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Environmental Assessment and Evaluation of Anthropogenic Impacts on Sulaibikhat Bay Tidal Flat Area, Kuwait

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Abstract: Sulaibikhat Bay is situated along the northern coastline of Kuwait. It occupies the southwestern part of Kuwait Bay, between latitudes 29° 19″ and 29° 24″ north and longitudes 47° 50″ and 47° 55″ east, and covers a total area of about 45 km^2. The lagoon bay is a shallow (7-8 m) tide-dominated embayment with a very soft muddy flat basin. It has a simple bottom topography, with a maximum water depth of about 8 m. The main objectives of this study is to delineate the water quality of Sulaibikhat Bay, to study the input of anthropogenic activities on the water quality, to recommend methods to improve water quality of the bay and to study the sediment and their heavy metals contents. About 15 marine water and 15 sediment samples were collected along the Sulaibikhat Bay. The samples were analyzed chemically for Total Petroleum Hydrocarbons, Trace Metals, and Total Organic Carbon. Also Biological Oxygen Demand, Chemical Oxygen Demand, and physically analyzed for Dissolved Oxygen, temperature, salinity, PH, Conductivity and nutrient levels. Data analyses for sediment and water reveal that the level of contamination is within the international standard however there are some higher reading of trace metals and other chemicals from the outlets of the power station more than the inlets. As, two sources or large input of trace metals in the coastal water of Sulaibikhat Bay are suggested in this study namely; estuarine fluviatile source of Shatt Al-Arab trace metal rich and dust fallouts.

Keywords: Heavy Metals, Nutrients, Anthropogenic Impact, Tidal bay, Water Quality, Bottom Sediments, Sewage Outlets, Contaminations

1. Introduction

Sulaibikhat Bay is a part of the large Kuwait Bay (Figure 1), mainly formed of soft sediments and shallow depth which has weak currents and low wave energy [1]. The lagoon bay is a shallow tide-dominated embayment with a very flat basin [2]. It has simple bottom topography, with a maximum water depth of about 8 m. The most important features are the large extensive muddy tidal flats (20 km^2) and the main tidal channel. The study focuses on update of environmental profile of Sulaibikhat Bay and to evaluate the anthropogenic impacts on its water quality and sediments. Hydrodynamics of the bay is very weak and is tide dominated. Tidal range is between 3-4 meters. Long shore current is from north to south. There are several out falls along the Sulaibikhat Bay: the Al-Ghazali out let, Al-Jahara out let, Entertainment city out let, Hospital out let and Doha Power Station east and west out lets.

The objectives of this paper is to delineate the water quality of Sulaibikhat tidal flat by studying the physical and chemical parameters (dissolved oxygen, nitrite, nitrate, ammonia, phosphate, silicate, total organic carbon, total petroleum hydrocarbon and trace metals); the input of anthropogenic activities on the water quality; detect the bottom sediment pollution, and propose mitigation measures to improve water quality.

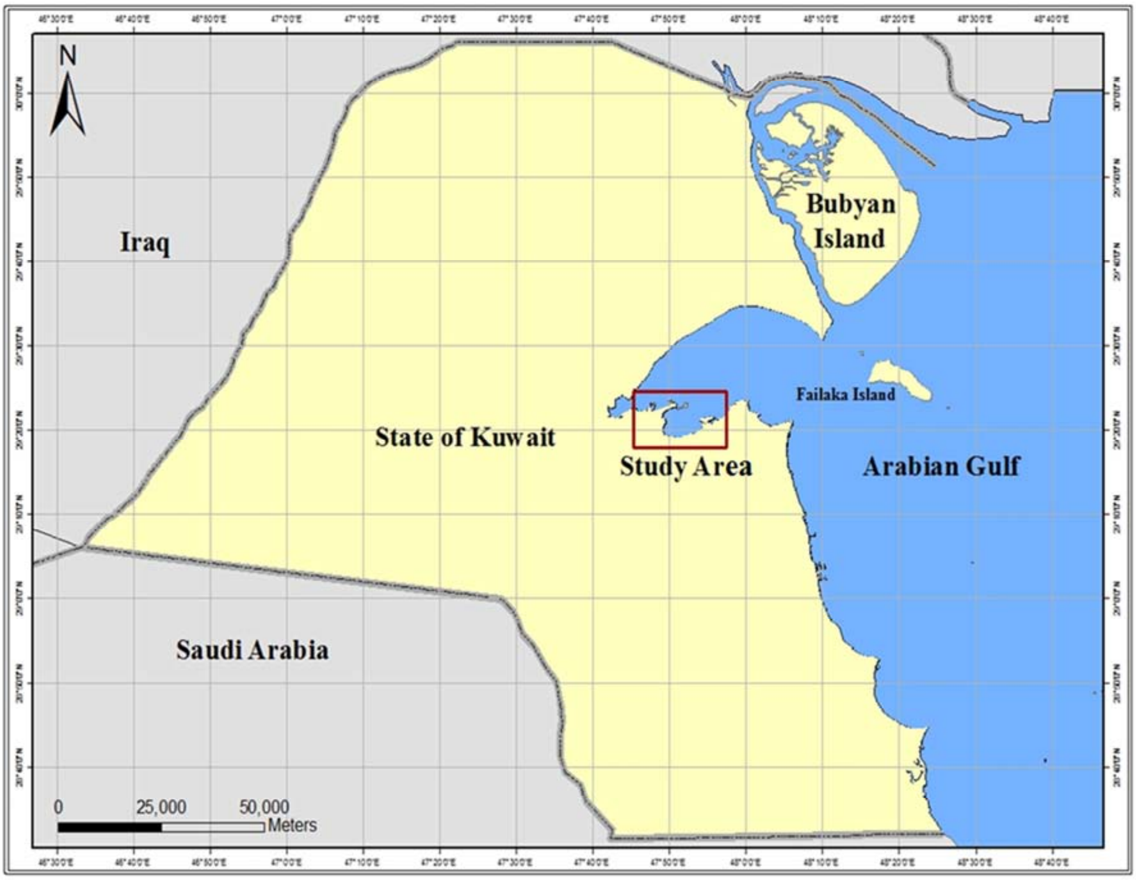


Figure 1. *Location map of the study area.*

2. Literature Review

The Arabian Gulf has been subject to several wars during the last three decades (1980-2003). Therefore, large number of investigations have emphasized the consequences of the Gulf war on the marine environment, and the substantial changes associated with the oil spills and toxic heavy metal contamination. Of these, important investigations were conducted by [3]and [4]. The previous studies document the continuous monitoring of the changing environmental impacts that were associated with physical and biological conditions of Arabian Gulf [5]. Stress imposed by diverse input of pollutants into the marine environment is likely to have severe consequences as a result of the Gulf War. Therefore, maintaining good marine environmental quality is crucial for several socio-economic reasons [6]. [7] studied the trace elements at bottom sediments of the Kuwait Bay.

[8] and [9] studied the oil pollution around the bay and found several environmental degradation spots. In addition, [1] studied the sedimentological properties of the bay and found that the degree of contamination was increasing rapidly. [8] studied the mercury level within Kuwait Bay. While the trace metals within the sediment in Kuwait and Sulaibikhat bays were investigated by [10] and [11]. Moreover, they found that the trace metals within the entire water of the bays were recorded with different concentrations. From the above citations, the fate and flux of pollutants will go up either in the bottom sediments, water or in the fishes of the site. [12] studied the mineralogical characteristics of surface sediment in Sulaibikhat Bay. Their study shows abundance of carbonate, clay minerals, feldspar, pyrite, gypsum and muscovite in different parts of the Bay. [13], studied the secular variation of mineralogical contents in the bottom sediments of Sulaibikhat Bay. [14], studied the sediment deposition rates in the Kuwait Bay. Five bottom sediment cores from the Kuwait Bay were dated using 210Pb and 137Cs radionuclides. For evaluating the sedimentation rate two methods were applied: geochronology with the constant rate of supply unsupported 210Pb (CRS model) and the Weibull distribution of anthropogenic 137Cs. [15], studied the trace metal concentrations in the surface sediments of Sulaibikhat Bay and most of them were found to be higher than the allowable limits. [16], and [12] studied the microbiological water quality along the Kuwait Waterfront Project. [17] studied the marine status of the Gulf area.

[18], studied the petroleum hydrocarbons and trace metals

in the nearshore Gulf sediments and biota before and after the 1991 Gulf war. Immediately following the Gulf war, a survey was organized to determine the extent and degree of contamination by petroleum hydrocarbons and trace metals that entered the Gulf from the massive oil spill and oil field fires in Kuwait. Between June-October 1991 samples of near shore sediments, bivalves and fish were collected from Kuwait, Saudi Arabia, Bahrain, UAE and Oman. [19] studied the metals pollution in marine sediments of the United Arab Emirates creeks along the Arabian Gulf shoreline. The study of trace metals in the marine environment of the United Arab Emirates is very important since coastal regions are presently experiencing a phenomenal rate of growth in terms of industrial and urban development. Special emphasis is given to enclosed areas and creeks due to the vastness of these parts of the country's waters, their richness in marine life. Therefore, it is highly recommended to minimize the discharged loads of trace metals and other organic pollutants into these fragile ecosystems.

3. Materials and Methods

Water and sediment marine samples were taken and collected from fifteen stations along the Sulaibikhat Bay during spring of 2016 (Figure 2). The collected samples have been analyzed to determine the concentration of (BOD, COD, TPH, TM, TOC, TSS). Water temperature, PH, Salinity and dissolved oxygen. The physical parameters were measured in-situ using a calibrated hydro lab quanta multi parameter instrument directly in the field. Spectrophotometer was used to analyze the heavy metals, nutrients, phosphate, silicates and ammonium and COD. Ammonia and phosphate were measured spectroscopically at 425 nm radiation by making a color complex with Nessler's reagent.

Table 1. *Comparison of the certified and obtained values (mg kg-1 dry wt) for trace metal concentrations in standard reference material SRM 1646.*

	Cu	Zn	Cd	Pb	Ni
Certified	18.0 ± 1.5	138.0 ± 5	0.360 ± 0.050	28.2 ± 1.8	32.0 ± 3
Obtained	17.2 ± 1.4	137.0 ± 10	0.405 ± 0.051	27.2 ± 1.2	30.0 ± 2.5

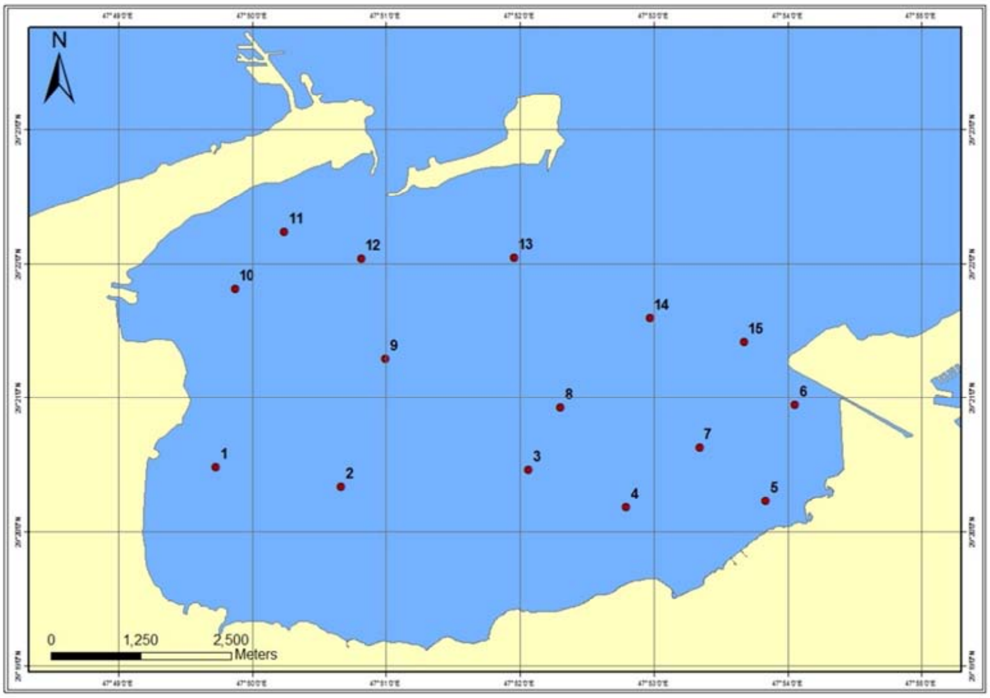


Figure 2. *Sampling locations.*

4. Results

4.1. Environmental Parameters in Water Samples

Temperature: The average temperature of water samples was 25.6°C for all samples in 15 Stations while maximum temperature was 26.1 in Station 12 and minimum was 25.2 C in Station 4.

pH: The average pH of water samples was 7.99 for all 15 stations samples while maximum pH was 8.2 in Station 9 and minimum was 7.88 in Station 14 (Figures 3 and 4).

Salinity: The average salinity of water samples was 41.84 ppt. for all 15 Stations samples while maximum salinity was 42.2 ppt. in Station 1 and minimum was 4.12.

Conductivity: From the results of present investigation it was observed that electrical conductivity of all Stations are almost similar (Figure 3).

Dissolved Oxygen: The average dissolved oxygen of sea water samples was 4.662 mg/L for all 15 Stations samples while maximum concentration was 4.92 mg/L in Station 4 and minimum was 4.21 mg/L in Station 10 (Figure 5).

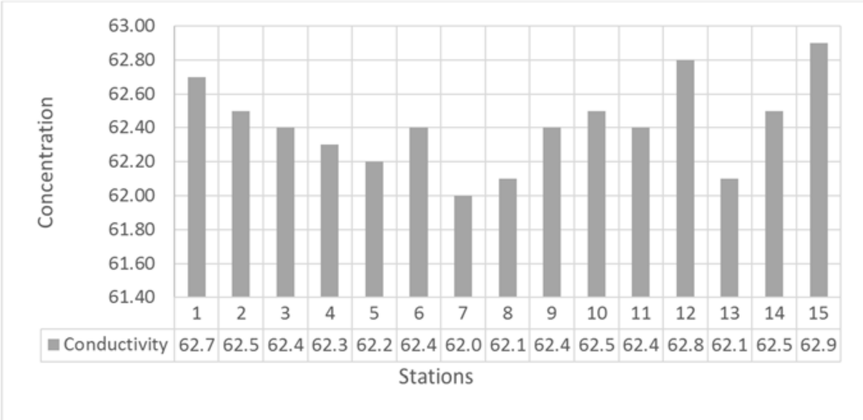


Figure 3. *Conductivity of sea water in Sulaibikhat Bay.*

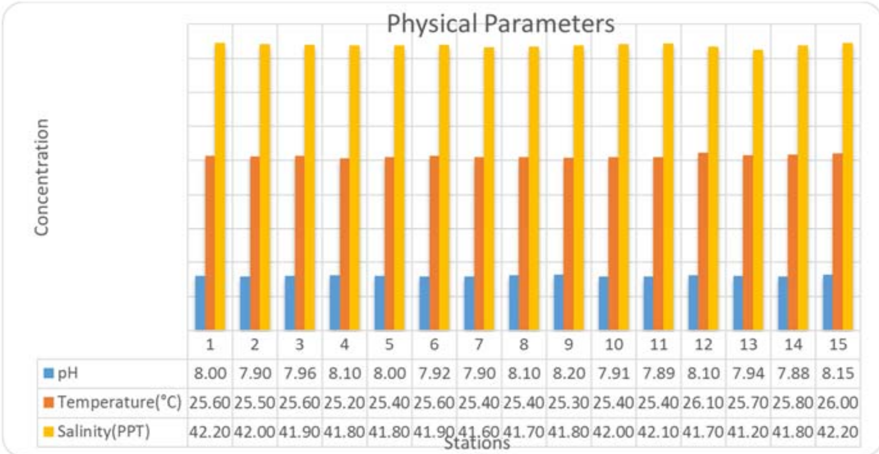


Figure 4. *Physical parameters of sea water in Sulaibikhat Bay.*

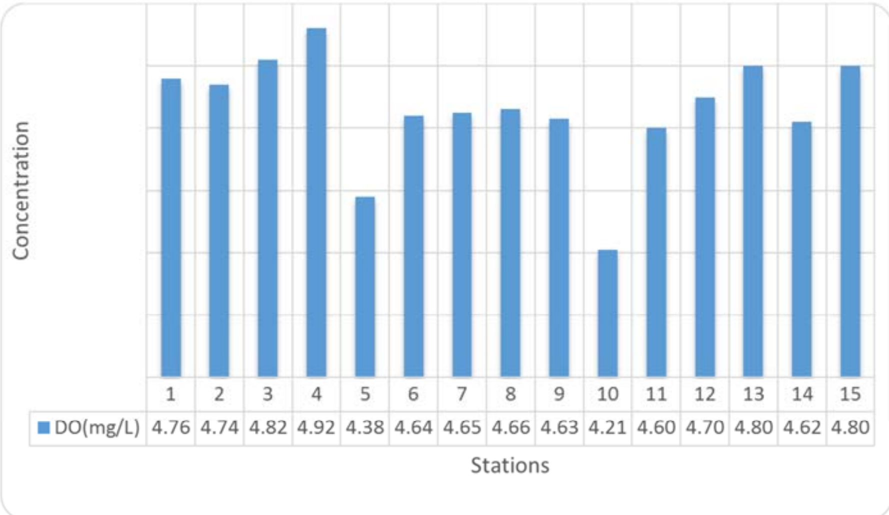


Figure 5. *Dissolved Oxygen in water samples.*

Biochemical Oxygen Demand (BOD): The average BOD of sea water samples was 18.73 mg/L for all 15 Stations samples while the maximum concentration was 24.0 mg/L in station 11 and minimum was 14 mg/L in Station 13 (Figure 6).

Chemical Oxygen Demand (COD): The average COD of sea water samples was found as 94.3 mg/L of all 15 stations samples and maximum concentration were found as 120 mg/L in station 14 and minimum was found as 72.5 mg/L in station 9 (Figure 6).

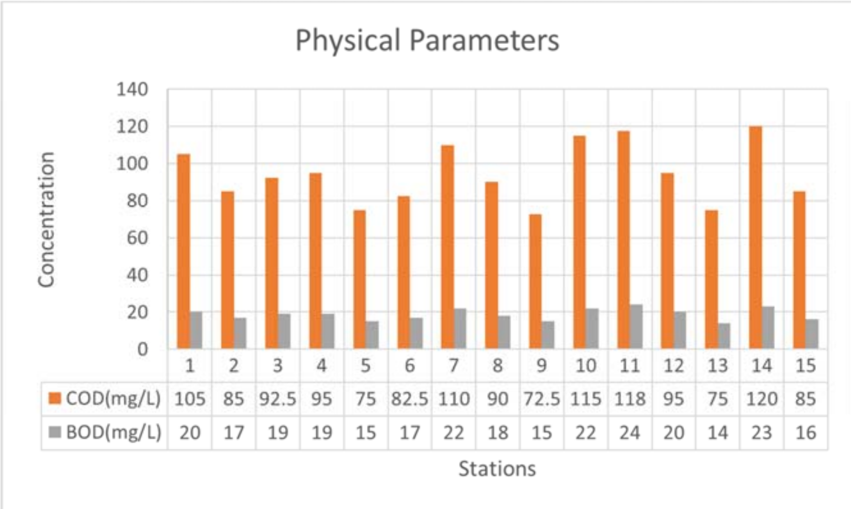


Figure 6. BOD & COD of sea water in Sulaibikhat Bay.

Total Suspended Solids (TSS): The average TSS of sea water samples was 77.83 mg/L for all 15 Stations samples (Figure 7) while maximum concentration was 119.5 mg/L in station 10 and minimum was mg/L in Station 2.

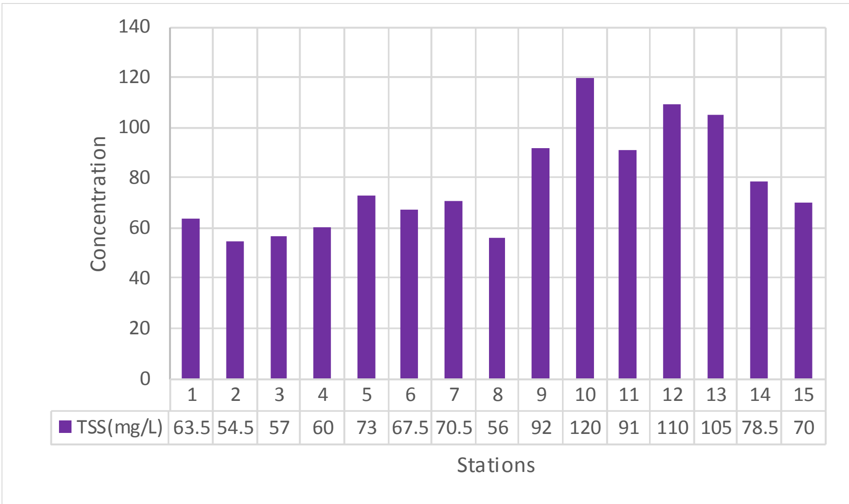


Figure 7. TSS of sea water in Sulaibikhat Bay.

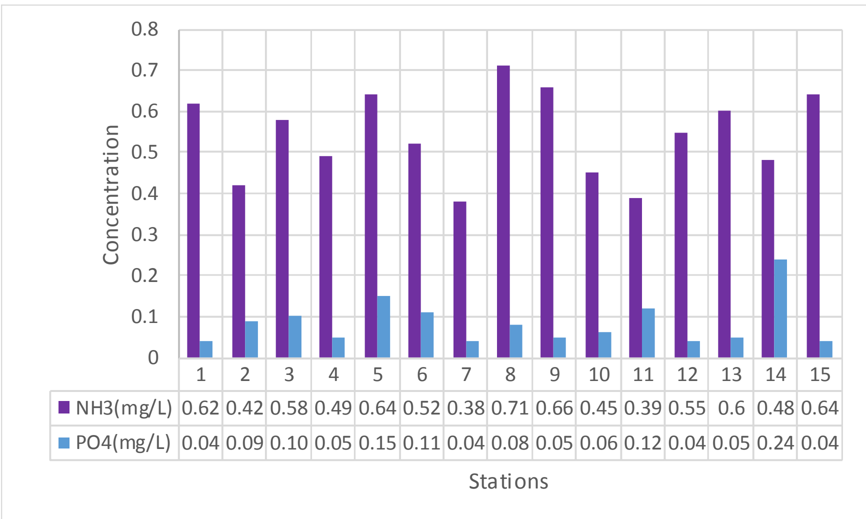
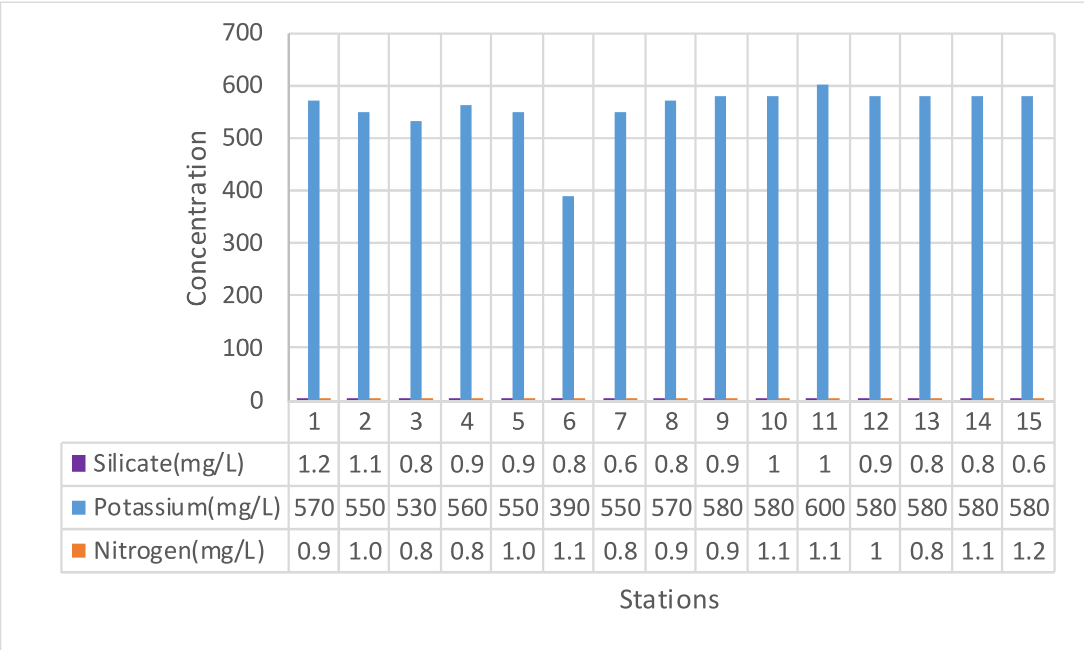


Figure 8. Anions of sea water in Sulaibikhat Bay.

Ammonia (Nitrogen): The average concentration of ammonia in sea water samples was 0.54 mg/L in all 15 Stations samples while maximum concentration was 0.71 mg/L in Station 8 and minimum was 0.38 mg/L in station 7 (Figure 8). *Phosphate:* the average concentration of phosphate in sea water samples was 0.084 mg/L in all 15 Stations samples while maximum concentration was 0.24 mg/L in station 14 and minimum was 0.04 mg/L in Station 7 (Figure 8). *Silicates:* the average concentration of silicate in sea water samples was 0.866 mg/L in all 15 Stations samples while maximum concentration was 1.19 mg/L in Station 1 and minimum was 0.63 mg/L in Station 7. *Potassium:* the average concentration of potassium in sea water samples was 556 mg/L in all 15 Stations samples while maximum concentration was 600 mg/L in Station 11 and minimum was 390 mg/L in Station 6. *Nitrogen:* the average concentration of nitrogen in sea water samples was 0.99 mg/L in all 15 stations samples while maximum concentration was 1.15 mg/L in Station 1 and minimum was 0.81 mg/L in station 13 (Figure 9).

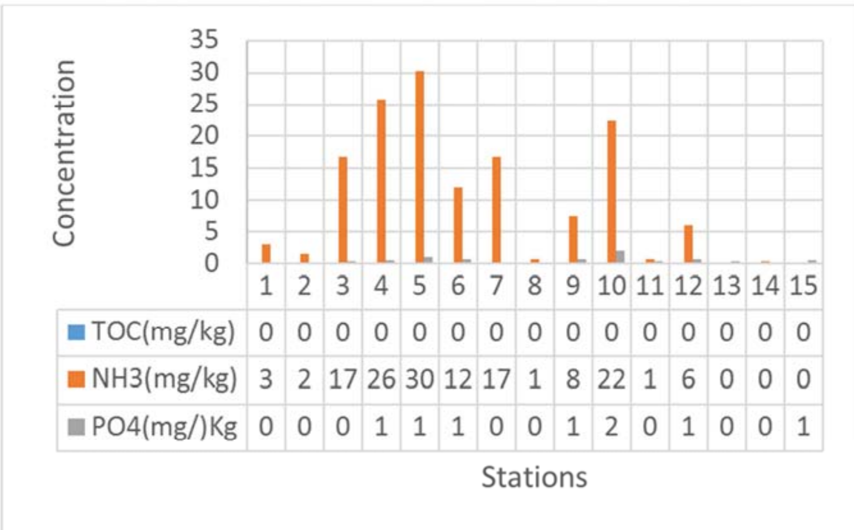


Stations	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Silicate(mg/L)	1.2	1.1	0.8	0.9	0.9	0.8	0.6	0.8	0.9	1	1	0.9	0.8	0.8	0.6
Potassium(mg/L)	570	550	530	560	550	390	550	570	580	580	600	580	580	580	580
Nitrogen(mg/L)	0.9	1.0	0.8	0.8	1.0	1.1	0.8	0.9	0.9	1.1	1.1	1	0.8	1.1	1.2

Figure 9. *Si, K and N concentration in sea water from Sulaibikhat Bay.*

Total Organic Content, NH_3 *and* PO_4 *in Marine Sediment:*

The organic content varied between 0.041 mg/kg to 0.184 mg/kg with an average 0.098 mg/kg. TPH was not detected in any of the sediment samples. Ammonia was detected in the range between 0.29 mg/kg to 30.32 mg/kg while Phosphate was detected in the range between 0.11 to 2.04 mg/kg (Figure 10).



Stations	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
TOC(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NH3(mg/kg)	3	2	17	26	30	12	17	1	8	22	1	6	0	0	0
PO4(mg/)Kg	0	0	0	1	1	1	0	0	1	2	0	1	0	0	1

Figure 10. *Chemical analyses of marine sediments.*

Nitrogen, Potassium, Phosphorous and Silicates:

Nitrogen varied between 1.23 mg/kg to 30.9 mg/kg with an average 13.12 mg/kg. Maximum concentration was found in Station 5 while minimum was found in Station 11. Potassium concentration varied between 993.3 mg/kg to 3674.5 mg/kg with average concentration 2708 mg/kg. Phosphorous concertation was varied between 0.06 to 0.66 mg/kg with average concentration 0.19 mg/kg. Maximum concentration of PO_4 was 2.04 mg/kg in Station 10 and minimum concentration was 0.0 in Station 8. Silicate concentration varied between 269 mg/kg to 372 mg/kg with average concentration 316 mg/kg. Maximum concentration was 372 mg/kg in Station 9 and minimum concentration was 269 mg/kg in Station 10 (Figure 11).

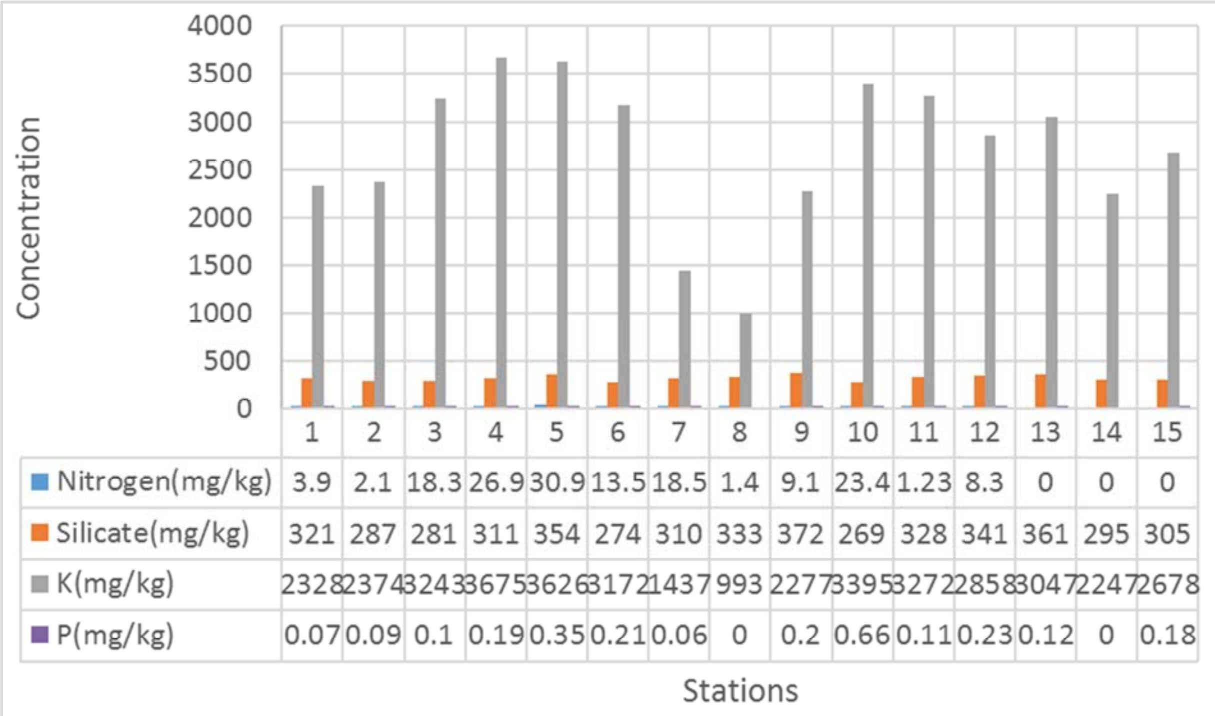


Figure 11. *Nutrient analysis.*

4.2. Distribution of Trace Elements in Bottom Sediments:

Cadmium: The concentration of Cadmium in sediment samples were found in all stations. Average cadmium concentration is 5.22 mg/kg of the 15 stations samples and maximum concentration were found as 6.13 mg/kg in station 12 and minimum were found as 4.38 mg/kg in station 12.

Possible sources of Cd high concentration in the study area were Al-Ghazali outlet that discharges sewage and industrial waste water from the Shuwaikh industrial area.

Chromium: The concentration of chromium in sediment samples were found in all stations. Average chromium concentration is 29.17 mg/kg of 15 stations samples and maximum concentration were found as 40.43 mg/kg in station 1 and minimum were found as 19.1 mg/kg in station 7. High Cr concentrations was detected in areas close to Al-Ghazali outlet, Kuwait University, Kuwait Institute for Scientific Research as well as in the northern and western part of the study area (Table2).

The back ground level of Cr in Sulaibikhat Bay sediment was 80.00 mg/kg (Anderlini et al. 1986). It is concluded that Cr Concentration in the study area is lower than the back ground level.

Cobalt: The concentration of cobalt in sediment samples were found in all stations. Average cobalt concentration is 22.06 mg/kg of 15 stations samples and Maximum concentration were found as 24.5 mg/kg in Station 15 and minimum were found as 17.31 mg/kg in Station 7. Possible sources of Co Concentration in the study area are Al-Ghazali outlet that discharges sewage from Shuwaikh industrial area.

Copper: The concentration of copper in sediment samples were found in all stations. Average copper concentration is 19.02 mg/kg of 15 station samples and maximum concentration were found as 36.08 mg/kg in station 5 and minimum were found as 5.49 mg/kg in station 8. Possible sources of Cu high concentration in the study area were discharge from the new Chest Hospital, discharge from Free Zone outlet, oil spills from Shuwaikh harbor, the back ground level of Cu in Sulaibikhat Bay sediment was 23.00 mg/kg [20]. It is concluded that Cu concentration in the study area is higher than the back ground level.

Iron: The concentration of iron in sediment samples were found in all stations. Average iron concentration is 8060 mg/kg of 15 stations samples and maximum concentration were found as 10200 mg/kg in station 5 and minimum were found as 4018 mg/kg in Station 8. High concentration of Fe was recorded in an area close to the shoreline, Al-Ghazali outlet, the Free Zone outlet, and Shuwaikh port in the northern part of the study area (table 2). The back ground level of Fe in Sulaibikhat Bay sediment was 16000 ppm [20]. It is concluded that Fe concentration in the study area is lower than the background level.

Lithium: The concentration of lithium in sediment samples were found in all stations. Average lithium concentration is 12.02 mg/kg of 15 stations samples and maximum concentration were found as 14.78 mg/kg in Station 11 and minimum were found as 10.04 mg/kg in station 2. High Li was recorded in areas close to Al-Ghazali outlet as well as in the northern and the western of the study area (Table 2). Possible sources of Li concentration in the study area are Al-Ghazali outlet that discharges sewage from Shuwaikh industrial area and high sediment influx carried by rivers to Shatt Al-Arab and then to the area during the summer season. There is no information for the back ground level of Li in Sulaibikhat Bay sediment. From the results shows that Li concentration is high in station 11.

Manganese: The concentration of manganese in sediment samples were found in all stations. Average manganese concentration is 288.82% of 15 stations samples and maximum concentration were found as 394.2% in Station 11 and minimum were found as 103.6 % in station 8. High Mn was recorded in areas close to Al-Ghazali outlet as well as in the north and the west of the study area (Table 2). Possible sources of Mn concentration in the study area are Al-Ghazali outlet that discharges sewage from Shuwaikh industrial area and high sediment influx carried by rivers to Shatt Al-Arab and then to the area during the summer season. The back ground level of Mn in Sulaibikhat Bay sediment was 470 mg/kg. From the results shows that Mn Concentrations are very high in all stations than back ground level.

Magnesium: The concentration of magnesium in sediment samples were found in all stations. Average magnesium concentration is 1.35 mg/kg of all 15 stations samples and maximum concentration were found as 1.54 mg/kg in Station 4 and minimum were found as 1.15 mg/kg in station 1.

Nickel: From the Table 1 and Figure 4 illustrates that the concentration of nickel in sediment samples were found in all stations. Average nickel concentration is 94.32 mg/kg of all 15 stations samples and Maximum concentration were found as 125.3 mg/kg in station 4 and minimum were found as 42.1 mg/kg in station 8. High Ni Concentration was detected in areas close to Al-Ghazali outlet, Free Zone outlet and Kuwait University (Table 2).

Table 2. *Heavy metals in Marine Sediment of Sulaibikhat Bay.*

Sector	Station	As	Cd	Cr	Co	Cu	Fe	Pb	Li	Mg	Mn	Mo	Ni	Se	U	V	Zn
		mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg
1	SS9	<1	5.1	28.5	20.4	14.6	7573.3	<1	10.2	282.6	1.3	<1	86.4	<1	<1	32.3	61.5
	SS10	<1	4.8	35.0	21.3	27.5	8549.3	<1	11.1	335.2	1.3	<1	111.6	<1	<1	31.1	94.6
	SS11	<1	4.9	23.8	22.7	30.6	8508.6	<1	14.8	394.2	1.3	<1	114.3	<1	<1	29.4	99.0
	SS12	<1	4.4	26.2	22.8	29.1	8277.4	<1	13.2	323.7	1.2	<1	96.6	<1	<1	32.6	81.0
	SS13	<1	4.7	26.7	23.1	18.5	8904.5	<1	12.9	331.2	1.2	<1	107.1	<1	<1	29.3	73.5
	Min.		4.4	23.8	20.4	14.6	7573.3		10.2	282.6	1.2		86.4			29.3	61.5
	Max.		5.1	35.0	23.1	30.6	8904.5		14.8	394.2	1.3		114.3			32.6	99.0
	Average		4.8	28.1	22.0	24.0	8362.6		12.4	333.4	1.3		103.2			30.9	81.9
2	SS1	<1	5.4	40.4	22.8	15.6	8705.8	<1	11.7	358.9	1.5	<1	102.4	<1	<1	31.7	66.5
	SS2	<1	5.3	36.7	22.1	11.4	7633.6	<1	10.0	315.4	1.3	<1	92.8	<1	<1	31.0	54.5
	SS3	<1	5.2	29.6	22.4	15.4	8817.9	<1	13.6	345.7	1.4	<1	104.7	<1	<1	30.3	63.7
	Min.		5.2	29.6	22.1	11.4	7633.6		10.0	315.4	1.3		92.8			30.3	54.5
	Max.		5.4	40.4	22.8	15.6	8817.9		13.6	358.9	1.5		104.7			31.7	66.5
	Average		5.3	35.6	22.4	14.1	8385.5		11.8	340.0	1.4		100.0			31.0	61.6
3	SS14	<1	5.5	25.9	22.9	10.5	7145.7	<1	13.1	279.3	1.2	<1	85.7	<1	<1	30.6	43.7
	SS15	<1	6.1	26.8	24.5	10.2	8100.0	<1	12.8	276.8	1.4	<1	94.5	<1	<1	29.9	36.9
	Min.		5.5	25.9	22.9	10.2	7145.7		12.8	276.8	1.2		85.7			29.9	36.9
	Max.		6.1	26.8	24.5	10.5	8100.0		13.1	279.3	1.4		94.5			30.6	43.7
	Average		5.8	26.3	23.7	10.3	7622.9		12.9	278.1	1.3		90.1			30.3	40.3
4	SS6	<1	5.4	30.6	22.9	30.8	9646.0	<1	11.5	232.2	1.4	<1	93.3	<1	<1	29.3	118.7
	SS7	<1	5.6	19.1	17.3	6.9	5389.7	<1	11.2	151.0	1.4	<1	51.8	<1	<1	29.4	18.0
	SS8	<1	5.0	25.6	19.4	5.5	4018.1	<1	10.9	103.6	1.4	<1	42.1	<1	<1	27.8	21.1
	Min.		5.0	19.1	17.3	5.5	4018.1		10.9	103.6	1.4		42.1			27.8	18.0
	Max.		5.6	30.6	22.9	30.8	9646.0		11.5	232.2	1.4		93.3			29.4	118.7
	Average		5.3	25.1	19.8	14.4	6351.3		11.2	162.3	1.4		62.4			28.8	52.6
5	SS4	<1	5.6	30.3	23.6	22.9	9443.9	<1	12.6	343.5	1.5	<1	125.3	<1	<1	29.6	102.9
	SS5	<1	5.3	32.5	23.1	36.1	10200.0	<1	10.6	259.0	1.5	<1	106.2	<1	<1	28.6	225.2
	Min.		5.3	30.3	23.1	22.9	9443.9		10.6	259.0	1.5		106.2			28.6	102.9
	Max.		5.6	32.5	23.6	36.1	10200.0		12.6	343.5	1.5		125.3			29.6	225.2
	Average		5.4	31.4	23.3	29.5	98220		11.6	301.3	1.5		115.8			29.1	164.1

Possible sources of Ni concentration in the study area are Al-Ghazali outlet that discharges sewage from Shuwaikh industrial area, discharge from Free Zone outlet, and discharge from the emergency outlets close to Kuwait University campus. The background level of Ni in Sulaibikhat Bay sediment was 91.0 mg/Kg [20]. The average Ni concentration in the study area is recorded higher than the background level.

Vanadium: The concentration of vanadium in sediment samples were found in all stations. Average vanadium concentration is 30.19 mg/kg of all 15 stations samples and maximum concentration was found as 32.6 mg/kg in station 12 and minimum were found as 27.8 mg/kg in station 8. High concentration of Vanadium was detected in area close to Al-Ghazali outlet, the Free Zone outlet, Kuwait University and Shuwaik harbor. Possible sources of V in the study area are Al-Ghazali outlet that discharges sewage from Shuwaikh industrial area, discharge from the Free Zone outlet, oil spills from Shuwaikh harbor, and discharge from the emergency outlet close to Kuwait University. The background level of Vi in Sulaibikhat Bay sediment was 43.0 mg/kg [20]. The maximum Vi concentration in the study area is 32.6. Therefore, it is concluded that Vi concentration in the study area is lower than the background level.

Zinc: The concentration of zinc in sediment samples were found in all stations. Average zinc concentration is 77.38 mg/kg of all 15 stations samples and maximum concentration were found as 225.2 mg/kg in station 5 and minimum were found as 17.96 mg/kg in station 7. High Zn Concentration was recorded in areas close to the Free Zone outlet. The background level of Zinc in Sulaibikhat Bay sediment was 57.00 mg/kg [20]. In this study, Zn concentration in the study area is higher than the background level.

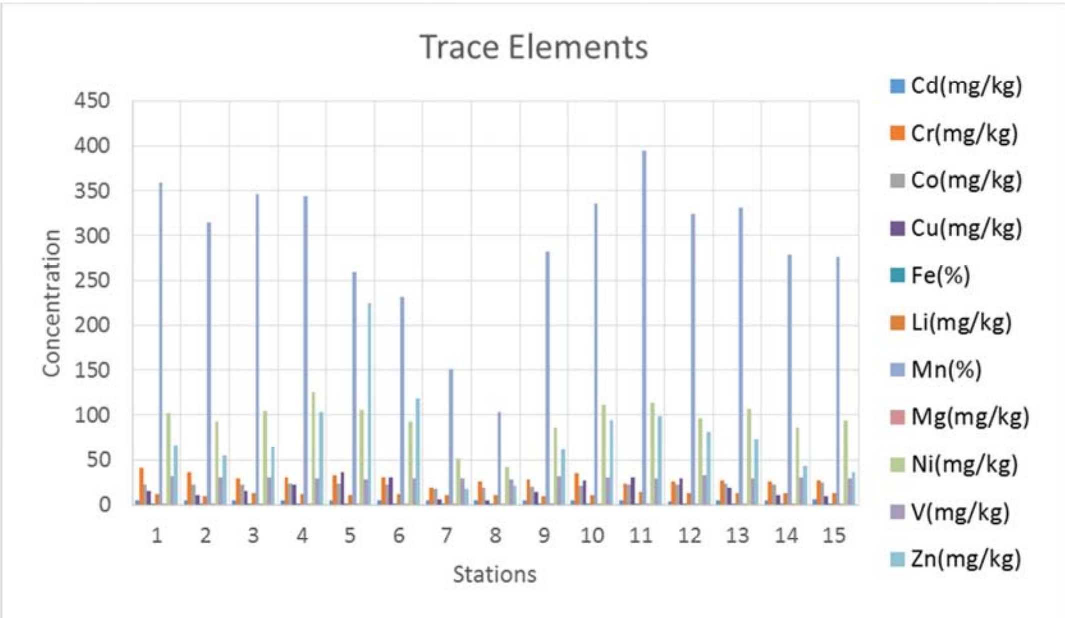


Figure 12. *Trace Metal Analysis.*

5. Discussions

Significance and Interpretation

Based on the results on present and previous studies [21], [10] and [9] it was found that the outputs of Gulf war near Ras ushairij and Shuwaikh Port Area could provide direct sources for the elevated levels of Fe in the offshore sediment areas.

[21] attributed the presence of Cu pollutants in some areas in the Arabian Gulf partly to Cu antifouling coatings used by ships and fishing boats. Such vessels were noticed frequently in Sulaibikhat Bay, particularly in the vicinity of Ras ushairij (Al Doha) and Kuwait university area where a fishermen village and two coastal ship repair workshops are located [10] and [22]. Other studies [23] and [24] suggested that Cu contaminations are due to industrial effluents from Doha Power and desalination plants in the northwest and various light industries around Shuwaikh area in the east of Sulaibikhat Bay. Fluctuation in the activities in this area were accounted for the elevated concentrations of some heavy metals (e.g. Pb and Hg) in summer.

On the other hand, sludge's from recent sewage discharges, such as those observed in the southern and eastern parts of the Bay, could provide the main source of Zn pollutants in the area under study [24].

The Relative magnitude of the significant positive correlations of trace metal concentrations with TOC was Cu>Zn>Co>Ni>As. Al-Majid 2015 found a significant positive correlation between TOC and Hg(r=0.86, p<0.05) in sediments from Kuwait Bay.

The strong positive inter correlations among TOC, Cu, and Zn, in sediments of Sulaibikhat Bay suggest that these trace metal contaminants probably have a common origin or that they have been introduced to the Bay attached to organic matter. In the present study, a positive correlation of selected trace metals(As, Cu, and Zn) with TOC in Sulaibikhat Bay was obtain, this observation might suggest that sorption mechanism of these metals in Sulaibikhat Bay sediments are mainly controlled by chemical adsorption, rather than physical or deposition of metals with organic matter on the top of the sediments.

This study revealed negative correlations between trace metal concentrations and the sand fraction and calcium carbonate. This is because quartz sand is trace metal poor and normally makes a much smaller contribution to trace metal binding than the clay fraction. This finding agrees well with that of [25] who showed that the presence of carbobates has a dilutig effect on trace metals that are of terrigenous origin. In other area, some studies have found negative correlations and others positive correlations, between trace metal concentrations and the calcium carbonate content.

It is known that the organic content of the sewage dumped into Kuwaiti waters is also relatively high and often septic due to low flows, long retention times, high ambient temperatures and concomitant anaerobic [16] and [26]. Trace metal pollution has been detected sewage and their accumulation has been attributed to the closed, shallow nature of the receiving beaches and outlets discharging within a few meters of the shoreline [27] and [9].

5.1. Environmental Controlling Factors and Sources of Stressors

Generally, the major factors controlling sedimentation processes on the Sulaibikhat Bay are considered herein as natural sources of stresses in the Bay, of these factors are: mixed sources of particulates including trace metal-rich dust fallouts and/or Shatt Al-Arab river derived sediments; regionally and locally; hydrodynamic conditions, lithological characteristics of bottom sediments in addition to other natural sources of stress (natural oil seeps, biogeochemical cycles and genetic forms of trace metals). However, these natural environmental factors are essentially combined with intensive anthropogenic sources of stresses which are mainly represented by the large input of effluents from nearby industrial centers (Al Shuwaikh Al-Ghazali Center and Doha desalination plants) as well as domestic sewage and wastewater discharges as result of urbanization expansion. Furthermore, accidental inputs (Gulf war oil spill and oil-well fire fallout) are additional sources of stressors on the Sulaibikhat Bay.

5.1.1. Hydrological Factors

Two sources or large input of trace metals in the coastal water of Sulaibikhat Bay are suggested in this study namely; estuarine fluviatile source of shatt Al-Arab trace metal rich and dust fallouts from dust storms that deposited in the water as suspended or re-suspended particulates. Another, suggestion is that these metals are involved in biogeochemical cycles, either actively as micronutrients and skeletal materials or passively by adsorption on to particle surfaces, or adsorption on to particle surfaces or co - precipitation with various solid phases [28].

5.1.2. Anthropogenic Factors

Generally, V and Ni are the largest trace metal constituents of crude oils including the Arabian Gulf crudes, and hence their presence in high concentrations in marine sediment would indicate direct input from oil pollutants [21]. It is recorded that the facilities at Shuwaikh Port discharge waste, mainly oily sludge directly into the marine environment. Furthermore, some used fuel oil was dumped into the Kuwait bay water through the outfalls of Doha power and desalination plants. Where the bottom sediments are known to be heavily polluted with V and to less extent with Ni [23]. It is worth to mention that this pollution status in Sulaibikhat Bay is recently studied and it is different from such previous status since 30 years ago.

5.2. Potential Environmental Impacts

5.2.1. Impacts on Sea Water

Physical and chemical impacts include effect of water temperature, salinity, dissolved oxygen (DO), total suspended solids (TSS) and other water quality parameters. The impacts of these parameters and their magnitude of dispersion depend on the type of outlet effluents from each point source of pollution and the local hydrogeological condition in Sulaibikhat Bay. Of these most effective on water quality are Al-Doha desalination plants in the west, sewage dumping sites and water storm outlets in the south and Al-Ghazalli-Shuwaikh port industrial region in the east.

The average temperature in the study water samples is 25.6°C while their salinity is 41.84 ppt. and these values are within the permissible limits where no apparent threats were observed within the western part of the Sulaibikhat Bay. This resultant conclusion may be attributed to improvement technological condition inside the Doha plant as well as dilution and dissipation of the brine by the anticlockwise longshore current in the immediate area after out falling point. Consequently, the salinity tends to return to ambient condition and spread southward over a large area where it is more or less similar to the local salinity condition. Therefore, the thermal impact at vicinity of Al-Doha Plant out falling area could be negligible or very slightly harmful on micro fauna.

5.2.2. Impacts on Bottom Sediments

As previously mentioned, Sulaibikhat Bay is a part of Kuwait Bay and receives most of its pollution from the Sulaibikhat entrance and the main tidal channel (Figure 13). Trace (heavy) metals that are discharged from thermal desalination plants and from heavy industries in Sulaibikhat Bay, may be present in dissolved form depending on their soluble properties and/ or may remain suspended in the effluent and get settled in bottom sediments (Figures 14 and 15). These sediments thus act as sink to these metals and offer a better matrix for assessing the distribution and impacts of anthropogenic inputs in localized areas near industrial activities than seawater [29].

Studies have recorded lower concentration of the majority of identified metals in bottom sediments of Sulaibikhat Bay and other coastal areas in Kuwait, these ranges can be considered as regional guideline for the upper permissible limits of trace metal concentrations in unpolluted sediments of Kuwait. Marine environment including the study area (Table 2).

[22] compared the state of trace metal pollution in bottom sediments of Sulaibikhat Bay from the period between 1980 [23] to 1996 (Figures 13, 14 and Table 3).

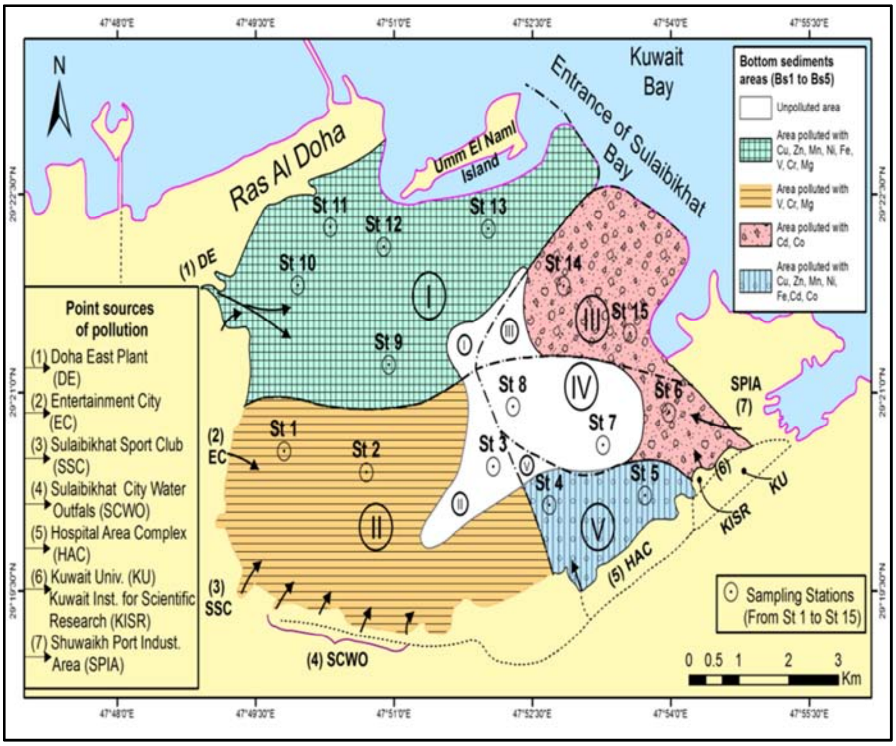


Figure 13. *Point source of pollution.*

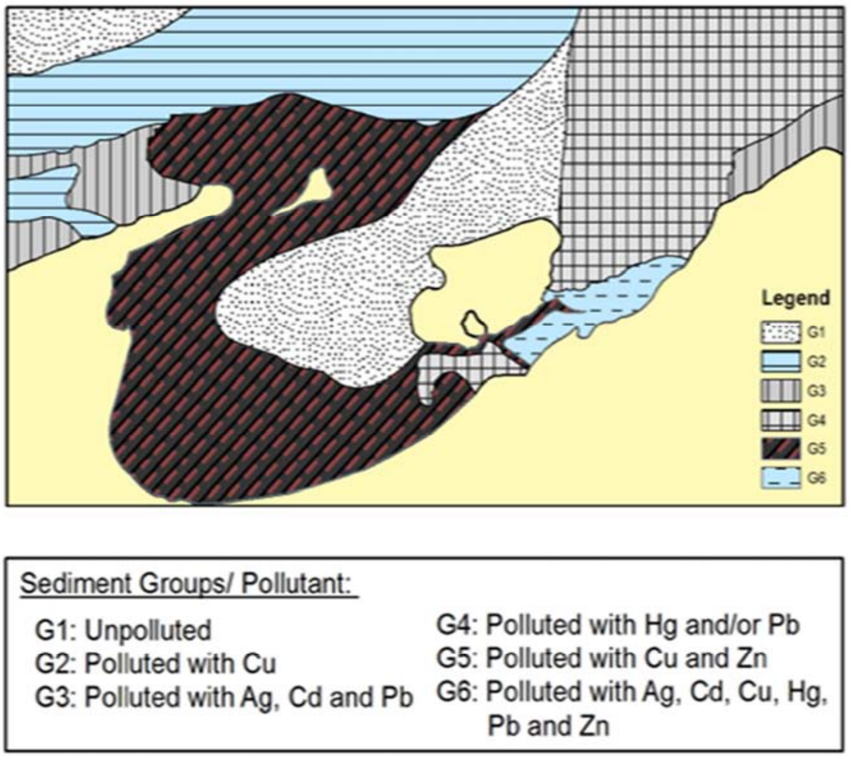


Figure 14. *Heavy metals in Sulaibikhat Bay.*

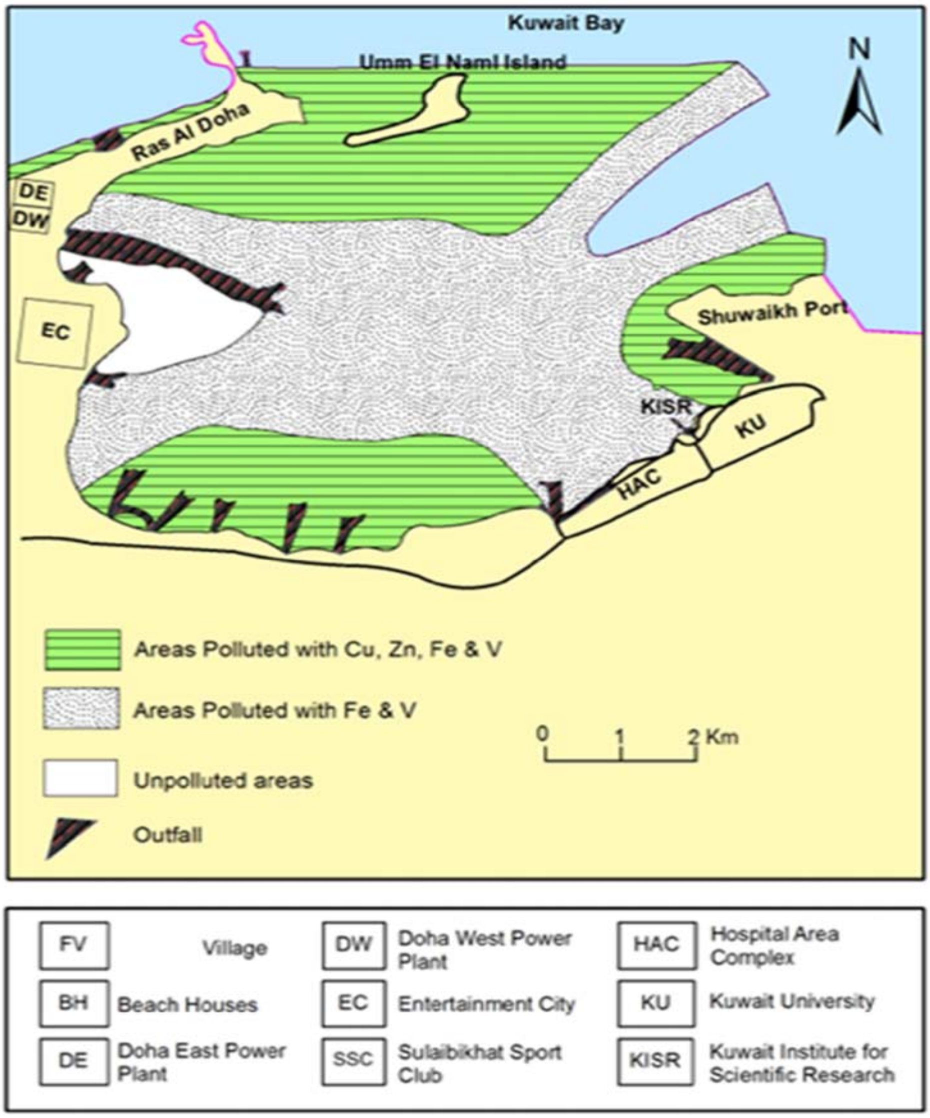


Figure 15. *Distribution of heavy metals from 1980 through 2015.*

Table 3. *Comparison of average and ranges of heavy metal Concentrations (mg/kg wet) from the study Sulaibikhat Bay bottom sediments with those in other Kuwait and Arabian Gulf sediments as unpolluted Backgrounds after [23], [21] and [22].*

Heavy Metals	The present study					Background level		
	Max.	**St. No.**	**Minim**	**St. No.**	**Average**	**[23]**	**[21]**	**[22]**
Cd	6.13	15	4.38	12	5.22	5.75	1.2 - 2.0	-
Cr	40.43	1	19.10	7	29.17	80.0	-	55.60
Co	24.5	15	17.30	7	22.06	-	-	-
Cu	36.08	5	5.49	8	19.02	23.0	1.2 - 2.0	28.98
Fe	10200	5	4018	8	8060	16,000	10,000- 20,000	2490
Pb	-	-	-	-	-	22.0	15 - 30	5.60
Mn	394.2	11	103.60	8	288.8	470	500 - 800	187.97
Ni	125.3	4	42.0	8	94.32	91.0	70 - 80	13.97
V	32.6	12	27.80	8	30.19	43.0	20 - 30	63.87
Zn	225.2	5	17.96	7	7.38	57.0	6.0 - 30	73.50

Table 4. *Distribution of trace metals pollution areas in the Sulaibikhat bay bottom sediments that forming the percent (recent) status of pollution.*

Sectors	Location	Near by offshore area of outfall	Trace metal pollution Status
(1)	Northwestern Area	Doha East Plan	Cu, Zn, Mn, Ni, Fe, V, Cr & Mg
(2)	Southwestern Area	Entertainment city, Sulaibikhat sport & Sulaibikhat city water outfalls	V, Cr & Mg
(3)	Southeastern Area	Hospital area complex	Cu, Zn, Mn, Ni, Fe, Cd & Co
(4)	Eastern and Northeastern Area	Shuwaikh port Industrial zone & Kuwait Univ.	Cd & Co
(5)	Central area	Central offshore Port of the Bay	Unpolluted area

6. Conclusions

The anthropogenic inputs in Sulaibikhat Bay are more effective source of pollution than the natural ones (e.g. external supply of trace metals either from fresh water of Shatt Al-Arab River and/or from aeolian source). The distribution of trace metals are listed in Table 4. For this reason, human activities that effect the coastal ecosystem of the Bay should be minimized.

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