Kuwait J.Sci., Vol.50, No.(1B),January.2023,pp(1-18)

Evaluation of Seawater Quality of Kuwait Bay Using Physio-Chemical Parameters

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Abstract

This study emphasizes on the effects of current anthropogenic activities altering seawater physio-chemical parameters around Kuwait Bay. The research aims to evaluate the spatial variations in seawater quality in Kuwait Bay. Fifty-two seawater samples were collected from 1-meter depth, between April and May 2017 and analyzed for Total Suspended Solids (TSS), nutrients: Ammonia (NH_3), Nitrate (NO_3), Nitrite (NO_2) and Silicate (SiO_2), and designated trace elements: Chromium (Cr), Zinc (Zn), Selenium (Se), Nickel (Ni), Arsenic (As), and Mercury (Hg). In addition, five real-time monitoring buoys data were used to assess seawater quality based on Kuwait Environmental Public Authority (KEPA) standards to evaluate six parameters: turbidity, Dissolved Oxygen, pH, salinity, conductivity, and seawater temperature. The results of this study reveal that: (1) average level of physio-chemical parameters: temperature, salinity, conductivity, turbidity, Dissolved Oxygen and pH in Kuwait Bay water were 27.8 ^{0}C, 40.2 ppt, 60.2 µs/cm, 5.9 NTU, 6 mg/l and 8.2, respectively; (2) average level of nutrients; silicate, nitrate, nitrite and ammonia were 333 µg/l, 83 µg/l, 235 µg/l and 43.5 µg/l, respectively; (3) average level of elements found in Kuwait Bay's seawater were 14.7 mg/l for Barium (Ba), 380 mg/l for Calcium (Ca), 9727 mg/l for Sodium (Na), 411 mg/l for Potassium (K) and 1432 mg/l for Magnesium (Mg); (4) The total suspended solids (TSS) had an average of 25.3 mg/l; (5) mean concentrations of the elements in TSS decrease in the order of Cr (15.6), Zn (5.4), Se (4.5), Ni (3.3), As (1.2), Co (0.2) and Hg (0.1mg/kg) and they are 1.6 to 22 times lower than their soil background values in, while Pb was detected in 2 samples only with average concentration of 0.7 mg/kg; and (6) Cr shows maximum enrichment relative to the upper continental crustal component (Mn). The distribution of pollutants in Kuwait Bay seems to be controlled and produced mainly by the anthropogenic and recreational activities.

Keywords: Elements; enrichment; nutrients; physio-chemical parameters; pollutants

1. Introduction

Kuwait Bay is located at the northwestern corner of the Arabian Gulf and provides the most species diversity in the region; therefore, it is considered as the highest productive ecosystem in Kuwait seawater (Al-Yamani *et al.,* 2004). It is an elliptical-shape, semi-closed body of water, extending approximately 35 km inland and covering approximately an area of 750 km^2, with an average depth of 5 m (Al-Ghadban, 2004). Tidal current is the dominant force which effects the water movement in the Bay (Anderlini, *et al.,* 1982), with tidal range difference of 4 m vertically and 8 km horizontally. The maximum current speed in Kuwait Bay's entrance reaches approximately 1 m/s, with currents slowing toward the western portion of the Bay to less than 40 cm/s (Pokavanich and Al-Banaa, 2012; Al-Yamani *et al*., 2004). The study of Rakha *et al*. (2010) illustrated that the inner part of Kuwait Bay takes more than two years to flush.

Both anthropogenic and natural factors can cause marine pollution in Kuwait Bay (Al-Mutairi, *et al*. 2014a). However, the anthropogenic factors, associated with sewage discharge and effluent discharge from the rain sewers, and desalination and power plants, impose major environmental impacts on Kuwait Bay besides recreational facilities, hospitals and other urban and industrial buildings existing along its coast (Al-Mussalam, 1999; Al-Mutairi *et al*., 2014a; El–Anbaawy, *et al*., 2017). The natural pollution factors like the discharges from Shatt Al-Arab and dust fallout also play significant role in increasing the input of nutrients such as nitrate (NO_3) and phosphate (PO_4) as well as suspended sediments and multiple pollutants into Kuwait Bay (Al-Ghadban and El-Sammak, 2005; Al-Yamani, 2008).

In general, the main threats of pollution sources along the coast of Kuwait Bay include the following: (1) twelve rain sewers, (2) nine emergency sewage discharges, (3) five marinas and two ports, and (4) three desalination and power plants. Thus, the need for this research arises from its two main aims: (1) intensive assessing current physio-chemical status of water quality on spatial bases including total suspended solid (TSS), pH, conductivity, salinity, silicate, nitrite, nitrate, ammonia, turbidity, temperature and Dissolved Oxygen (DO), and (2) examining trace element concentrations in the seawater and TSS.

2. Materials and Methods

2.1 Data source

Kuwait Environmental Public Authority (KEPA) installed five real-time monitoring buoys in Kuwait Bay (Figure 1), their data was used for a period of one-month (April-May, 2017). Water quality data, assessed by KEPA guidelines and standards, represented six parameters. The procedures to measure concentrations of turbidity and Dissolved Oxygen were based on Manual of Oceanographic Observations and Pollutant Analyses Methods (ROPME, 1999), while the pH, salinity, conductivity and seawater temperature were measured using the hydro-lab multi-parameters field instrument.

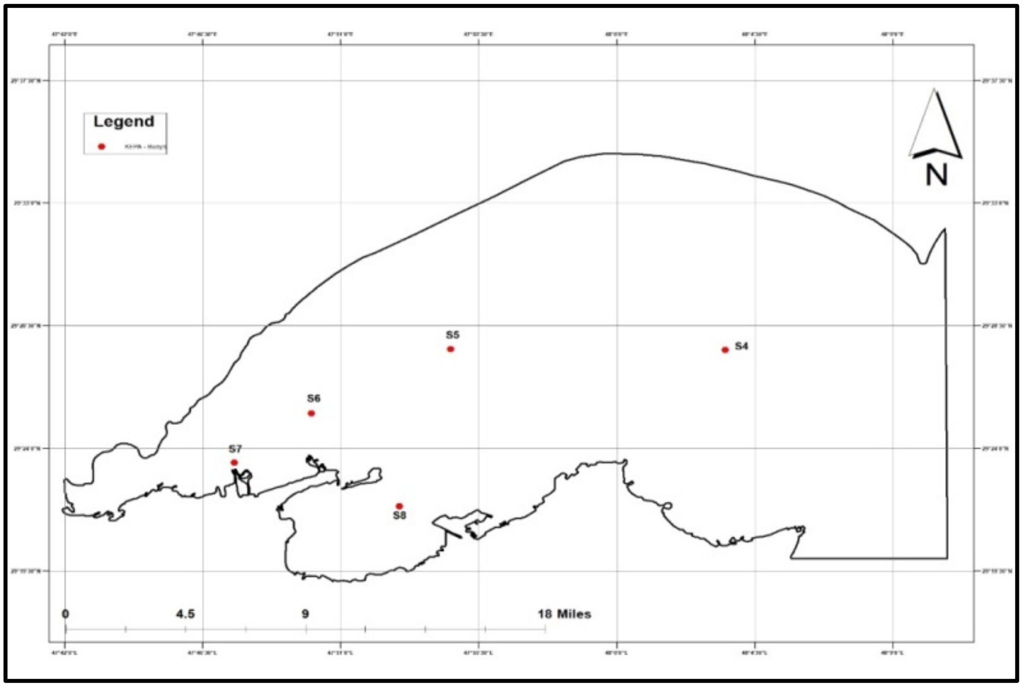


Fig. 1. Locations of marine water monitoring buoys of KEPA in Kuwait Bay.

In addition, 52 seawater samples were collected during the same period, at depth of 1 meter below sea surface at different locations covering the majority of Kuwait Bay area (Figure 2). The samples were examined and analysed in the Kuwait University laboratories to determine the following parameters: Total Suspended Solids (TSS), nutrients and selected trace elements.

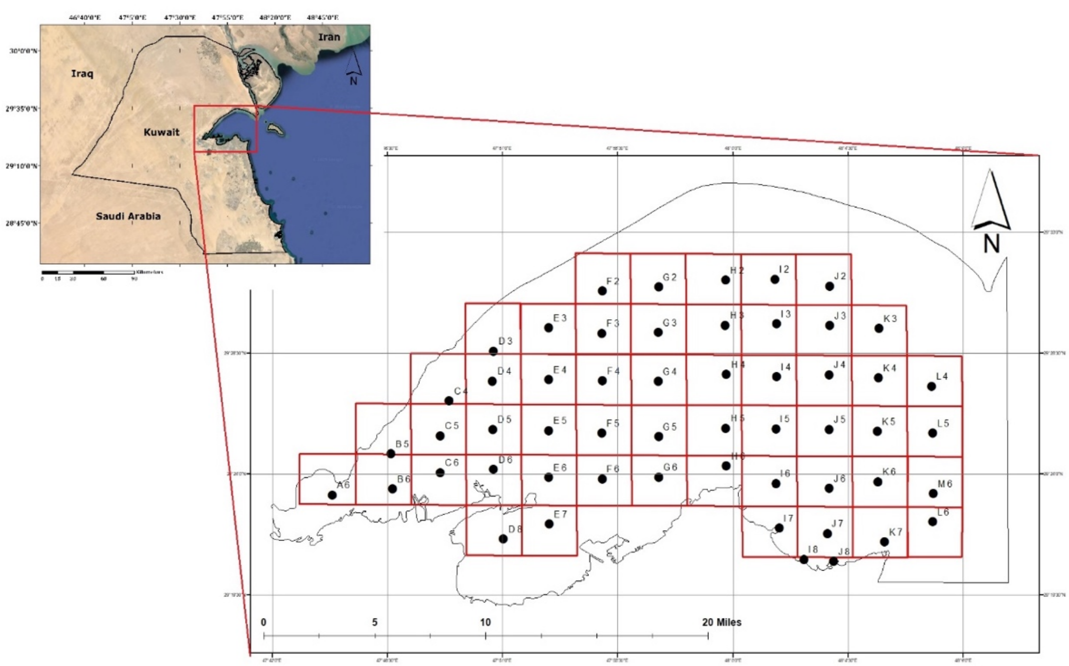


Fig. 2. Locations of seawater sampling sites in the Kuwait Bay.

TSS was measured according to the method of (MOOPA, 1999). TSS was determined by filtration of 100 ml of water through a previously dried and weighed Millipore membrane filter (porosity 0.45 µm). Filtration was done by using vacuum system under reduced pressure. The residue on the filter paper was washed several times by deionized water. The filters were then air dried in a desiccator, for at least 48 hours until constant weight was achieved. The filter papers were weighed to the nearest 3 decimal places and accordingly, the values of TSS were determined in mg/l. Inductively Coupled Plasma – Optical Emission Spectrometer (ICP-OES), Perkin Elmer, Optima 7300 was used to determine trace elements in 52-seawater samples and 24-TSS samples (Figure 3). According to US EPA method IO-3.2 (USEPA, 1999), two methods (No.3010A) and (No.3050B) were used for preparing water and TSS samples, respectively. The procedures were done by taking 0.5 g of TSS and 50 ml of seawater samples and place them in a polypropylene digestion vessel along with deionized water, 1:1 concentrated nitric (HNO_3) and hydrochloric (HCl) acids, and 30% hydrogen peroxide (H_2O_2) (for TSS sample) was added while heating at 95 ^{o}C then analysed by ICP.

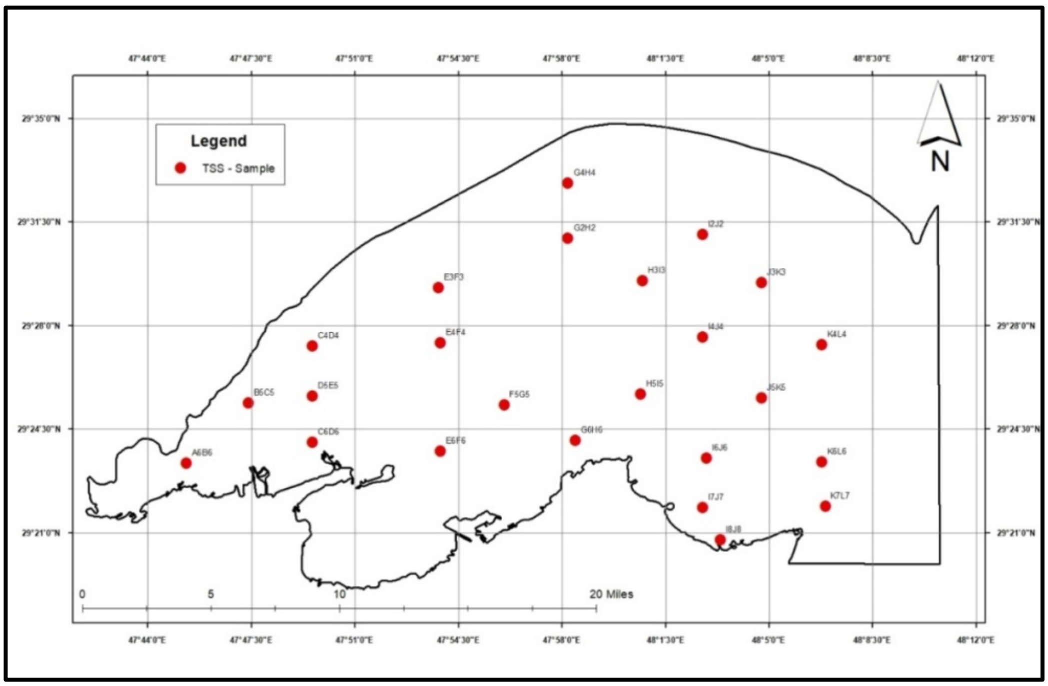


Fig. 3. Locations of the TSS samples used for ICP-OES analysis.

Seawater samples from each location were also analysed for nutrients, including Ammonia (NH_3), Nitrate (NO_3), Nitrite (NO_2) and Silicate (SiO_2), according to HACH DR/2500 method. Enrichment Factor (EF) method described by Sutherland (2000) was used to evaluate the potential impact of total suspended solids (TSS). The EF element can be compared with a pre-selected reference element and it is calculated using the following equation:

$$EF = [C_n \text{ (sample)} / C_{ref} \text{ (sample)}] / [B_n \text{ (baseline)} / B_{ref} \text{ (baseline)}] \quad (1)$$

Where C_n (sample) is the determined value of a specific element in the TSS, C_{ref} (sample) is the preselected reference element value in the TSS, B_n (baseline) is the background value of the examined element in Kuwait sediments, B_{ref} (baseline) is the preselected reference element background value in Kuwait sediments.

3. Results

3.1 Seawater Quality

Table 1 describes statistics of elemental and physio-chemical parameters measured in Kuwait Bay water.

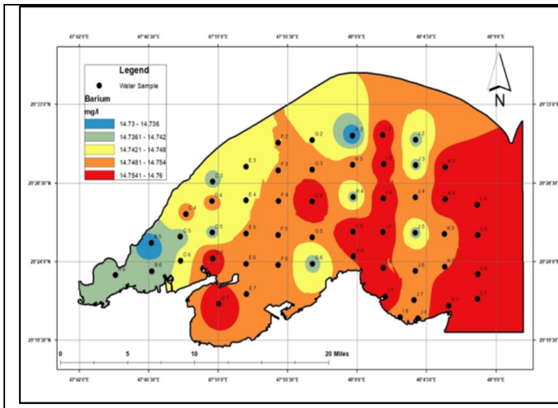
Table 1. Summary statistics of parameters measured for evaluating seawater quality in Kuwait Bay

	TSS	Ba	Ca	Na	K	Mg	Silicate	Nitrite	Nitrate	Ammonia
Units	Trace Elements mg/l						Nutrients µg/l			
Mean	25.3	14.75	380.5	9727.4	411.4	1432.3	333	235	83	43.5
Maximum	39.2	14.76	526.1	10510	639.1	1669.1	1270	791	1519	165
Minimum	13.2	14.73	223.1	8698	78	648.37	94.1	0	0	7.58
Std. Deviation	5.2	0.01	75.4	459	81.5	152.8	248	309	297	48
Median	24.7	14.75	385.9	9757.5	407.4	1449.5	268	154	8	15.7

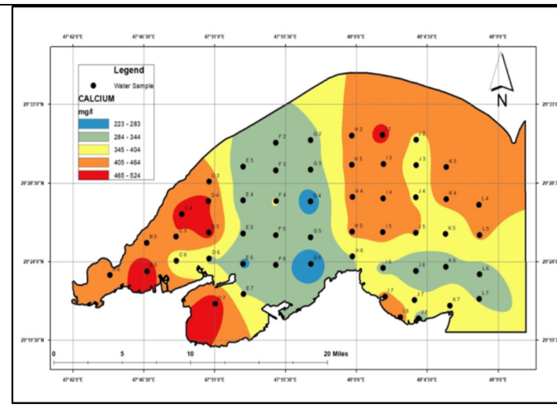
	pH	Turbidity	Conductivity	DO	Salinity	Temperature
Units		NTU	ms/cm	mg/l	ppt	ºC
Mean	8.2	5.9	60.2	6	40.2	27.8
Maximum	8.5	17.4	66.7	7.8	43.9	30.8
Minimum	8	1.9	46	4.5	30.1	23.9
Std. Deviation	0.1	3.4	4.8	0.5	3.6	1.8
Median	8.2	4.7	62.1	6.1	41.9	28.3

3.1.1 Elemental analysis of seawater

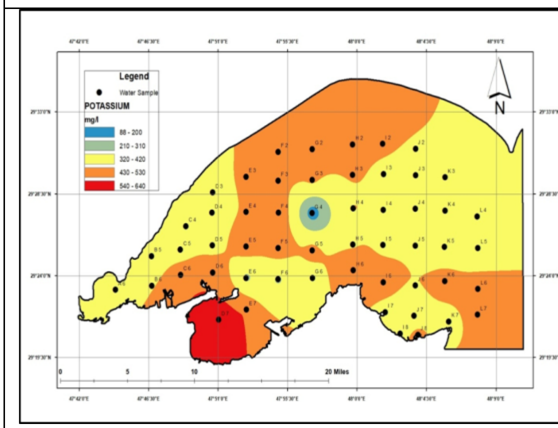
Heavy elements in seawater samples at surface layers were only obtained for barium (Ba); other targeted elements were undetectable. Figure 4 shows the values and distributions of elements measured in Kuwait Bay. The concentration of total dissolved Ba ranged from 14.73 to 14.76 mg/l, with an average value of 14.75 mg/l; indicating similar concentration of Ba all over the Bay. The concentration of Ba is more than seven times higher than the KEPA maximum limits of Ba in industrial water waste permissible to be discharged into the seawater (2 mg/l). High standard deviation of other measured elements in seawater, include: Calcium (Ca), Magnesium (Mg), Potassium (K) and Sodium (Na), clarifies the wide range of data. Lower values of concentrations of these elements are found in the middle area of the Bay, while the higher concentrations are measured at the west side near Al-Doha power plants and Sulaibikhat Bay.



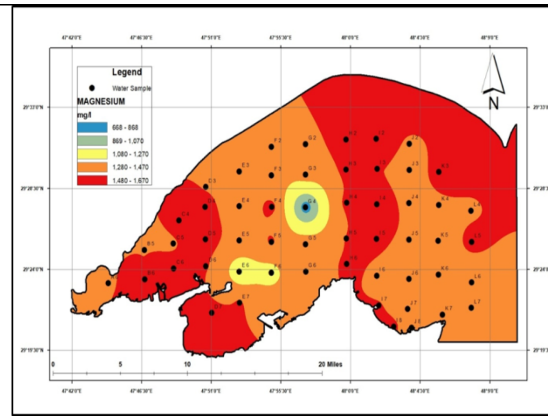
a) Barium



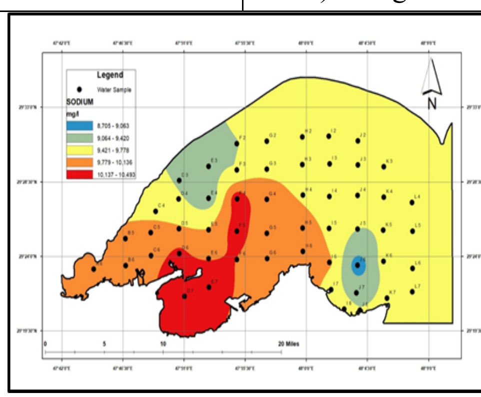
b) Calcium



c) Potasium



d) Magnesium

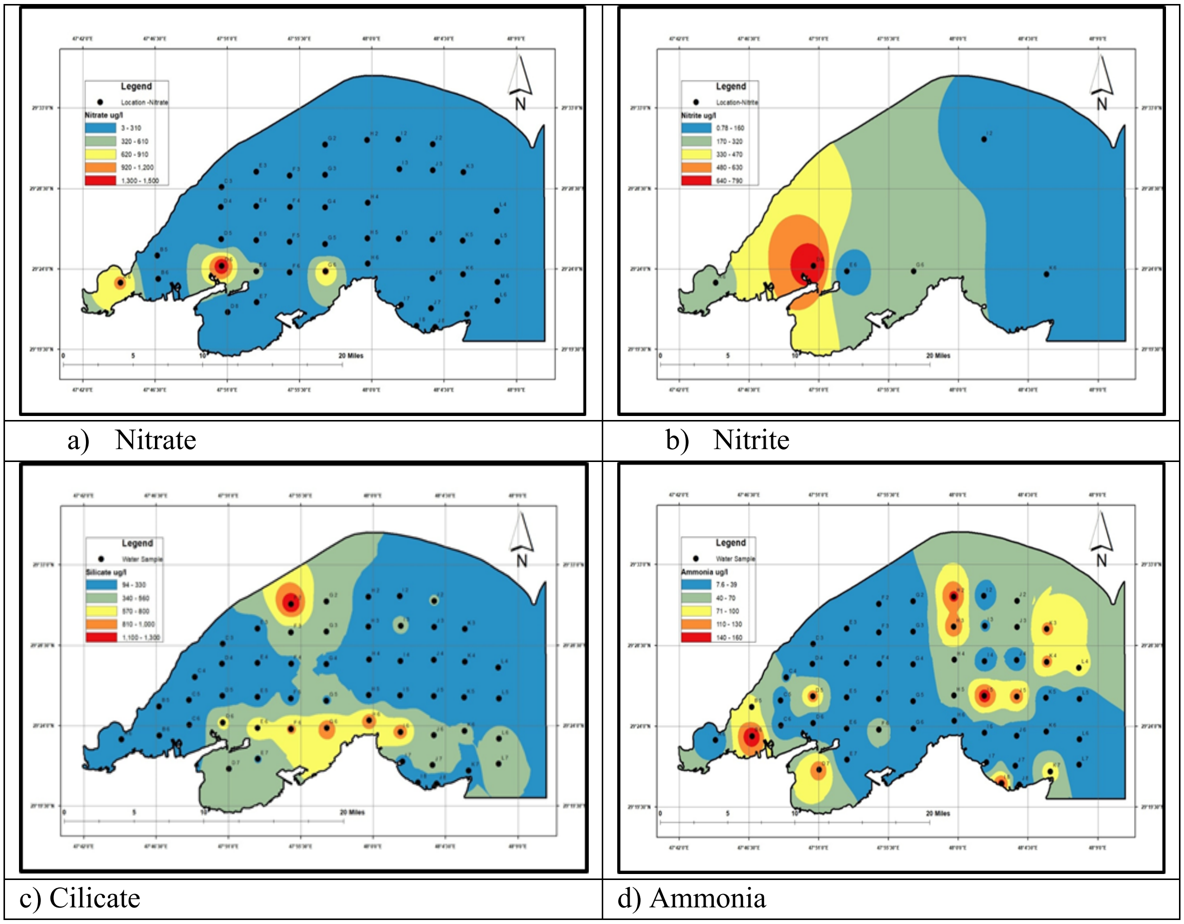


e) Sodium

Fig. 4. Distribution of elements measured in Kuwait Bay's seawater.

3.1 Nutrients in seawater

Figure 5 shows the values and distributions of the following nutrient contents: Nitrate (NO_3), Ammonia (NH_3), Nitrite (NO_2), and Silicate (SiO_4) in seawater of Kuwait Bay. The mean concentrations of NO_3, NH_3, Nitrite NO_2, and SiO_4 are 83, 43.5, 235 and 333 µg/l, respectively. Higher values of nutrient contents are displayed around Sulaibikhat Bay and Al-Doha and Subiyah power plants in the south-west of the Bay. Furthermore, the maximum concentration of NO_3, 1519 µg/l, exceeded the K-EPA limits, 94.7 µg/l.



a) Nitrate

b) Nitrite

c) Cilicate

d) Ammonia

Fig. 5. Distribution of measured nutrients in Kuwait Bay's seawater.

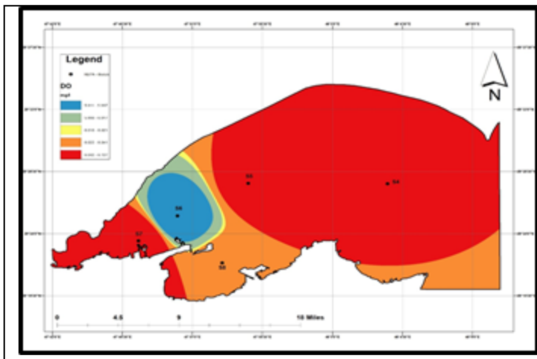
3.2 Physio–chemical analysis of seawater

Figure 6 shows the distribution of physio-chemical parameters in the surface water of Kuwait Bay. The Dissolved Oxygen (DO) variations are minimal across the Bay with a mean value of 6.03 mg/l. Minimum concentration of DO (4.5 mg/l) was recorded at the west of the Bay near the power plants and sewer discharges, where organic matter degradation is common. This value is close to the KEPA standard limit (> 4.5 mg/l). The mean pH in Kuwait Bay was calculated at 8.2 with a maximum value of 8.5 recorded near the power and desalination plants in the west side of the Bay. The pH value decreases towards the Bay's entrance at the east side with limited spatial variation in pH value (0.5). The pH range between 6.5 and 8.5 is acceptable according to KEPA standards.

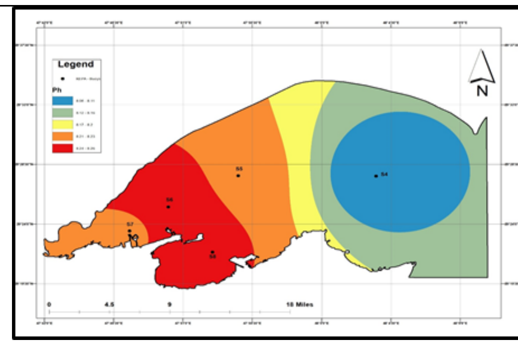
The mean surface water temperature was calculated to be 27.8 ^{0}C. The lower temperatures (23.9 ^{0}C) were recorded at the mouth of Kuwait Bay where water mixing is well, while higher values of water temperature (30.8 ^{0}C) were recorded near Doha and Subiya desalination and power plants and along the shore areas where water mixing is less. In general, the water temperature decreases towards the Bay's entrance at the east side with considerable spatial variation in temperature value (approximately 7 ^{0}C).

Highest salinity value (42.2 ppt) was located in the north western area, where the power and desalinization plants are controlling factor of salinity. The mean salinity value was calculated to be 40.2 ppt, while the minimum value was recorded at Sulaibikhat Bay (30.1 ppt); minimum conductivity value (55.6 mS/cm) was also recorded in the same area. In general, spatial distribution of conductivity values coincides with the salinity distribution pattern in Kuwait Bay seawater (Figures 6.c and 6.d).

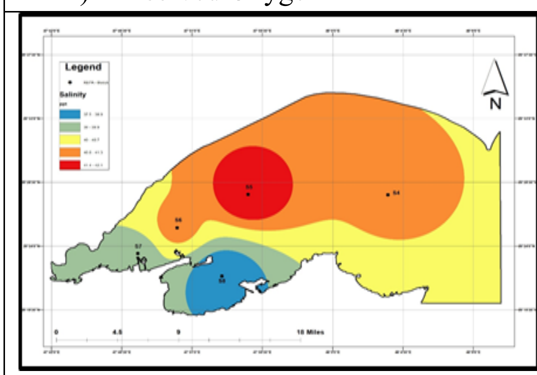
The highest turbidity (8.4 NTU) was found in waters in the middle of the Bay; i.e., near Khor Al-Sabiya where the water circulation pattern and sediment transport are higher than other parts of the Bay and decrease southwards. Accordingly, Kuwait water clarity increased gradually from south to north and from near-shore to off-shore with minimal value of 4.4 NTU and a mean value of 5.9 NTU.



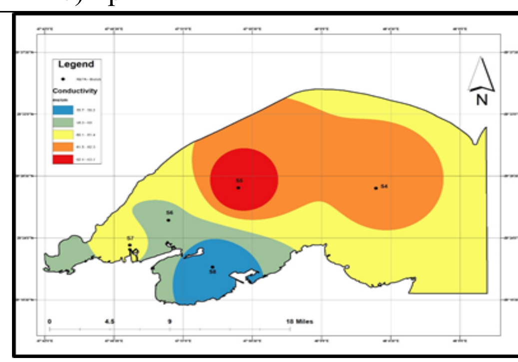
a) Disolved Oxygen



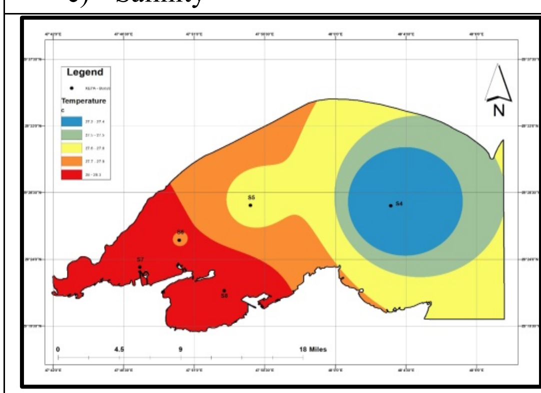
b) pH



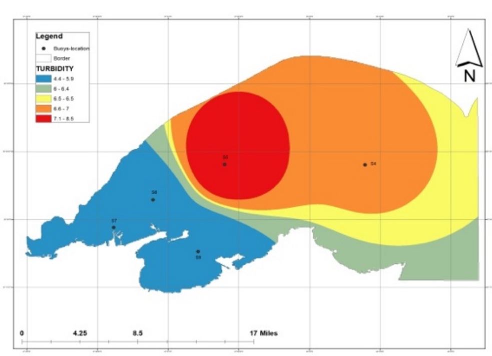
c) Salinity



d) Conductivity



e) Temperature



f) Turbidity

Fig. 6. Distribution of physio-chemical parameters in Kuwait Bay's seawater.

Table 2 presents the analysis of correlations of the measured physio-chemical parameters in the Kuwait Bay. The analysis showed that negative correlations occurred among temperature, salinity and turbidity, while there is a weak positive correlation between pH and salinity as well as between salinity and turbidity. Such negative and week correlations indicate that the variation of each measured parameter is controlled by different source input. The week correlation between pH and salinity may be attributed to a similar input of waste brine planned for production at the three power plants erected along Kuwait Bay.

Table 2. Pearson correlations between Kuwait Bay physical parameters

Correlations					
	pH	Turbidity	DO	Salinity	Temperature
pH	1				
Turbidity	-0.136	1			
DO	0.116	-.174*	1		
Salinity	0.104	.215**	-.221**	1	
Temperature	-.258**	-.415**	.277**	-.389**	1

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

3.4 Total suspended solids (TSS)

Figure 7 shows the distribution of the TSS concentrations in the seawater of Kuwait Bay. The TSS has range concentration values of a minimum 13.2 mg/l and a maximum of 39.2 mg/l, with a mean value of 25.3 mg/l. The highest value of TSS concentration occurs along the south onshore of the Bay where ports, power plants and sewer discharges are erected as well as in the middle of the Bay where the turbidity is high.

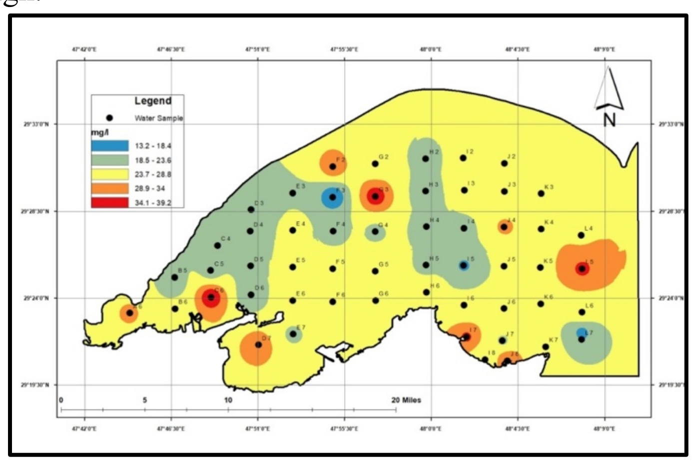


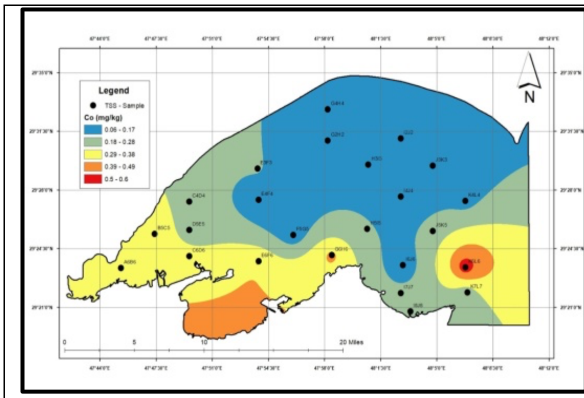
Fig. 7. Distribution map of TSS in Kuwait Bay.

3.4.1 Elemental concentration in the TSS and its distribution

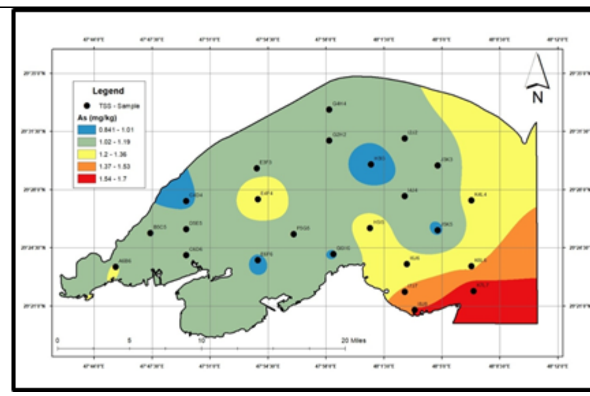
The element concentrations in the TSS show that Cr and Fe concentrations were the highest in the samples collected from all sites with average concentration values of 15.6 and 13.8 mg/kg, respectively (Table 3). The concentrations of the elements ranged from 0.1 (Hg) to 15.6 mg/kg (Cr). The mean concentrations of the elements in TSS decrease in the order of Cr (15.6), Zn (5.4), Se (4.5), Ni (3.8), As (1.2), Co (0.2) and Hg (0.1mg/kg); Pb was detected in 2 samples only with average concentration of 0.7 mg/kg (Figure 8). Ar and Se show high values at the Bay entrance in the eastside of the Bay and their values decrease in a systematic manner towards the west side of the Bay, while Ni, Co, Fe and Mn show high values at the south coast of the Bay as well as in Sulaibikhat Bay. On the other hand, Cr, Hg and Zn show higher values in the west part of the Bay near Al-Doha power plant and Shuwaikh port.

Table 3. Arithmetic mean concentrations and standard deviation of elements in TSS.

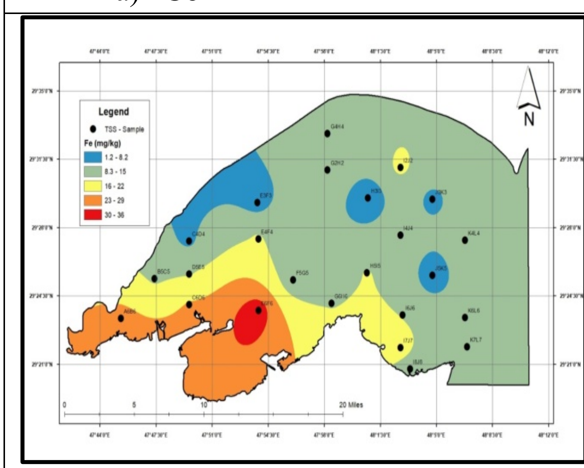
	Arsenic As	Cobalt Co	Chromium Cr	Iron Fe	Mercury Hg	Manganese Mn	Nickel Ni	Selenium Se	Zinc Zn
Units					**mg/kg**				
Mean	1.2	0.2	15.6	13.8	0.1	3	3.8	4.5	5.4
Maximum	1.8	0.7	19.3	36.4	0.36	4.4	12.9	10.3	19.5
Minimum	0.8	0	12.9	1.2	0	2.2	0	2.4	1
Std. Deviation	0.2	0.2	1.6	7.8	0.1	0.5	4	1.7	4.1
Median	1.2	0.1	15.6	14	0.1	2.9	1.3	4.3	5.1



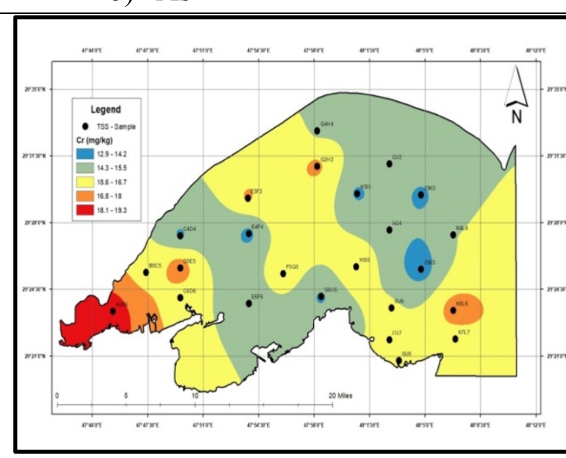
a) Co



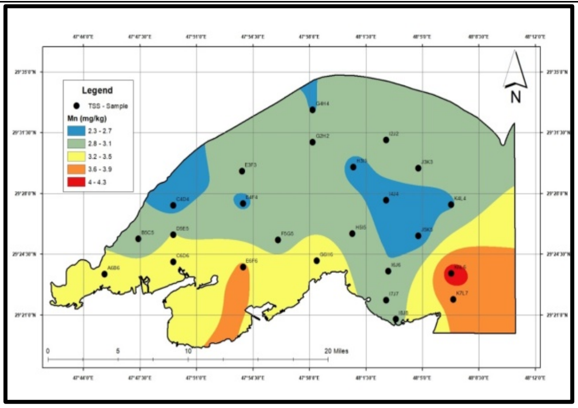
b) As



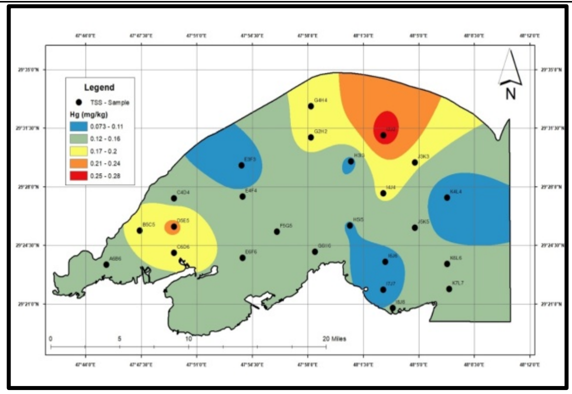
c) Fe



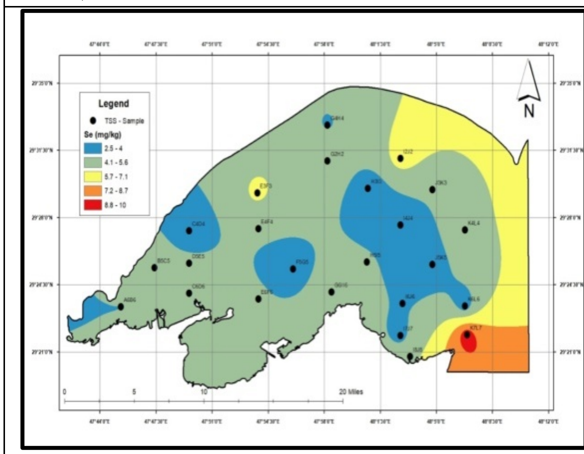
d) Cr



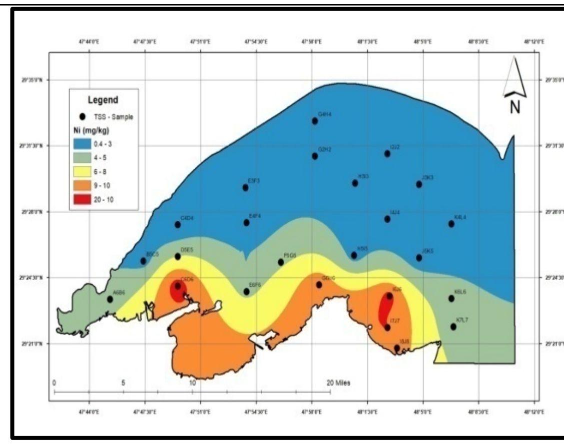
e) Mn



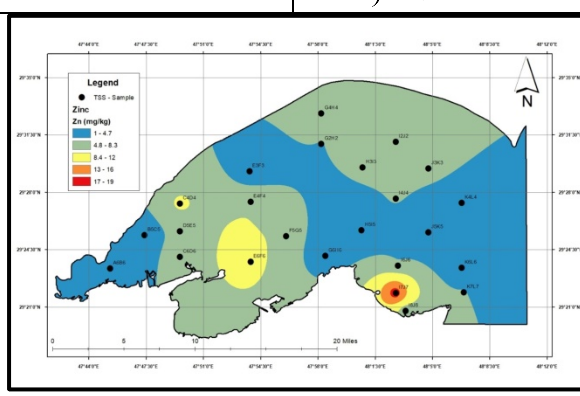
f) Hg



g) Se



h) Ni



i) Zn

Fig. 8. Distribution map of elements concentration in TSS in Kuwait Bay's seawater.

On comparison of the measured trace elements in the TSS with the Marine Sediment Quality Guideline (1999) and Ontario Provincial Sediment Quality Guideline (2018) (Table 3), it was found that the heavy elements in the TSS, except for Hg, are within acceptance limits. The result also shows that the heavy element contamination in TSS is higher than the contamination in seawater. This indicates that the sediments can adsorb and adhere to the contaminants to their bodies more than seawater.

Table 4. Comparison of the trace element concentration in the TSS in Kuwait Bay with Marine Sediment Quality Guideline (ISQGs) and Ontario Provincial Sediment Quality Guideline (OPSGs) (Ontario, 2018; CCME, 1999)

Element	Maximum Level Kuwait Bay	Lowest Effective Level ISQGs (mg/kg)	OPSGs
Cr	19.3	52.3	26
Fe	36.4	_	2%
Zn	19.5	124	120
Ni	12.9	_	16
Mn	4.4	_	460
As	1.2	7.24	6
Hg	0.36	0.13	0.3

3.5 Enrichment factor (EF) analysis

The elements content in Kuwait soils was determined by Al-Awadhi and Al-Shuaibi (2013) by analysing 184 top surface soil samples collected from different types of surface sediments. The results of the soil analysis are presented in Table 5 that shows the results of 5 toxic elements analysed in TSS samples. Their average concentrations are lower than the soil background values from the desert and coast of Kuwait by 1.6 to 22 times. Based on the finding of Al-Awadhi and AlShuaibi (2013), Mn is considered the baseline content of the reference element (B_{ref}) in Kuwait sediments. Accordingly, the results of the EFs for the elements in TSS in Kuwait Bay seawater are presented in Table 6, using Equation (1). Table 6 shows that most examined elements have EFs mean less than or equal to 20 with a decreasing order of their overall contamination degrees of TSS in the order of Cr>Zn>As>Ni>Co>. Table 7 presents five contamination categories recognized based on the EF values (Sutherland, 2000; Loska and Wiechuya, 2003). Thus, elements having maximum EF higher than 20, such as Cr (25.6) can be presented as a significant contamination. On the other hand, Co (1.6) represents minimal contamination, while Ni (4.9) and As (12.2) represent moderate and significant enrichments, respectively.

Table 5. Elemental contents in soil of Kuwait (mg/kg) compared to element contents in TSS collected in Kuwait Bay's seawater

Element	**Soil (N=184) mg/kg**	**TSS (N=24) mg/kg**	**Times lesser**
As	25.6	1.17	22
Co	3.7	0.2	18.5
Cr	25.6	15.63	1.6
Ni	22	3.7	6
Zn	18.4	5.3	3.4

Table 6. Results of the enrichment factor (EF) for different elements in the TSS samples

EF/Sample No.	As	Co	Cr	Ni	Zn
A6B6	8.8		27.8	6.2	2.0
B5C5	8.8	3.6	26.6	2.3	4.4
C4D4	8.9		26.5	1.3	25.1
C6D6	8.6		23.5	18.6	14.9
D5E5	9.1	1.7	27.9	0.0	10.9
E3F3	9.7	1.9	28.9	1.7	2.8
E4F4	12.7	0.5	25.1	0.9	21.1
E6F6	6.3	3.2	19.1	5.9	17.9
F5G5	10.4	0.2	29.4	0.0	18.8
G2H2	8.4	0.4	26.4	3.5	9.3
G4H4	10.8	0.0	27.2	1.7	19.1
G6H6	6.4	3.6	18.8	13.7	2.5
H3I3	7.4		25.9	1.6	14.6
H5I5	11.4		27.6	2.0	2.5
I2J2	9.6	1.1	25.2	4.1	13.1
I4J4	9.8	1.2	27.9	1.2	13.1
I6J6	10.8	0.4	27.2	20.0	11.5
I7J7	11.3		25.3	16.7	43.2
I8J8	12.8	2.2	26.9	0.0	10.1
J3K3	9.2		23.4	3.6	12.8
J5K5	9.6		27.6	1.2	3.0
K4L4	11.9	0.9	28.5	1.7	8.8
K6L6	7.0	4.2	19.7	4.3	1.6
K7L7	11.9	1.1	21.3	5.1	9.2
Average	9.6	1.6	25.6	4.9	12.2

Table 7. Contamination categories based on EF values (Sutherland, 2000)

Enrichment factor (EF)	Comment
EF < 2	Deficiency to minimal enrichment
EF = 2–5	Moderate enrichment
EF = 5–20	Significant enrichment
EF = 20–40	Very high enrichment
EF > 40	Extremely high enrichment

4. Discussion

Kuwait Bay is considered as one of the most important marine features in the Arabian Gulf. The location of the Bay is surrounded by residential areas, industries, harbours, and Jaber Causeway. Several sources of potential stress and pollution were identified around the Bay mainly from sewage and Industrial effluent. The only polluted element detected in the seawater was Ba. The possible pathways by which Ba can enter an aquatic environment include atmospheric transport and deposition, sediment suspension and biological behavior. The emitted source of Ba could possibly be associated with lubricating oil additives, fuel synthesis, fuel combustion, phosphate fertilizers, and sewage sludge (Al-Ghadban and El-Sammak, 2005).

Large amounts of nutrients were recognized in seawater; namely nitrate (NO_3), ammonia (NH_3), nitrite (NO_2), and silicate (SiO_4) in Kuwait Bay. Major contributors to these nutrients are Shatt Al-Arab, sewage outlets, urban run-off, and particulates deposited by dust storms (Al-Yamani *et al*. 2004; El-Sammak *et.al.,* 2005). High concentrations of nutrients were found around emergency sewer outlets, where effluents and raw sewage discharges exist. This confirms the role of contributing anthropogenic activities, including wastewater from treatment plants, in increasing nutrients influx such as nitrites and ammonia in Kuwait Bay (Al-Abdulghani, *et al*.,2013). Generally, concentrations of these nutrients increase during winter and spring (Al-Yamani *et al.,* 2004).

The lower values of Dissolved Oxygen (DO) recorded in some areas in Kuwait Bay can also be associated with low mixing of the water column. Fluctuation of DO levels over the Bay may be due to many factors such as: high water temperature, sea plants, wave action and longshore currents direction, besides the amount of discharged organic matters such as sewage and industrial waste (Al-Yammani, *et al.,* 2004; Al-Shemmari, 2000). The mean concentration of DO in the Bay was calculated to be 6 mg/l, and according to Weiner (2000), the seawater with DO concentration between 4.5- and 6.5mg/l is classified as moderately polluted water. The DO reduction due to high temperature besides sewage waste impact can also minimize metabolic rates which produce dwarfed species and cause different types of deformations for marine species such as thin walled and less ornamentation in shells (Boltovasky, *et al.,* 1991; *Alve,* 1991).

The limited pH variation in surface water of Kuwait Bay can be linked to the following factors: sewage and waste brine discharges, and high productivity and decomposition rates (Al-Shemmari*, et al*., 2002; Al-Yamani, *et al*., 2004). However, the high mixing of seawater pH near the brine outfall will most likely affect the surrounding waters (El–Anbaawy, *et al.,* 2017). However, considerable spatial variations in temperature values (approximately 7 °C) were recorded across the Bay. Al-Rashidi *et al.* (2009) indicated that desalination and power plants contribute 13% of decadal increase in the seawater temperature in Kuwait Bay and the seawater temperature increases by 0.6 ºC per decade; i.e., about three times higher than the global average rate reported by the Intergovernmental Panel on Climate Change (IPCC) (Al-Mutairi *et al.,* 2014b). Also, the increase of seawater temperature directly affects the marine plants and fish and changes their life (Mann and Lazier, 2005). Therefore, high seawater temperature weakens the fish immune system and creates unstable conditions that may lead to massive Fish kill (Al-Marzouk, *et al*., 2005).

Temperature and salinity could affect directly the marine fauna and flora and alter marine ecosystem (Dawoud, 2012; Al-Dousari, *et al.,* 2012). Also, the increase of temperature and salinity will cause the concentration and saturation of oxygen to decrease, and may result in disorientation of marine life (Uddin, 2014). However, the salinity spatial distribution showed little variations throughout the Kuwait Bay. The lower salinity in Sulaibikhat Bay, for example, may be attributed to the large amounts of sewage discharges (fresh water) in that area, while areas of Al-Doha and Shuwaikh power plants, where the hyper saline brine water is released, did not show significant salinity variation, indicating that the salinity of the brine discharged into the seawater has a limited spatial impact on the seawater salinity of the Bay. Generally, the mass influx of fresh water flowing from Iraq's rivers play a vital role in salinity variation in Kuwait Bay (Al-Abdulghani *et al*., 2013).

The turbidity values fluctuate over the seawater of Kuwait Bay, the highest turbidity level occurs in its center. This finding also concurs with the study of Al-Sahli (2009). Shatt Al-Arab discharge and dust storms may play an important role in increasing the turbidity of Kuwait Bay's waters (Al-Ghadban and A. El-Sammak, 2005), beside anthropogenic activities taking place around the Bay, such as the Subiya and Doha power plants (Al-Rashidi, *et al.,* 2009).

Furthermore, the distribution pattern and genesis of total suspended solids (TSS) indicate the possibility of tidal currents' effect and dust fallout's contribution (Al-Ghadban and El-Sammak, 2005) as well as, to a lesser extent, the effect of Shatt Al-Arab—especially in the northeastern part of Kuwait Bay. According to Al-Ghadban and El-Sammak (2005), the counter- clockwise eddy currents and the effect of the bottom currents are the main reasons of trapping the sediments in the water column.

The enrichment factor EF can be used to distinguish between metals produced from human activities and those from natural procedures, and to assess the level of anthropogenic influence. Cr shows maximum enrichment relative to the upper continental crustal component (Mn), while Zn, As, Ni and Co show lesser enrichment, respectively. Clear fluctuating range in the concentrations of hazard elements in Kuwait Bay could be attributed to different anthropogenic inputs like industrial. Locally, there are many sources of the anthropogenic activities surrounding Kuwait Bay including the desalination and power plants, rain and sewage discharges and recreational activities. These anthropogenic influences can affect the ecosystem of Kuwait Bay. For example, Bu-Olayan and Thomas (2008) have found out that the concentrated trace metal found in mullet fish reared in Kuwait Bay were higher than the mullets found in other coastal waters. According to Al-Ghadban *et al.* (2002), the desalination and power plants processes are responsible for 22% of total water pollution where the discharged sewage are responsible of 43% of total water pollution in Kuwait Bay.

5. Conclusions

In this study, the intensive anthropogenic activities along the coastline of Kuwait Bay have contributed in changing seawater quality in some areas of the bay. Since Kuwait has invested in many projects around the Kuwait Bay, the results of this study will be useful for the integrated and sustainable development for planning and implementation of new coastal projects. Thus, the spatial variations of seawater characteristics, carried out in this study, will be important parameters for assessing the probability and residual impacts on the marine environment. The present investigations did not show that the entire study area is polluted or quality-reduced except some parts close to nearshore waters of Kuwait Bay, where sources of the anthropogenic activities exist including the desalination and power plants, rain and sewage discharges and recreational activities.

TSS analysis showed moderate element pollution enrichment, on average, relative to the upper continental crustal component (Mn). Potential impacts of salinity and temperature at the vicinity of the power plants outlets were clearly recognized; found to be 3.7 ppt and 3ºC above mean salinity and temperature of seawater in Kuwait Bay, respectively. While DO reduction rate was recognized near in the vicinity of sewage water outlets and it was found to be 1.5 mg/l below mean DO value. The increase of Biological Oxygen Demand (BOD) will cause Fishkill in the areas where the salinity and temperature are high especially in summer times.

ACKNOWLEDGEMENTS

1- The National Unit for Environmental Research and Services – NUERS with Project No. SRUL01/13, Faculty of Science, Research Sector, Kuwait University.
2- The Environmental Public Authority – EPA for data source.

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Submitted: 20/09/2021
Revised: 03/01/2022
Accepted: 04/01/2022
DOI: 10.48129/kjs.16319