 \longrightarrow 2H_2SO_4 \quad (14)$$

Finally, the water temperature, pH, and chloride ions were within the appropriate limits for the aquatic ecosystem [37-38].

4. Recommendations and Conclusions:

1. The current study indicates the deterioration of the water quality of Duhok valley as a result of the high levels of alkalinity, total hardness, BOD5, phosphate ions, sulfate, with a lack of DO for some sites and for some periods due to the huge amount of urban and agricultural wastewater presented to it.
2. The quality of the studied water according to WQI was of the category of Bad quality water, which increases the possibility of a negative impact on the water quality of Mosul Dam lake.

Therefore, we recommend spreading environmental and national awareness among the local population and treating wastewater before it is dumped into the valley, taking care and activating periodic environmental monitoring to preserve water resource.

5. Declaration of Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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