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Seasonal Variation and Assessment of Heavy Metals in Coastal Seawater of Kuwait Bay, Northeast Coast of Kuwait

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Abstract

Fe, Mn, Zn, Cu, Pb, Ni, Co, Cr, and As were assessed in 20 seawater samples collected from 10 sites for two seasons along the coast of Kuwait Bay, where it is considered one of the most important habitats for many fish and shrimp. The southern region of it is considered one of the most important commercial and industrial operations in Kuwait. Environmental indices such as enrichment factor (EF), contamination factor (CF), degree of heavy metals contamination (C_{deg}) and Pollution load index (PLI) were used to describe the extent of contamination and estimate the degree of pollution in the Kuwait Bay. The results showed that Cu was moderately enriched in winter. Furthermore, the degree of heavy metals contamination (C_{deg}) in this area was moderately contaminated during summer and low in winter. To emphasize this, the average heavy metals content in ten coastal sites along Kuwait Bay during the summer season was higher than the ones in the winter season. These results indicate that the coastal seawater environment of Kuwait Bay is not worse with the presence of sources of pollution represented by the presence of fertilizer manufacturing and oil refining along the coast of the bay, plastic baggage, rubber tires, old and broken ships, cork bags, building rubble, and concrete blocks. In addition, some pollutants come from Shat Al-Arab River. However, all heavy metal concentrations were within the world health organization permissible limits.

Keywords: Assessment; Heavy metals; Contamination; Seawater; Kuwait Bay

1. Introduction

The coastline of Kuwait, which runs over 500 km, is made up of nine islands. The southern shoreline of this coast is distinguished by some openings, whereas Kuwait Bay is more prominent in the northern part of the country (Alkuwairan, 2012). The water in Kuwait Bay has an average annual temperature of 23.8 °C (Al-Yamani *et al.,* 2004). The Kuwait Bay seawater temperature has climbed at a rate three times faster than the world mean rate since 1985, according to satellite data (Al-Rashidi, 2009). However, most Kuwaitis have been compelled to dwell near the bay's southern coast due to the aridity of the terrain and a paucity of agricultural supplies (Al-Ghadban *et al.,* 2002).

Kuwaiti marine environment has been threatened by regional and local water quality and ecological risks for decades. Moreover, various governmental and private sector facilities have been constructed along Kuwait Bay's shore to meet the needs of the populace. Many of these institutions discharge their wastewater into Kuwait Bay, endangering the environment (Al-Mutairi *et al.,* 2014). Meanwhile, desalination has been the only way to ensure a consistent supply of freshwater in Kuwait. The brine released from these desalination plants is usually three times saltier than the water in Kuwait Bay previously (Alkuwairan, 2012). Kuwait Bay is becoming more salinized and warmer because of concentrated saltwater discharge brines and excessive sewage effluent dumping

(Saif Unddin *et al.,* 2011). In addition, an estimated 5 to 8 million barrels of oil were discharged into Kuwaiti waterways during the Gulf War in 1991 (UNEP, 1991). In addition, the presence of fertilizer manufacturing and oil refining industries along the coast of the bay contributed to such a finding (Forstner and Wittman, 1979). Simultaneously, scientists have determined that the Shat Al-Arab River in Iraq may be a source of pollution in the Arabian Gulf, contaminating the seas off the coast of Kuwait as a result (Anderlini *et al.,* 1982; Abaychi and DouAbul, 1985).

Many environmental studies around the world have proven the importance of evaluating the levels of heavy metals and the distribution of their concentrations in marine sediments (Chen *et al.,* 2007; Abdel Wahab *et al.,* 2011; Nour, 2015; Nour and Nouh, 2020a), seawater samples (Spivack, 1985; Bazzi, 2014; Nour, 2019a; Nour and El-Sorogy, 2020), as well as the seashells of the marine organisms (Ferrell *et al.,* 1973; Fallon *et al.,* 2002; Helal and Abdel Wahab 2012; Nour, 2020; Nour and Nouh, 2020b). These materials represent strategic stores for the quantities of these pollutants. Therefore, to maintain the quality of the marine environment, pollutants must be monitored and evaluated on a regular basis. For this purpose, the main objective of the current study was to study the distribution of concentrations of some heavy metals in the coastal water of the Gulf of Kuwait during the summer and winter seasons. In addition, to assess the concentration of pollutants in these waters and compare their quality with other coasts around the world.

2. Material and Methods

2.1 Study area

A total of 20 coastal seawater samples were taken during the summer (August 2020) and winter (January 2021) from ten important sites along the coast of Kuwait Bay (Figure 1). These sites were chosen near industrial and human pollutants, as well as near rain streams that drain into Kuwait Bay. The first site is located south of Kuwait Bay at the beach of Gulf Street (site 1), while the second site is located 2.81 km northwest of the Gulf Street beach (site 2). The third site is represented at the Kuwait Towers beach (site 3), while the fourth site is located on Shuwaikh beach (site 4). The fifth site is located at the Kuwait free zone (site 5), while the sixth site is located at the Sulaibikhat beach (site 6). The seventh site is located at Ashiraj beach (site 7), while the beach of West Doha chalets was the eighth site (site 8). The ninth site is located at Saif Kazma beach (site 9), while the tenth site is located Al-Khuwaisat beach (site 10).

2.2 Analytical and statistical analysis

Water temperature, pH, total dissolved solids (TDS), and electrical conductivity (EC) were measured in situ during the collection of water samples. The pH of the water samples was measured by a pH meter. Whereas, the total dissolved solids, water temperature, and electrical conductivity were measured by a TDS and EC meter. Unfiltered coastal seawater samples had been gathered in 1-liter pre-acidified polyethylene boxes, kept in an

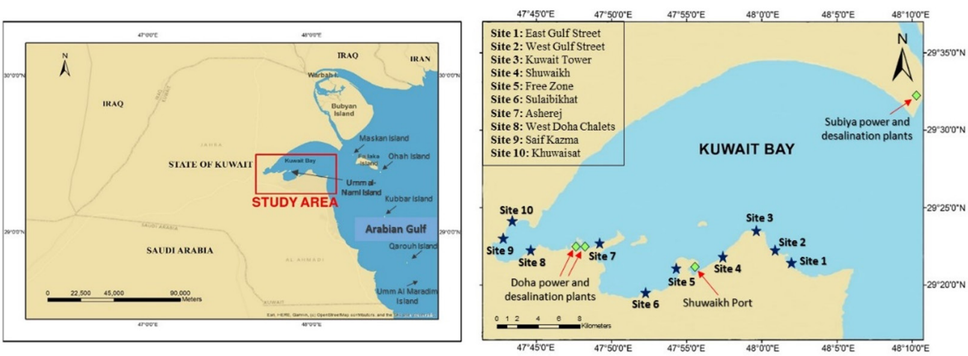

Figure 1: Location map of the study area

icebox (at 4 °C), and transported to the water laboratory for subsequent chemical analyses. Nine heavy metals (Fe, Mn, Zn, Cu, Pb, Ni, Co, Cr, and As) were measured by Inductively Coupled Plasma Mass Spectroscopy (ICP MS Perkin Elmer 2000 – USA model). The seawater samples were analyzed at Kuwait University by the Research Sector Project Unit (RSPU).

The results outcomes of heavy metals levels in the studied seawater were compared with standard marine water to assess the degree of water pollution by heavy metals along the coast of Kuwait Bay. The enrichment factor (EF) according to Zhao *et al.,* (2013), the contamination factor (CF) Al-Taani *et al.,* (2014), the degree of contamination (C_{deg}) Swarnalatha *et al.,* (2015), and the pollution load index (PLI) Ramadan *et al.,* (2021) were measured in Kuwait Bay surface coastal water to evaluate the quality of seawater. The standard seawater quality according to kabata-Pendias and Pendias (1999) and Siegel (2002) were used as background values. Moreover, the correlation matrix, hierarchal cluster analysis (HCA) and principal component analysis (PCA) were calculated with the SPSS program.

3. Results and discussion

3.1 Hydro-chemical parameters

The temperature of the surface seawater recorded significant changes between the two seasons (summer and winter) in the studied area (Table 1). It ranged from 30 °C to 32 °C in summer with an average of 30.9 °C. While it ranged from 18 °C to 20 °C in winter with an average of 19 °C. In addition, pH was varied between two seasons, where it ranged from 6.63 to 6.88 in summer with an average of 6.8 and it ranged from 7.12 to 7.97 in winter with an average of 7.53. On other hand, all the other studied water quality parameters did not show fundamental differences between the summer and winter seasons. TDS ranged from 32220 to 41810 mg/L in summer with an average of 35961 mg/L. While it ranged from 32870 to 41220 mg/L in winter with an average of 36088 mg/L. In addition, EC ranged from 29520 to 62530 µs/cm in summer with an average of 60604 µs/cm, while in winter it ranged from 59900 to 61800 µs/cm with an average of 60728 µs/cm. Furthermore, the salinity ranged from 34.53 to 37.84 g/kg in summer with an average of 36.18 g/kg. While it ranged from 45.24 to 49.00 g/kg. The salinity degree in the winter season was considered within the normal values for this region of the Arabia Gulf.

These results indicated that there is a significant negative correlation between temperature and pH (r = -0.74) and between temperature and salinity (r = -0.80). On the other hand, there are significant positive correlations between pH and salinity (r = 0.51), between TDS and EC (r = 0.99), between TDS and salinity (r = 0.53), and between EC and salinity (r = 0.59) (Figure 2).

Table 1. The basic water quality parameters

Site	Temperature (°C)		EC (µs/cm)		TDS (mg/L)		pH	
	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
Site-1	32°	18°	59780	60260	32580	34460	6.81	7.12
Site-2	31°	18°	61260	60420	38240	35580	6.86	7.9
Site-3	30°	19°	59520	60340	32220	35460	6.88	7.97
Site-4	31°	18°	60240	59900	34730	32870	6.82	7.66
Site-5	30°	20°	60480	62300	35570	41220	6.74	7.11
Site-6	33°	20°	61310	60140	38950	33430	6.63	7.77
Site-7	30°	19°	62530	60460	41810	35520	6.83	7.86
Site-8	32°	20°	60310	60860	35490	36820	6.64	7.39
Site-9	30°	20°	60280	60800	34810	36160	6.88	7.28
Site-10	30°	18°	60330	61800	35210	39360	6.87	7.24

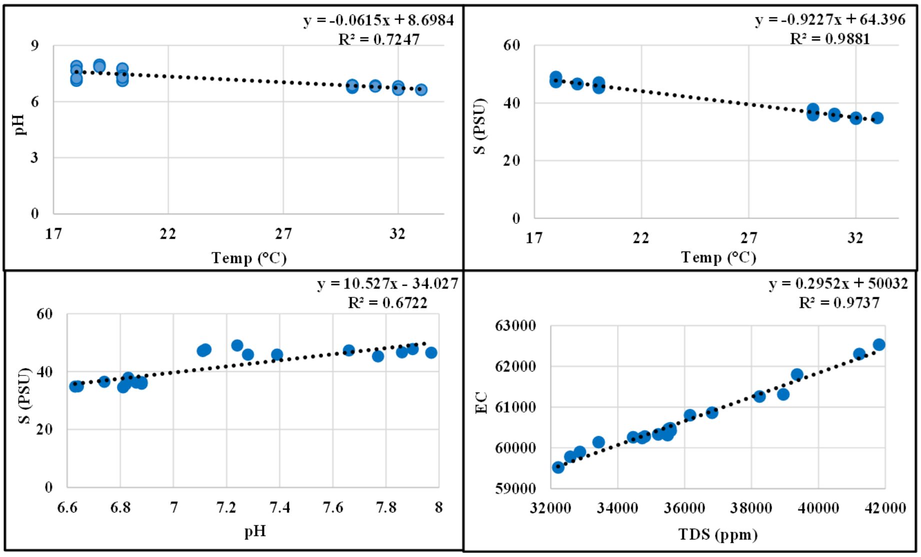

Figure 2. Scatter plot of hydro-chemical parameters during study period at Kuwait Bay, Kuwait

3.2 Heavy metals distribution

The heavy metal concentrations in seawater samples of Kuwait Bay were obtained in Table 2. The results showed that Fe was recorded the highest level (2417 µg/L) in site-7 during the summer. The average concentration of Fe in summer (1333.5 µg/L) was higher than in winter (1244 µg/L). Mn has recorded the highest level (85.10 µg/L) in site-6 during the summer. The average concentration of Mn in summer (32.57 µg/L) was higher than in winter (28.89 µg/L). Zn has recorded the highest level (538.4 µg/L) in site-7 during the summer. The average concentration of Zn in summer (358.7 µg/L) was slightly higher than in winter (253.29 µg/L). Cu was recorded the highest level (732 µg/L) in site-8 during the summer. The average concentration of Cu in summer (656.3 µg/L) was higher than in winter (292.74 µg/L). Pb has recorded the highest level (19.4 µg/L) in site-9 during the summer. The average concentration of Pb in summer (17.3 µg/L) was higher than in winter (10.94 µg/L). Ni has recorded the highest level (187.8 µg/L) in site-6 during the summer. The average concentration of Ni in summer (121.3 µg/L) was higher than in winter (86.78 µg/L). Co has recorded the highest level (7.10 µg/L) in site-10 during the winter. The average concentration of Co in summer (2.76 µg/L) was slightly higher than in winter (2.68 µg/L). Cr has recorded the highest level (266 µg/L) in site-1 during the winter. The average concentration of Cr in summer (230.85 µg/L) was higher than in winter (205.4 µg/L). As recorded the highest level (5.32 µg/L) in site-6 during the summer. The average concentration of As in summer (1.58 µg/L) was lower than in winter (2.71 µg/L).

The distribution of heavy metals in the studied area indicated that the beach of Sulaibikhat has the highest content of Mn, Ni and As, while Ashiraj beach recorded the highest levels of Fe and Zn. Moreover, the highest levels of Cu, Pb, Co, and Cr were recorded in the beaches of West Doha chalets, Sif Kazma, Al-khuwaisat, and Gulf Street beaches respectively. Generally, the average concentrations of the studied heavy metals in the summer season were higher than ones in the winter season (Figure 3). In addition, the distribution of the heavy metals in coastal seawater of Kuwait Bay was similar during the two seasons summer and winter in order: Fe > Cu > Zn > Cr > Ni > Mn > Pb > Co > As.

Table 2. The concentration of heavy metals (μg/L) in coastal seawater of Kuwait Bay for two seasons

Summer	Latitudes	Longitude	Fe	Mn	Zn	Cu	Pb	Ni	Co	Cr	As
Site -1	29°21′3.10″ N	48°2′4.31″ E	1161.0	31.33	345.68	697.53	17.88	117.46	2.06	245.62	0.978
Site -2	29°22′11.37″ N	48°0′52.69″ E	1050.0	15.32	368.24	662.06	17.15	108.39	2.18	231.94	0.825
Site -3	29°23′31.28″ N	47°59′52.66″ E	1111.1	19.63	371.24	672.51	18.57	118.72	2.41	238.03	0.893
Site -4	29°21′54.20″ N	47°57′23.95″ E	1041.2	15.82	324.15	653.71	16.24	109.78	2.22	237.35	0.905
Site -5	29°21′5.65″ N	47°54′17.18″ E	916.5	13.51	331.42	617.79	17.44	105.41	1.93	220.34	0.909
Site -6	29°19′11.71″ N	47°51′41.10″ E	1875.3	85.1	336.30	699.77	16.48	187.82	3.42	226.75	5.318
Site -7	29°22′53.82″ N	47°49′46.76″ E	2417.5	38.02	538.42	599.52	11.54	108.18	3.01	219.27	0.956
Site -8	29°22′10.29″ N	47°44′27.04″ E	1454.7	42.52	331.72	732.03	19.13	139.29	4.28	254.48	3.183
Site -9	29°23′35.94″ N	47°42′58.46″ E	1350.7	39.58	316.33	693.98	19.35	134.55	4.15	243.73	0.911
Site -10	29°24′10.91″ N	47°43′52.19″ E	957.1	24.89	323.14	534.27	19.24	89.29	1.97	191.03	0.932
Winter											
Site -1	29°21′3.14″ N	48° 2′ 4.15″ E	1033.5	9.55	81.72	235.78	11.52	88.79	2.011	266.12	2.076
Site -2	29°22′11.49″ N	48°0′52.58″ E	999.8	31.75	29.87	298.24	8.807	75.85	1.031	189.15	2.977
Site -3	29°23′31.37″ N	47°59′52.88″ E	1022.1	5.604	212.1	265.24	15.01	81.47	3.19	212.31	2.145
Site -4	29°21′54.35″ N	47°57′24.16″ E	1021.2	43.901	199.9	247.25	11.22	83.64	2.861	177.54	2.186
Site -5	29°21′5.73″ N	47°54′17.00″ E	900.0	15.68	376.3	365.98	5.441	81.47	4.701	162.45	2.633
Site -6	29°19′11.75″ N	47°51′41.28″ E	1759.2	37.643	395.3	324.25	10.9	106.24	1.37	178.45	4.937
Site -7	29°22′53.67″ N	47°49′46.51″ E	2235.7	80.804	325.8	345.12	11.28	87.24	1.551	199.54	2.592
Site -8	29°22′10.40″ N	47°44′27.13″ E	540.8	17.701	344.3	270.22	11.7	122.14	1.451	213.41	2.771
Site -9	29°23′36.19″ N	47°42′58.61″ E	1874.4	4.7709	241.7	298.74	11.34	63.36	1.511	212.14	2.186
Site -10	29°24′10.83″ N	47°43′51.87″ E	1055.3	41.504	325.9	276.55	12.21	77.48	7.101	243.12	2.64

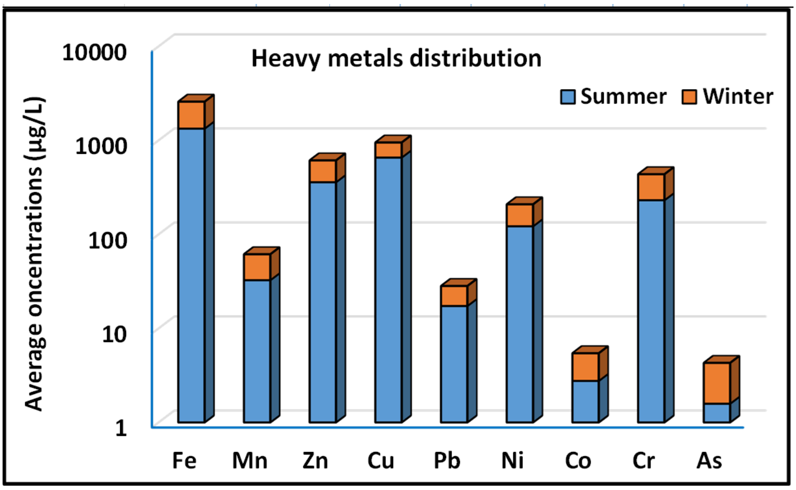

Figure 3. The comparison of the average concentrations of heavy metals in the two seasons

Figure 4 showed that the average heavy metals content in ten coastal sites along Kuwait Bay in the summer season was higher than ones in the winter season. However, this figure indicated that sites 7, 6, 8, and 9 were the highest in heavy metals content during the summer, while sites 7, 6, and 9 recorded the highest total metal content in winter. The study area has different sources of pollution, where the field observations showed that the beach of Sulaibikhat was characterized by weak currents due to the relatively stagnant water on this beach. Moreover, the human pollutants have been found due to popular cafes and pollutants which include building particles come from production agencies that build homes near the seaside, in addition to plastic baggage and numerous thrown rubber tires on the seaside for a long time. In addition, Doha East Station is located near small companies and factories located on the beach. Also, several industrial pollutants were noticed on the beach as old and broken ships, paints, rubber tires, cork bags, and plastic cans. West Doha chalets beach suffers from many human pollutants, such as building rubble that is thrown from the chalet construction, plastic water cans, rusty cans, and pieces of copper. in addition, the presence of rain streams region. Saif Kazma beach and contains human pollutants such as cork cups thrown on the beach, the wheels of cars, and several concrete blocks (Figure 5).

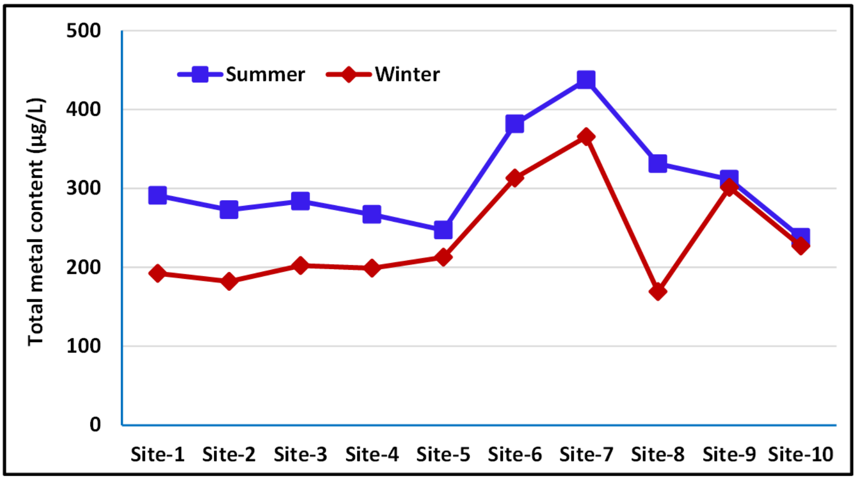

Figure 4. The comparison of heavy metals content in studied sites in both seasons

Figure 5. Different beach appearances for studied sites: a. Al-Khuwaisat; b. Sif Kazma; c. West Doha; and d. Sulaibikhat

3.3 Heavy metals evaluation

The annual average of the concentrations of the heavy metals in the coastal seawater of Kuwait Bay was compared with the published concentrations for other coasts around the world (Table 3). Moreover, the results of the current study indicated that it was the highest compared to the rest of the neighboring regions around the world. However, Fe in Kuwait Bay recorded 32 times than the average Oceanic concentration (Broecker and Peng, 1982) (Figure 6), while Zn recorded 765 times than the average Oceanic concentration and 2039 times than ones in both north Atlantic and north Pacific Oceans (Donat and Bruland, 1995). In addition, Cu recorded 3954 times than the average Oceanic concentration, and 412 to 527 times than ones in the North Atlantic Ocean and in the North Pacific Oceans. Cr recorded 661 times than in the average Ocean concentration 62 north Atlantic and north Pacific Oceans. While Pb recorded 14120 times than the average Oceanic concentration and it recorded levels less than in both of north Atlantic and north Pacific Oceans. Furthermore, Co recorded levels less than in both of north Atlantic and north Pacific Oceans, while As was less than in both of north Atlantic and north Pacific Oceans

Table 3. The comparison of annual average of heavy metals in Kuwait Bay with the other published ones for other coasts around the world

Location	Fe	Mn	Zn	Cu	Pb	Ni	Co	Cr	As	References
Kuwait bay	1289	30.73	306.0	474.5	14.12	104.3	2.72	218.1	2.15	Present work
Oman sea			11.70	2.770	2.220	10.90		15.5		Bazzi (2014)
Bahrain sea			0.840	0.200	0.160	0.310				Al-Sayed et al. (1994)
Gulfof Aqaba			0.240	0.140	0.320	0.220	0.17			Shriadah et al. (2004)
Red Sea			5.500	0.970	0.030	0.760	0.03	0.18	1.29	Ali (2012)
Abu Zenima seawater	1.970		0.230	0.430	0.510	0.010				Nour & El-Sorogy (2020)
Jinzhou Bay			11.87	3.060	0.610					Wang et al. (2012)
North Atlantic Ocean			0.150	1.150	125.0		159	3.50	20.0	Donat & Bruland (1995)
North Pacific Ocean			0.150	0.900	32.00		27.0	3.00	30.0	
Average Ocean	0.040		0.400	0.120	0.001			0.33		Broecker & peng (1982)

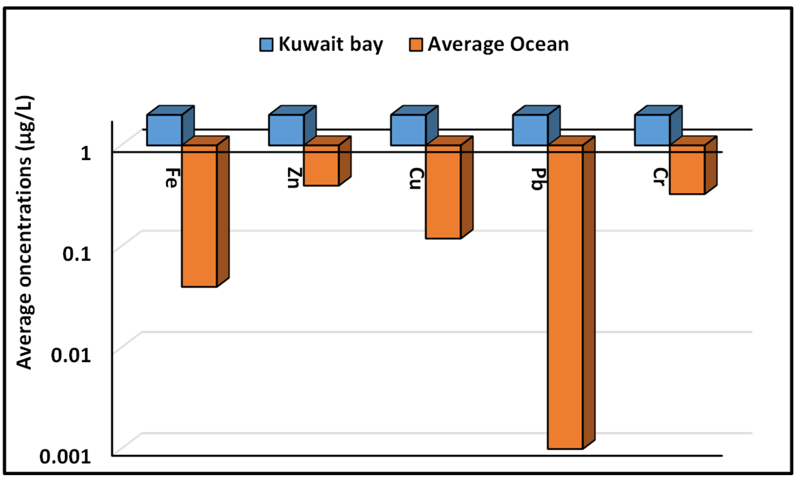

Figure 6. The comparison of heavy metals in Kuwait Bay with the average of Oceanic concentration

Several authors used EF, CF, C_{deg}, and PLI to evaluate the quality of seawater (Reeder *et al.,* 1979; Sadiq, 1992; Karadede and Unlu, 2000; Pan and Wang, 2011; Zhao *et al.,* 2013; Al-Taani *et al.,* 2014; Ramadan *et al.* 2021). The results of these environmental parameters (Table 5 and Figure 7) indicated that the coastal water of Kuwait Bay had no enrichment (EF = <1) with Mn, Zn, Pb, Ni, Co, Cr, and As in both seasons summer and winter. Furthermore, EF indicated that the studied area was in moderate enrichment with Cu (EF = 2 - 5). However, CF showed that the studied area was considerably contaminated with Cu in summer (CF = 3 - 6) and moderately contaminated with Fe and Cu in the winter. Meanwhile, other studied heavy metals were recorded low contaminated in Kuwait Bay. The degree of heavy metals contamination (C_{deg}) in the Kuwait Bay seawater was moderately contaminated during summer and low contaminated in winter.

Pearson's correlation coefficient is a tool for determining the metals relationship to each other and the possibility that they come from the same sources (Nour, 2019b; Nour *et al.,* 2021). The results of these correlation (Table 6) showed that summer seawater samples recorded a positive correlation between Fe with Zn and Mn; Cu with each of Cr and Ni; Mn with each of Ni and Co; Pb with Co, and Ni with Co. Meanwhile, the correlation for winter seawater samples indicated positive correlations were observed between Fe with Cr and As; Mn with Cu; and Cr with As. These results are supported by HCA analyses (Figure 8). For the summer season, the HCA dendrogram was classified heavy metals into three different groups. The first includes Cu, Cr, and Pb, the second includes Mn, Ni, and Co, while the third one includes Fe, Zn, and As. Meanwhile, HCA dendrogram in the winter season was grouped heavy metals into three different groups. The first includes Mn and Cu, the second includes Cr, As, Fe, and Zn, while the third one includes Ni, Co, and Pb. These results confirm that there is a difference in the sources of heavy metals during the summer and winter seasons.

Table 5. Environmental parameters in seawater of Kuwait Bay coast

EF	Fe	Mn	Zn	Cu	Pb	Ni	Co	Cr	As	PLI
Summer		0.117	0.143	2.667	0.481	0.193	0.214	0.627	0.0002	3.065×10^{-7}
Winter		0.120	0.119	1.347	0.341	0.169	0.258	0.646	0.0004	1.519×10^{-8}
CF										C_{deg}
Summer	1.333	0.163	0.179	3.282	0.577	0.244	0.276	0.770	0.00023	6.824
Winter	1.242	0.128	0.114	1.443	0.362	0.176	0.217	0.692	0.0004	4.376

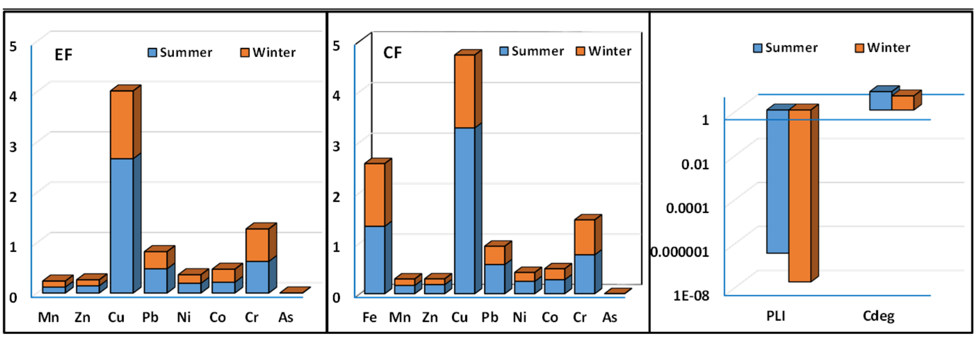

Figure 7. Season variation of EF, CF and C_{deg} indices in seawater of Kuwait Bay coast

Table 6. Correlation matrix among heavy metals in two seasons of coastal seawater of Kuwait Bay

Summer	Fe	Mn	Zn	Cu	Pb	Ni	Co	Cr	As
Fe	1								
Mn	0.648*	1							
Zn	0.738*	0.043	1						
Cu	0.089	0.387	-0.161	1					
Pb	-0.201	0.187	-0.584	0.555	1				
Ni	0.437	0.896**	-0.144	0.682*	0.467	1			
Co	0.518	0.619	0.022	0.579	0.626	0.643*	1		
Cr	0.017	0.091	-0.043	0.929**	0.494	0.399	0.492	1	
As	-.874**	-0.485	-.654*	-0.095	0.094	-0.315	-0.543	-0.061	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Winter	Fe	Mn	Zn	Cu	Pb	Ni	Co	Cr	As
Fe	1								
Mn	0.489	1							
Zn	0.032	-0.450	1						
Cu	0.404	0.704*	0.095	1					
Pb	0.039	-0.423	0.166	-0.480	1				
Ni	-0.089	0.234	-0.177	-0.141	0.155	1			
Co	0.071	0.051	-0.484	-0.249	0.200	0.454	1		
Cr	0.517	0.016	0.117	0.225	-0.288	-.727*	-0.159	1	
As	0.509	-0.117	-0.036	-0.204	0.306	-0.351	0.143	0.668*	1

*. Correlation is significant at the 0.05 level (2-tailed).

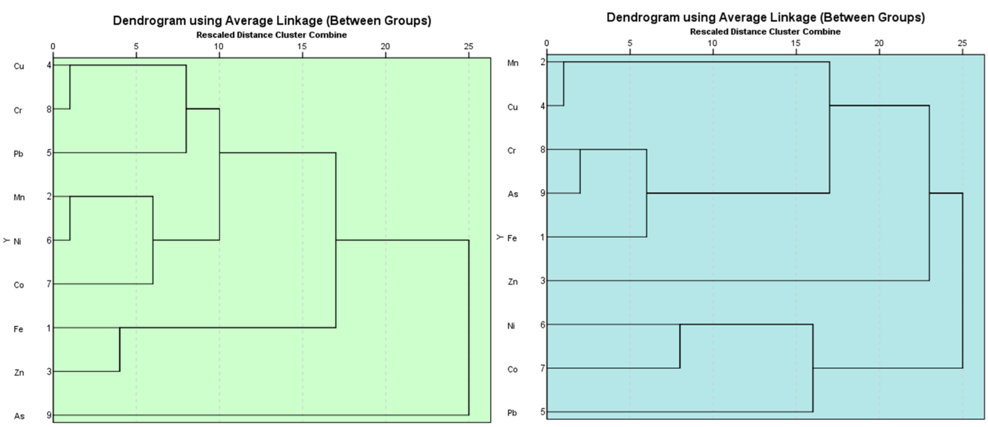

Figure 8. Dendrogram for hierarchal clusters analyses of heavy metals in two season of surface seawater of Kuwait Bay

Table 7. Principal component loadings and explained variance for the three components with varimax normalized rotation in two seasons

Component Matrix[a]			
Summer	Component		
	1	2	3
Fe	0.617	-0.772	-0.005
Mn	0.793	-0.209	-0.504
Zn	0.102	-0.862	0.449
Cu	0.757	0.469	0.360
Pb	0.512	0.698	-0.100
Ni	0.875	0.130	-0.332
Co	0.885	0.048	-0.018
Cr	0.598	0.457	0.644
As	-0.583	0.701	-0.098
% of Variance	45.59	31.17	12.56
Cumulative %	45.59	76.76	89.33
Extraction Method: Principal Component			
a. 3 components extracted.			

Component Matrix[a]				
Winter	Component			
	1	2	3	4
Fe	0.681	0.106	0.481	0.461
Mn	0.398	0.851	0.196	0.114
Zn	0.118	-0.471	-0.547	0.586
Cu	0.613	0.599	-0.267	0.256
Pb	-0.408	-0.526	0.379	0.491
Ni	-0.645	0.492	0.268	0.360
Co	-0.346	0.176	0.762	-0.137
Cr	0.868	-0.349	0.138	-0.228
As	0.475	-0.540	0.619	-0.004
% of Variance	29.93	25.35	20.43	11.96
Cumulative %	29.93	55.27	75.70	87.66
Extraction Method: Principal Component				
a. 4 components extracted.				

Table 7 illustrates the component matrix, from which three principal ones in summer and four principal components are extracted. These components account in summer for 89.33% of the total cumulative percentage. The first component accounts for 45.59% and shows high positive loading of Co, Ni, Mn, and Cu (0.885, 0.875, 0.794, and 0.757 respectively). The second component explains 31.17% and contains positive loading for As (0.701) and Pb (0.689). The third component factor accounts for 12.56% and shows positive loading for Cr (0.644). Each group of elements possibly originates from similar sources. Regarding the winter season, these components account in winter for 87.66% of the total cumulative %. The first component accounts for 29.93% and shows high positive loading of Cr, Fe, and Cu (0.868, 0.681, and 0.613 respectively). The second component explains 25.35% and contains positive loading for Mn and Cu (0.851 and 0.599). The third component factor accounts for 20.43% and shows positive loading for Co and As (0.762 and 0.619). The fourth component factor accounts for 11.96% and shows positive loading for Zn (0.586).

4. Conclusion

Environmental indicators suggested that the coastal water of Kuwait Bay had no enrichment with Mn, Zn, Pb, Ni, Co, Cr, and As in both summer and winter. The EF and CF factors indicated that the Cu was moderately enriched in the winter, whereas the other examined heavy metals were found to be a low polluted Kuwait Bay. Heavy metals distribution in the Sulaibikhat coast has the highest content of Mn, Ni, and As, while Ashiraj beach recorded the highest levels of Fe and Zn. Moreover, the highest levels of Cu, Pb, Co, and Cr were recorded in the beaches of West Doha chalets, Sif Kazma, Al-khuwaisat, and Gulf Street beaches respectively. The degree of heavy metals pollution (C_{deg}) in the study area was moderate during the summer and low during the winter. Moreover, the average concentrations of these metals in the summer season were higher than those in the winter season. In the end, it can be concluded that the quality of seawater on the coast of Kuwait Bay is moderate to non-polluted by heavy metals.

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