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Comparative assessment of some heavy metals in water and sediments from Sawa Lake, South Iraq

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ABSTRACT

The goal of the current study was to assess a few chemical and physical properties, including water temperature and pH, electrical conductivity (EC), dissolved oxygen (DO), biological oxygen demand (BOD_5), nitrite (NO_2), nitrate (NO_3), phosphate (PO_4) and the level of some heavy metals, like lead, cadmium, zinc, iron, manganese and nickel in water of Sawa Lake, Iraq. Three locations were selected in Lake. The samples were taken on a monthly basis from October 2021 to February 2022. The results indicated that the water temperature varied between 13.4 and 25.25 ºC, pH values 8.06 - 9.70, electrical conductivity 27984.33- 65622.3 µs cm^{-1}, dissolved oxygen 0.0-4.3 mg L^{-1}, biochemical oxygen demand (BOD_5; 2.58-8.08 mg L^{-1}), nitrite 1.14-8.02 µg L^{-1}, nitrate 0.65-57.19 µg L^{-1} and phosphate 0.20-8.11 µg L^{-1}. The study results of heavy metals concentrations in water were as follows: lead (Pb; 0.00-0.34 mg L^{-1}), cadmium (Cd; 0.00-0.007 mg L^{-1}), zinc (Zn; 0.00-0.036 mg L^{-1}), iron (Fe; 0.21-0.78 mg L^{-1}), manganese (Mn; 0.00-0.10 mg L^{-1}), and nickel (Ni; 0.00-0.10 mg L^{-1}). While in sediments, elements concentrations were as follows: Pb 2.66-27.15 mg kg^{-1}, Cd; 0.001-0.62 mg kg^{-1}, Zn 10.92-17.07 mg kg^{-1}, Fe 1382.56-2268 mg kg^{-1}, Mn 63.20-154.98 mg kg^{-1}, and Ni 7.33-23.51 mg kg^{-1}. The water quality of Sawa Lake under this study was exceeding the permissible limit for PH, EC, BOD_5 and NO_3. Increasing levels of heavy metals in the Sawa Lake water and sediment were over the allowable limit, implying heavy metal water pollution.

Key words: Physicochemical parameters, Heavy metals, Sawa Lake.
Article type: Research Article.

INTRODUCTION

The aquatic environment, specifically the water quality, is thought to be the primary determinant of the health and disease of both cultivated and wild fish. The existence of aquatic animals, especially fish, is seriously threatened by the pollution of the aquatic environment by inorganic and organic chemicals. Large amounts of inorganic anions and heavy metals are added to the water bodies and sediment by drainage water from agriculture that contains fertilizers and pesticides, runoff from industrial processes, and sewage effluents (ECDG 2002). Industrial processes, petroleum contamination, and sewage disposal are the primary human-caused sources of metals (Santos *et al.* 2005). Hydrological cycling, temperature regulation, and the provision of habitat for aquatic creatures are all made possible by aquatic systems. For a category of metals and metalloids that have been associated to contamination, potential toxicity, or eco toxicity, the term "heavy metals" is frequently used. In the environment, heavy metals are regarded as dangerous chemicals (Phillips *et al.* 2015). Because of the environmental toxicity, persistence, and bioaccumulation of heavy metals, which can have adverse effects on living organisms and the entire ecosystem, heavy metal contamination in the aquatic environment has garnered attention on a global level (Phillips 2015; Sattari *et al.* 2019a,b,c,d; Sattari *et al.* 2020a,b,c,d; Forouhar Vagargah *et al.* 2020a,b; Forouhar Vagargah *et al.* 2021; Wali Alwan 2022; Talib Jawad *et al.* 2022; Al-Asaadi *et al.* 2022). Ecosystems in lakes that are affected by contamination by heavy metals are a worldwide environmental problem. Although some heavy

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metals, such as Cu, Fe, Mn, Ni, and Zn, are essential in very small amounts as micronutrients for the processes of life in animals and plants, other metals, such as Cd, Cr, Hg, and Pb, have no known physiological activity and exhibit extreme toxicity even at trace levels (Nicolau *et al*. 2006; Kar *et al*. 2008). Metal ions can be concentrated in aquatic species to a point where it impacts their physiological status and can be assimilated into food chains. The heavy metals are among the most harmful pollutants because of their extensive effects on the environment and all living organisms. Heavy metals accumulation in water decreases the quality of the water and makes it unusable for several purposes. Clean safe water is another essential component for human well-being (Mirzabeygi *et al*. 2017). The majority of anthropogenic causes of water contamination, including industrial effluent, sewage treatment plants, agricultural activities, and municipal surface water drainage, are heavy metals (Singovszka *et al.* 2017). Anthropogenic (agricultural, industry, and mining) and natural (weathering of soils and rocks) sources of heavy metals both exist (Al-Sarraj *et al.* 2019; Sulaiman *et al*. 2021; Abdulhameed *et al*. 2021). Heavy metals enter aquatic ecosystem sediment through anthropogenic activities including industrial wastewater discharge and agricultural fertilizer leaching as well as natural processes like atmospheric deposition, rock weathering and erosion, as well as hydrodynamic change (Zhang *et al.* 2014). The largest concentration of heavy metals in the aquatic environment is thought to be in sediment (Hu *et al.* 2013). It has been discovered that the majority of the heavy metal load in aquatic systems precipitates onto the sediment at the end (Peng *et al.* 2009). The concentrations of heavy metals in the sediment are often four to five times higher than those in the water above (Yuan *et al.* 2011). As a result, sediment quality can provide insight into the ecosystem's overall level of heavy metal pollution. In order to provide information on the heavy metal pollution of the entire aquatic ecosystem, it is essential to evaluate the amount of heavy metals in the sediment. Since heavy metals have a propensity to persist as environmental pollutants for an extended period of time and because their effects are amplified through the food chain, their presence in aquatic ecosystems is a growing problem that is raising concerns about their effects on plant and animal life (Ogunfowokan, *et al*. 2013). The aim of this study was to investigate and assess the spatial variation in the concentration of heavy metals in Sawa lake waters and sediments, even assess its suitability for different purposes by local people, besides determining its ability to sustain aquatic life

MATERIALS AND METHODS

Description of the study area

Sawa Lake is situated 22 km from the Euphrates River west and between the longitudes of 44° 59' 29" E and 45° 01' 46.61" E and the latitudes of 31°17' 43.10" N and 31°19' 49.79" N, approximately 23 km west of Al-Samawa City. The lake's longest length is around 4.74 km, although its greatest width is 1.77 km. The lake is surrounded by a total of 12.5 km of trail. It doesn't clearly have a geometric shape, yet it frequently resembles a pear (Hassan 2007). Once comparing this lake to other lakes in Iraq, it stands apart, since it is salty, has no inlets or outlets, and is bordered by gypsum.

Samples collection

From October 2021 to February 2022, samples were collected from Sawa Lake from three different sites (Fig. 1). The properties of the site are shown in able 1). Per site, we collected three replicates. Sediment samples were obtained using a Van Veen Grab sampler and stored in labelled plastic bags. Water samples for physico-chemical analyses were taken using a 5-L polyethylene bottle pre-washed twice by the water sample before filling. Six heavy metals were examined in the samples: Pb, Cd, Zn, Fe, Mn, and Ni. Throughout transportation, samples were stored in cold boxes at 4 °C. In the field, temperature, pH and electrical conductivity were measured instantly using a portable multimeter (Multi 350i/3500i, Germany). Biological oxygen demand (BOD_5) and dissolved oxygen (DO) were determined in the lab using a BOD_5 incubator and Azide, respectively. Utilizing spectroscopy techniques, nitrate (NO_3), nitrite (NO_2), and phosphate (PO4) were quantified in accordance with Parson *et al.* (1984) and APHA (2017).

Table 1. GPS values for study locations.

Sites	Latitude; East	Longitude; North
S_1	45.02415 E	31.30230 N
S_2	45.01325 E	31.31049 N
S_3	45.01067 E	31.31439 N

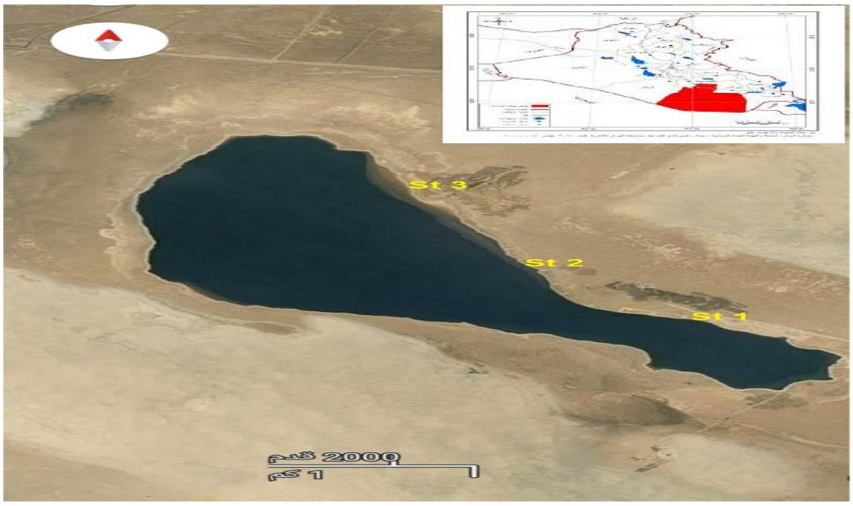

Fig. 1. Study sites of Sawa Lake.

Analysis of heavy metals

Water samples

Samples were digested by adding 1 mL concentrated (69-72%) HNO_3 and 2.5 mL concentrated (30%) HCl to a beaker with a watch glass on hot plate at 90 ℃, and boiling until the solution reached the mark (20 mL). The beaker was then taken out and cooled. Every sample of digested water was filtered by Whatman filter paper (No. 42) into a 100-mL volumetric flask, which was then filled to the mark with deionized water and 2 mL nitric acid to produce a clear solution (Kiflom & Tarekegn 2015). Atomic absorption spectrophotometer was used to calculate the concentrations of heavy metals.

Sediment samples

In the laboratory, samples were air dried at room temperature, ground into a fine powder using a mortar and pestle, and then sieved through a 2-mm mesh sieve. Afterward, the samples were kept in a plastic container, so they could be processed and examined (Jose *et al.* 2005). On a hot plate, one gram of dried sediment sample was dissolved in concentrated HNO_3 and HCL (1:3 v/v) in a 100-mL quartz tube. The tubes were cooled, and volumetric flasks containing double-distilled water were used to prepare the volumes. According to APHA (2017), the digested samples were subjected to atomic absorption spectrophotometer analysis to determine the presence of (pb, Cd, Zn, Fe, Mn, and Ni).

Statistical analysis

To compare means, Multivariate tests were used after the General Linear Model (GLM) and analysis of variance (ANOVA). Wherever the effect of the tested variables was significant (0.05), the estimated marginal means between the factors were compared using the least significant differences (LSD) test. Using Pearson's correction technique, linear regression and correlation between two variables were performed. SPSS 28.0 was used to do the statistical analysis (SPSS Inc., Chicago, IL, USA).

RESULTS AND DISCUSSION

Physical & chemical parameters

The aquatic ecology depends heavily on temperature, since it influences the species. The diversity and density of aquatic species, as well as the effects on cellular metabolism processes, are significantly influenced by the water temperature (Ranjbar *et al.* 2017). Temperature of Sawa lake ranged between 13.4 ± 0.02 and 25.25 ± 0.05 in S_3 and S_1 respectively (Fig. 2) The monthly fluctuations occurred due to a long day period in the summer, and a short day period in winter and relating to the climate in Iraq (Al-Fatlawi 2005; Al-Zubaidi *et al.* 2022). The spatial variations might be due to the difference in the time of collection of the sample at each station.

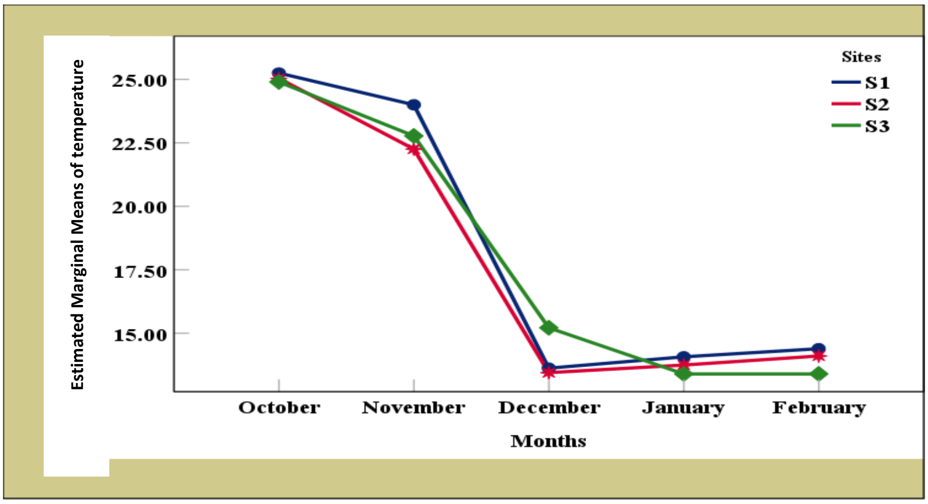

Fig. 2. Monthly variation in water temperature value in Sawa Lake during the study periods.

pH is a very important parameter influencing aquatic development and determines the suitability of water for various purposes (Ahipathy & Puttaiah 2006). The results showed that pH value ranged from 8.06 ±0.12 to 9.70 ±0.17 in S_1 and S_2 respectively (Fig. 3). This refers to the alkali pH caused by water rising from a depth through limestone, dolomite, gypsum, and anhydrite cracks, joints, fractures, and faults (Awadh & Muslim 2014) or due to photosynthesis of algae in this lake leading to uptake of CO_2 and consequently pH increase. According to Table 2, The water from Sawa Lake is not suitable for human consumption. The results showed significant differences ($p < 0. 05$) between the sites and the months.

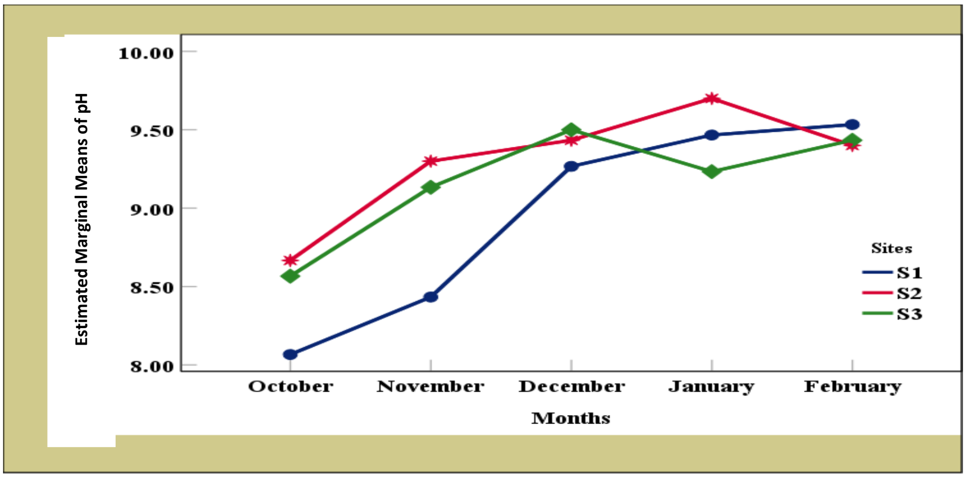

Fig. 3. Monthly variation in water pH value in Sawa Lake during the study periods.

Table 2. Comparison of the Sawa Lake physico-chemical characteristics and trace elements to standards and assessment of its appropriateness for drinking in comparison to Iraqi Standard (2009).

Parameters (ppm)	Present study	Iraqi Standard 2009	Decision
pH	9.7	6.5-8.5	Impermissible
EC (µs cm^{-1})	65622.3	1530	Impermissible
NO_3^-	57.19	50	Impermissible
Zn	0.036	3	Permissible
Pb	0.347	0.01	Impermissible
Cd	0.007	0.003	Impermissible
Ni	0.106	0.02	Impermissible
Fe	0.785	0.03	Impermissible
Mn	0.105	0.1	Impermissible

Very high electrical conductivity clear function that the water of Sawa lake is not permissible for drinking water for the purpose of evaluating the suitability for human drinking, the fundamental physical and chemical parameters and some heavy metals are compared with Iraqi standard (2009; Table 2). EC ranged between 27984.33 and 65622.3 µs cm^{-1} in S_2 and S_3 respectively. This may be due to brackish water or due to the effect of the soil surrounding the lake, characterizing by its gypsum and limestone nature and the accumulation of high salts in it, or may be due to the intense evaporation process in this desert area and the absence of water currents in the lake that contribute to the mixing of water. The main source of water was rain, which is the main reason for this decreasing results in reducing the supply of Dammam aquifer (Al-Zubedi 2022) in addition to the small area of the lake and its oval shape, which does not provide an opportunity for wind to form waves and contribute; or due to the lake drought, which reduces the lake's level, while the lake's mean evaporation rates, have been steadily increasing (Mahmoud *et al.* 2022; Fig. 4). Significant variations between the sites and the months were shown by statistical analysis ($p < 0.05$) and showed negative correlation between the electrical conductivity and water temperature ($r = -0.752$). In the current study region, DO data is shown in Fig. 5. Sites 1 and 3 recorded the lowest value of 0.0 mg L^{-1} in February, while site 1 recorded the highest value of 4.3 mg L^{-1} in October. According to the BOD_5 data that was acquired, in Site 1 minimum value was 3 mg L^{-1} in November, while in Site 2 maximum value was 12.33 mg L^{-1} in February (Fig. 6). Results showed the decreased oxygen value due to a rise in organic matter and water temperature, both of which have an impact on the activity of microbes that break down organic matter and consume oxygen (Taheer 2015) and the decreased water level, lack of photosynthesis effectiveness and anaerobic decomposition with emission of foul odors. Moreover, DO declines when salinity rises if other factors remain the same (Ezz El-Din 1990).

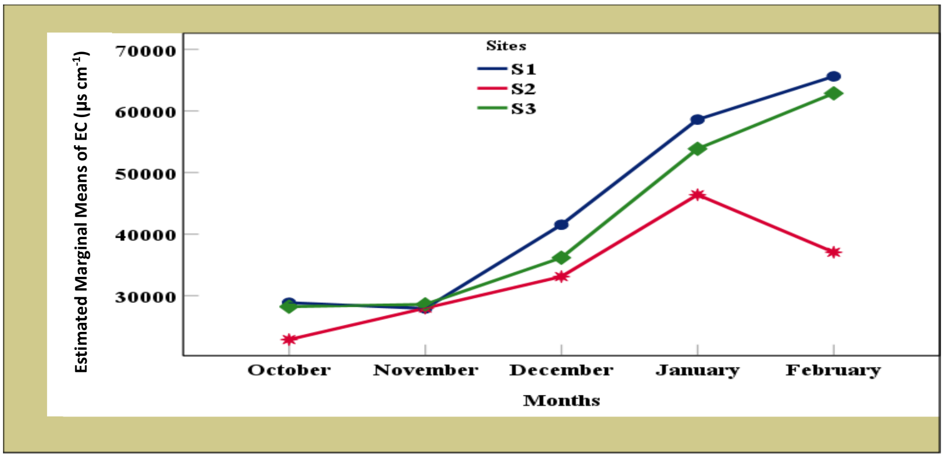

Fig. 4. Monthly variation in water electrical conductivity value in Sawa Lake during the study periods.

In some months, the levels of BOD_5 in sites 1, 2 and 3 exceeded both the WHO guidelines (2004) and the Iraqi Water Quality Standards (1998), which were both fewer than 5 mg L^{-1}. High BOD_5 levels indicate a reduction in DO, since the bacteria are consuming the oxygen in the water, making it impossible for fish and other aquatic species to live (Vaishali & Punita 2013). The results of statistical analysis showed a negative correlation between the dissolved oxygen and electrical conductivity ($r = -0.834$) as well as between BOD_5 and oxygen ($r = -0.739$).

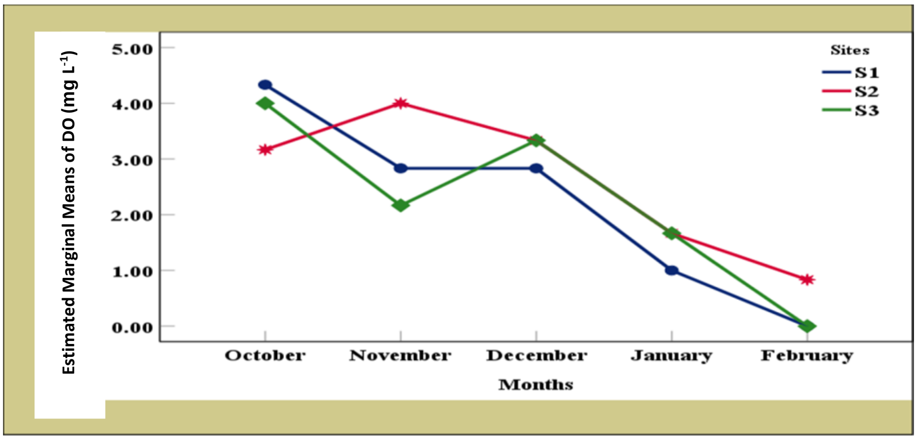

Fig. 5. Monthly variation in water dissolved oxygen value in Sawa Lake during the study periods.

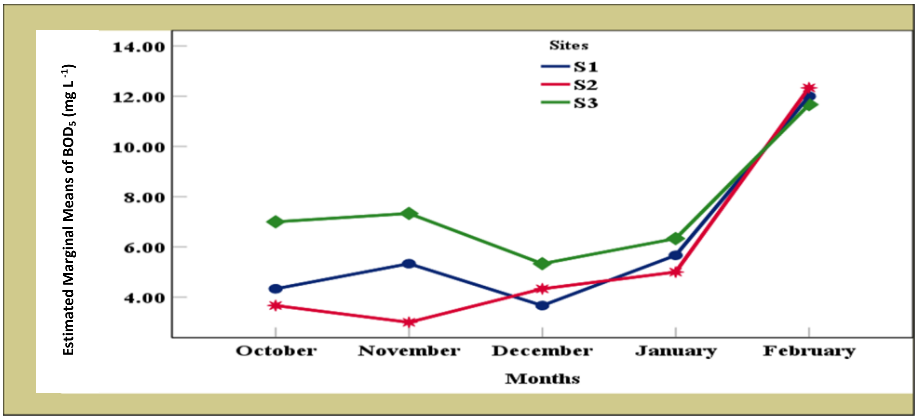

Fig. 6. Monthly variation in water BOD_5 value in Sawa Lake during the study periods.

Nitrite is an intermediate chemical created by either oxidizing ammonia or reducing nitrate to nitrite; it is oxidized to nitrate once it enters an aerobic environment and uses oxygen to do so. The overall outcome of the many interactions may be either the release of nitrogen or its fixation as organic matter (Varol & Sen 2012). Nitrite concentrations varied significantly during the months according to the statistical analysis. The highest value of nitrite 8.02 ± 0.14 µg L^{-1} was recorded in November, while the lowest value 0.141 ± 0.001 µg L^{-1} in October. High values recorded may be due to bacterial activity (Makei 2013), decomposition of organic matter and decrease in the uptake by phytoplankton.

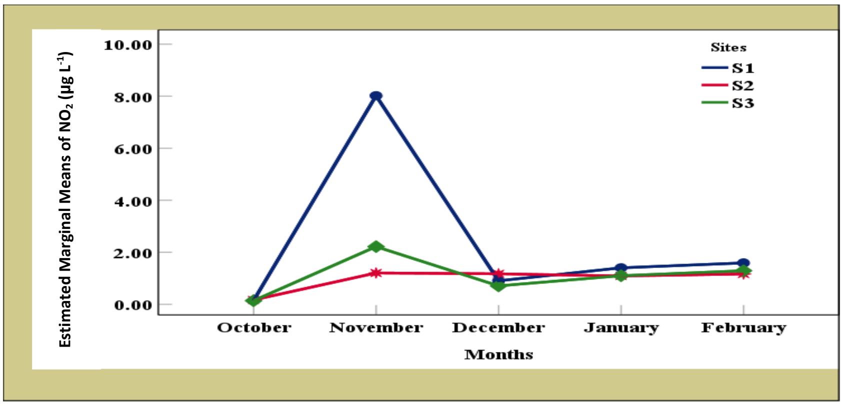

Fig. 7. Monthly variation in water Nitrite value in Sawa Lake during the study periods.

According to the statistical analysis, there were significant differences ($p < 0.05$) between sites and months, as well as the presence of a significant positive correlation with water temperature ($r = 0.181$) and a negative correlation with electrical conductivity ($r = -0.097$). Nitrate is necessary nutrient produced naturally by the growth and decay of plants and animals. It can be found in unpolluted water sources. Yet, too much nitrate can significantly accelerate plant growth and have a negative impact on both human and aquatic animal health (APHA 2017). In the current study, the results showed variations in the nitrate levels, the highest value was 57.198 ± 0.08 µg L^{-1}, while the lowest mean was 0.65 ± 0.04 µg L^{-1} (Fig. 8). Statistical analyses have also revealed significant differences ($p < 0.05$) among sites and months. High concentrations of nitrate may be due to deep groundwater with high nitrate concentrations which could be attributed to an important source of nitrate in surface waters as well as due to the inflow from rainfall. Phosphorus (PO_4) is found in natural waters and effluents almost solely as phosphates. These are classified as condensed phosphates, organically bound phosphates, and orthophosphate. Orthophosphates used as fertilizers on agricultural land are transported into rivers by storm runoff and, to a lesser extent, by snowmelt (APHA 2017). The results showed that the highest mean value of phosphate was 8.114 ± 0.22 (µg L^{-1}) in November while the lowest mean value (0.209 ± 0.01 µg L^{-1}) in October (Fig. 9). Table 3 illustrates that there are significant differences in three sites, the highest effect was in the first site for temperature; the highest effects were found in Site 2 for pH; in Site 2 and Site 3 for dissolved oxygen; in the Site 3 for BOD_5; in Site 2 for Nitrate and in Site 3 for phosphate.

Table 3. Estimated Marginal Means of some parameters.

Dependent Variable			**Mean size effects**	**95% Confidence Interval**		**Univarite p-value**
				Lower Bound	**Upper Bound**	
Temp. (℃)	October	S_1	25.25	25.118	25.382	0.002
		S_2	25.040	24.908	25.172	
		S_3	24.900	24.768	25.032	
	November	S_1	24.000	23.868	24.132	0.0001
		S_2	22.257	22.124	22.389	
		S_3	22.773	22.641	22.906	
	December	S_1	13.627	13.494	13.759	0.0001
		S_2	13.450	13.318	13.582	
		S_3	15.217	15.084	15.349	
	January	S_1	14.073	13.941	14.206	0.0001
		S_2	13.750	13.618	13.882	
		S_3	13.400	13.268	13.532	
	February	S_1	14.393	14.261	14.526	0.0001
		S_2	14.107	13.974	14.239	
		S_3	13.400	13.268	13.532	
pH	October	S_1	8.067	7.942	8.191	0.0001
		S_2	8.667	8.542	8.791	
		S_3	8.567	8.442	8.691	
	November	S_1	8.433	8.309	8.558	0.0001
		S_2	9.300	9.176	9.424	
		S_3	9.133	9.009	9.258	
	December	S_1	9.267	9.142	9.391	0.031
		S_2	9.433	9.309	9.558	
		S_3	9.500	9.376	9.624	
	January	S_1	9.467	9.342	9.591	0.0001
		S_2	9.700	9.576	9.824	
		S_3	9.233	9.109	9.358	
	February	S_1	9.533	9.409	9.658	0.287
		S_2	9.400	9.276	9.524	
		S_3	9.433	9.309	9.558	
Ec(µs cm^{-1})	October	S_1	28861.3	28619.1	29103.6	0.0001
		S_2	22882.0	22639.7	23124.3	
		S_3	28230.0	27987.7	28472.3	
	November	S_1	27938.0	27695.7	28180.3	0.001
		S_2	27984.3	27742.1	28226.6	
		S_3	28601.3	28359.1	28843.6	
	December	S_1	41534.0	41291.7	41776.3	0.0001
		S_2	33110.0	32867.7	33352.3	
		S_3	36175.0	35932.7	36417.3	
	January	S_1	58610.7	58368.4	58852.9	0.0001
		S_2	46402.3	46160.1	46644.6	
		S_3	53861.7	53619.4	54103.9	
	February	S_1	65622.3	65380.1	65864.6	0.0001
		S_2	37066.7	36824.4	37308.9	
		S_3	62866.7	62624.4	63108.9	
DO (mg L^{-1})	October	S_1	4.33	3.95	4.72	0.0001
		S_2	3.17	2.78	3.55	
		S_3	4.00	3.62	4.38	
	November	S_1	2.83	2.45	3.22	0.0001
		S_2	4.00	3.62	4.38	
		S_3	2.17	1.78	2.55	
	December	S_1	2.83	2.45	3.22	0.111
		S_2	3.33	2.95	3.72	
		S_3	3.33	2.95	3.72	
	January	S_1	1.00	0.62	1.38	0.024
		S_2	1.67	1.28	2.05	
		S_3	1.67	1.28	2.05	
	February	S_1	0.00	-0.38	0.38	0.004
		S_2	0.83	0.45	1.22	
		S_3	0.00	-0.38	0.38	
BOD_5 (mg L^{-1})	October	S_1	4.33	3.25	5.42	0.0001
		S_2	3.67	2.58	4.75	

		S_3	7.00	5.92	8.08	
	November	S_1	5.33	4.25	6.42	0.0001
		S_2	3.00	1.92	4.08	
		S_3	7.33	6.25	8.42	
	December	S_1	3.67	2.58	4.75	0.099
		S_2	4.33	3.25	5.42	
		S_3	5.33	4.25	6.42	
	January	S_1	5.67	4.58	6.75	0.223
		S_2	5.00	3.92	6.08	
		S_3	6.33	5.25	7.42	
	February	S_1	12.00	10.92	13.08	0.677
		S_2	12.33	11.25	13.42	
		S_3	11.67	10.58	12.75	
NO_2 (µg L^{-1})	October	S_1	0.15	0.07	0.22	0.843
		S_2	0.17	0.09	0.25	
		S_3	0.14	0.06	0.22	
	November	S_1	8.02	7.94	8.10	0.0001
		S_2	1.21	1.13	1.28	
		S_3	2.22	2.14	2.29	
	December	S_1	0.91	0.83	0.98	0.0001
		S_2	1.18	1.10	1.25	
		S_3	0.71	0.63	0.79	
	January	S_1	1.40	1.33	1.48	0.0001
		S_2	1.09	1.01	1.17	
		S_3	1.10	1.02	1.18	
	February	S_1	1.59	1.52	1.67	0.0001
		S_2	1.17	1.09	1.24	
		S_3	1.29	1.22	1.37	
NO_3 (µg L^{-1})	October	S_1	55.53	55.31	55.76	0.0001
		S_2	57.20	56.98	57.42	
		S_3	56.14	55.92	56.37	
	November	S_1	0.72	0.50	0.94	0.536
		S_2	0.82	0.60	1.04	
		S_3	0.65	0.43	0.87	
	December	S_1	7.08	6.86	7.30	0.0001
		S_2	9.95	9.73	10.17	
		S_3	4.16	3.94	4.38	
	January	S_1	51.14	50.91	51.36	0.0001
		S_2	49.92	49.70	50.14	
		S_3	49.64	49.42	49.86	
	February	S_1	53.88	53.66	54.10	0.012
		S_2	53.81	53.59	54.03	
		S_3	53.42	53.20	53.64	
PO_4 (µg L^{-1})	October	S_1	0.21	0.08	0.34	0.980
		S_2	0.22	0.09	0.35	
		S_3	0.23	0.10	0.36	
	November	S_1	3.21	3.08	3.34	0.0001
		S_2	5.98	5.85	6.12	
		S_3	8.11	7.98	8.24	
	December	S_1	2.96	2.83	3.09	0.0001
		S_2	1.70	1.57	1.83	
		S_3	2.48	2.35	2.61	
	January	S_1	2.89	2.76	3.02	0.0001
		S_2	3.02	2.89	3.15	
		S_3	6.06	5.93	6.19	
	February	S_1	4.29	4.16	4.42	0.0001
		S_2	3.43	3.30	3.56	
		S_3	6.87	6.74	7.00	

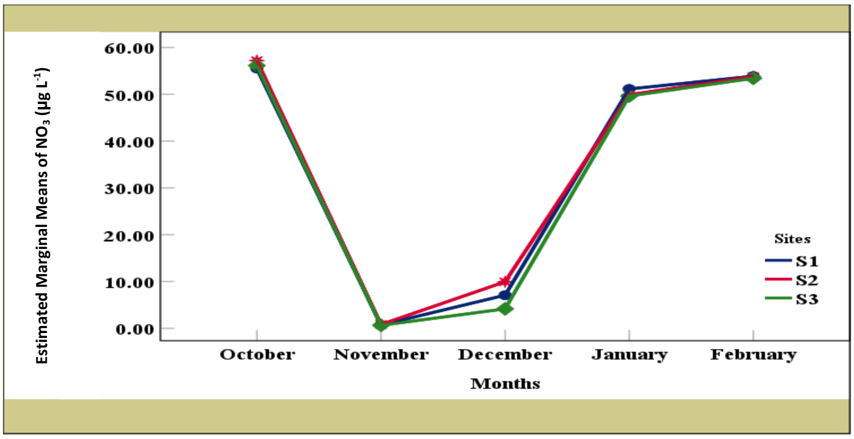

Fig. 8. Monthly variation in water Nitrate value in Sawa Lake during the study periods.

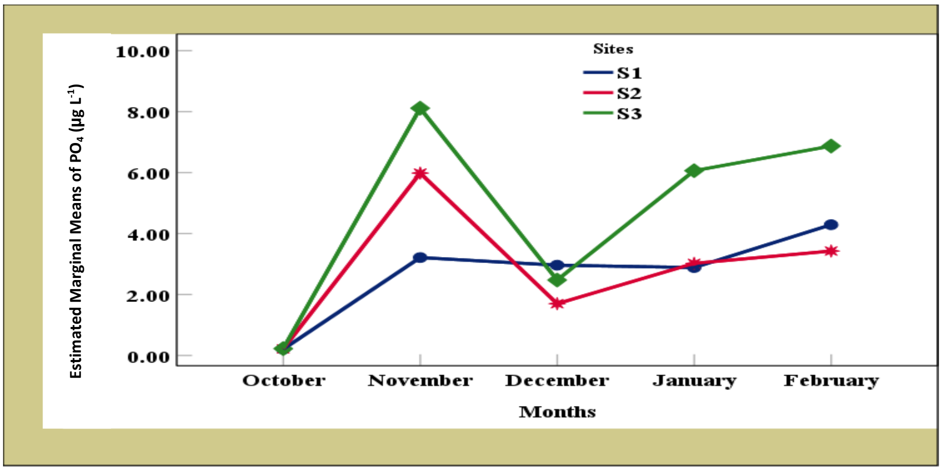

Fig. 9. Monthly variation in water phosphate value in Sawa Lake during the study periods.

Heavy metals

The concentration of heavy metals between the dissolved and particulate phases depends on water quality and physicochemical properties. Additionally, temperature which causes evaporation, increases in salinity, changes in water depth, and conductivity all exhibit impacts on the concentration of heavy elements (Al-Taher *et al.* 2020). When heavy metals enter aquatic environments, they frequently mix with other elements or accumulate in aquatic organisms, including plants and other life (Wang *et al.* 2019). The mean values of heavy metal concentrations in water and sediment samples are presented in Tables 4-5.

Table 4. Estimates metal element concentrations in Sawa Lake.

Sites	**Months**	**Mean ± SD**					
		Pb (mg L^{-1})	**Cd (mg L^{-1})**	**Zn (mg L^{-1})**	**Fe (mg L^{-1})**	**Mn (mg L^{-1})**	**Ni (mg L^{-1})**
S1	October	0.00 ± 0.00	0.002 ± 0.00	0.036 ± 0.001	0.785 ± 0.002	0.105 ± 0.00	0.00 ± 0.00
	February	0.347 ± 0.023	0.00 ± 0.00	0.001 ± 0.000	0.554 ± 0.11	0.00 ± 0.00	0.00 ± 0.00
S2	October	0.162 ± 0.006	0.007 ± 0.001	0.012 ± 0.001	0.341 ± 0.011	0.037 ± 0.001	0.054 ± 0.001
	February	0.145 ± 0.003	0.007 ± 0.001	0.00 ± 0.00	0.219 ± 0.01	0.037 ± 0.015	0.106 ± 0.001
S3	October	0.083 ± 0.012	0.002 ± 0.00	0.006 ± 0.001	0.236 ± 0.001	0.021 ± 0.01	0.051 ± 0.01
	February	0.235 ± 0.001	0.00 ± 0.00	0.012 ± 0.00	0.376 ± 0.113	0.005 ± 0.0001	0.00 ± 0.00
Multivariate (p-value)							
Sites		0.023	0.0001	0.0001	0.0001	0.0001	0.0001
Month		0.0001	0.0001	0.0001	0.066	0.0001	0.839
Months × Sites		0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
LSD		0.019	0.0011	0.0005	0.1318	0.0133	0.0073

Table 5. Estimates heavy metals in Sawa lake sediments.

Sites	Months	Mean ± SD					
		Pb (mg L^{-1})	**Cd (mg L^{-1})**	**Zn (mg L^{-1})**	**Fe (mg L^{-1})**	**Mn (mg L^{-1})**	**Ni (mg L^{-1})**
S1	October	11.671 ± 0.54	0.065 ± 0.001	11.39 ± 0.53	1512.19 ± 2.00	63.209 ± 0.36	7.33 ± 0.605
	February	4.618 ± 0.55	0.114 ± 0.017	16.07 ± 0.29	2268.43 ± 69.94	125.862 ± 1.0	23.51 ± 0.68
S2	October	14.17 ± 0.99	0.001 ± 0.000	10.92 ± 0.58	1382.56 ± 56.87	73.345 ± 1.04	11.09 ± 0.23
	February	2.663 ± 0.37	0.199 ± 0.015	17.07 ± 2.08	2068.4 ± 147.02	154.989 ± 0.58	16.01 ± 0.53
S3	October	17.257 ± 0.59	0.03 ± 0.002	13.78 ± 0.25	1507.25 ± 13.12	86.497 ± 1.86	8.02 ± 0.50
	February	27.154 ± 0.32	0.629 ± 0.04	12.57 ± 0.90	1692.15 ± 5.59	134.389 ± 2.19	21.08 ± 0.29
Multivariate (p-value)							
Sites		0.0001	0.0001	0.374	0.0001	0.0001	0.0001
Month		0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Months × Sites		0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
LSD		1.072	0.034	1.765	125.68	2.356	0.888

All of the sampling locations had pH values greater than 7 (Table 2), and several heavy metals, such as cd and pb, precipitated in the alkaline water, generating complex products that caused chemical speciation of the metals, which in turn affected metal toxicity in both the water and the sediment. In alkaline waterways and during the dry season, precipitation and sedimentation of zinc can also be increased, with the sediment phase acting as a significant sink for metals in water (Rashed 2001; Gunesa & Talinlib 2012). The aquatic organisms may be seriously threatened by excess harmful ions in water that is outside the usual pH range (6.5-8.5; Sabo *et al.* 2013). The results of heavy metal concentrations in water and sediment from Sawa lake are presented in Table 6 which compared with WHO/USEPA maximum limit. The mean concentrations of studied heavy metals in water followed as decreasing order of Fe > Pb > Ni > Mn > Z n> Cd while in sediments followed as decreasing order of Fe > Mn > Pb > Ni > Zn >Cd. The concentration of heavy metals in water samples more exceeded the WHO/USEPA guidelines for Pb, Ni & Fe while Pb, Mn, Ni and Fe for sediments.

Table 6. International guideline for heavy metals in water and sediments.

Heavy metals	**Mean concentration (mg L^{-1}; water)**	**Maximum limit WHO/ USEPA (mg L^{-1})**	**Mean concentration (mg kg^{-1}; sediment)**	**Maximum limit WHO/ USEPA (mg kg^{-1})**
Pb	0.347	0.05	27.154	10
Cd	0.002	0.01	0.629	6
Zn	0.036	3	17.07	123
Fe	0.785	0.3	2268.43	30
Mn	0.105	0.5	154.989	30
Ni	0.106	0.02	23.51	20

Elements were concentrated more in the sediment than in the dissolved phase. These results could be attributed to the current water flow, which does not allow enough time for metal segregation (Benzer *et al.* 2013), or to the heavy metals strong affinity for sediment (Al-Hejuje 2014), as well as to the ongoing accumulation of elements in sediments, which results in a noticeable increase in water flow rates and the deposition of suspended matter with high levels of heavy metals (Aprile & Bouvy 2010). From natural sediments and various human activities such as agriculture and the addition of chemical fertilizers all play an important role in the provision of heavy element pollutants to water and sediments (Santana *et al.* 2017). The low values of some of the elements studied in water could be attributed to the elimination of consumption by various aquatic organisms or by suspended sedimentation and adsorption (Abdul Jabbar *et al.* 2013). The presence of variation in concentrations of heavy elements between months may be attributed to the variation in water properties and its contents of organic and inorganic compounds and pollutants (Salman 2011). Results from the current study were lower than those obtained by Taheer (2015) and Al-Zurfi *et al.* (2019) in Bahr Al-Najaf. Significant differences between the months were revealed by the data's statistical analysis at $p < 0.05$ and showed an overlap between locations and months (Table 4). The highest effect of Pb was in S_2 in February while Zn, Fe and Mn in S_1 in October. Table 5 depicts the highest effect of Pb and Cd in S_3 in February, while Zn and Mn in S_2 in February as well as Fe and Ni in S_1 in February.

CONCLUSION

The present study determined that Sawa Lake's water quality is regarded as saline water and alkaline. The presence of significant differences in heavy metal concentrations between months and sites in both the water and sediment implied to a continuous addition of anthropogenic pollutants to the lake. The levels of the studied heavy metals in the water exceeded Iraqi determinants (2009) limits for Pb, Cd, Ni, Fe, and Mn, and WHO/USEPA guidelines limits for Pb, Ni &Fe, while Pb, Mn, Ni and Fe were found in the sediments.

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