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Major, Minor and Trace Elements Existence in Surface Sediments from Gwadar to Jiwani Coastal Areas of Pakistan

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Abstract: This study was carried out along the western coastal parts of Balochistan from Gwadar east Bay to Jiwani. The local anomaly of major, minor and trace elements were studied in this area. Zone-I (Gwadar east and west Bay) indicates that calcium oxide, potassium oxide and titanium dioxide have higher or average concentrations, while Zone-II indicates higher or average concentrations of calcium oxide, titanium dioxide and ferric oxide. Trace elements zirconium, chromium, europium, strontium, and copper are in higher or average concentrations in both zones. Gwadar west Bay and Jiwani are intermediate in carbonate, which show a high degree of maturity, suggesting the high rate of weathering in the source area. Sediment samples from Ganz, Jiwani, and Gwadar east Bay represent the quartz-rich fields in this region. Gwadar east Bay has a positive correlation between aluminium oxide and potassium oxide which suggests that abundance of potassium oxide is controlled by variation in K-feldspar contents. A positive correlation between strontium and calcium oxide suggests that strontium is associated with calcium oxide in biogenic carbonate material in Gwadar west Bay. The positive correlation between aluminium oxide, copper, and zinc in Pishukan indicates that the abundance of these elements is due to limited silt and clay fractions present in sediments. Enrichment factor shows that chromium and strontium are probably of anthropogenic origin in this region.

Keywords: Makran coastal area, X-ray fluorescence, major elements, trace elements.

Introduction

Sea and land are practically connected by the beaches in many places of the World (Malick et al., 2012). Beach usually has the structure as inclined layers towards the sea, and it forms in the inter-tidal zone (Ravisankar et al., 2006). Coral fragments and calcareous shells are the most common materials of the coastal sediments of beaches. Beach is also developed by the quartz sand and other coastal sediments called sand beaches. Some natural phenomena of the beach, for example, sufficient shell contents, gentle slope of the foreshore and temperature of groundwater are ideal for the formation of beaches. Many places in the World are the evidence of such types of beaches (Milliman, 1974; Scoffin and Stoddart, 1983; Kneale and Viles, 2000; Darren et al., 2003; Rey et al., 2004).

Several factors affect the geochemical variation and composition of coastal sediments which include source composition, climate, longshore drift, sorting, relief and winnowing by wave action. Some local factors also affect the processes which are fluvial discharge, tidal wave regimes, and wind transport (Carranza-Edwards et al., 2009). Beach sands comprise of feldspar, lithic fragments, quartz and other silicates, and biogenic material such as products of weathering, degradation, shells and fragmentation.

Shores along Balochistan are commonly sandy beaches. Cliffs and rocky shores are frequent in Balochistan (Baloch et al., 2014).

Conglomerates of sandstone and soft mudstone generally occur in the study area, which is highly susceptible to erosion (Akhtar et al., 2013). Prominent features in this area are the Headlands of Ormara, Gwadar, Rasjidi, Pishukan and Jiwani. These features are intervened by low-lying places comprising of alluvial deposits. There are several lagoons along the Balochistan coast, such as Gwadar Bay, Ormara Bay, and Somniani Bay. Mud flats are non-existent in Balochistan except a few in Gwadar Bay, Kalmat Khor, and Minani Hor lagoons, which are small. Sediments are composite and formed by the collapse of mountain slopes, erosion. These sediments are transported by the small channels and then carried by the currents and motion of waves to form beaches.

Many geochemical studies have been carried out in different parts of Indian shelf region such as west coast of India (Gogate et al., 1976, Paropkari et al., 1978), Bay of Bengal (Raman, 1995), Puri to port Novo (Mohapatra et al., 1992), the central east coast in India (Rao and Sarma, 1993) and Madras coast (Pragatheeswaran et al., 1986). In the last decade, some studies have been conducted on geochemical survey of sediments from the Winder stream, Balochistan (Naseem et al., 2002). However, studies on major and trace element abundance in size fractions along the shoreline of Balochistan were still lacking. The shoreline of different beaches of Balochistan is a significant tourism spot, as it hosts the massive sand dunes of Balochistan.

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The study aims to define the major, minor, and trace elements from the geochemistry of beach sediment samples collected from five sites along the shoreline of Balochistan. Different sources of sediment supply to the shoreline of Balochistan have a broad relationship among loads of elements in the beach sands from the shoreline of Balochistan. Compositions of major, minor, and trace elements of the continental crust provided by Taylor (1964) are used as global reference.

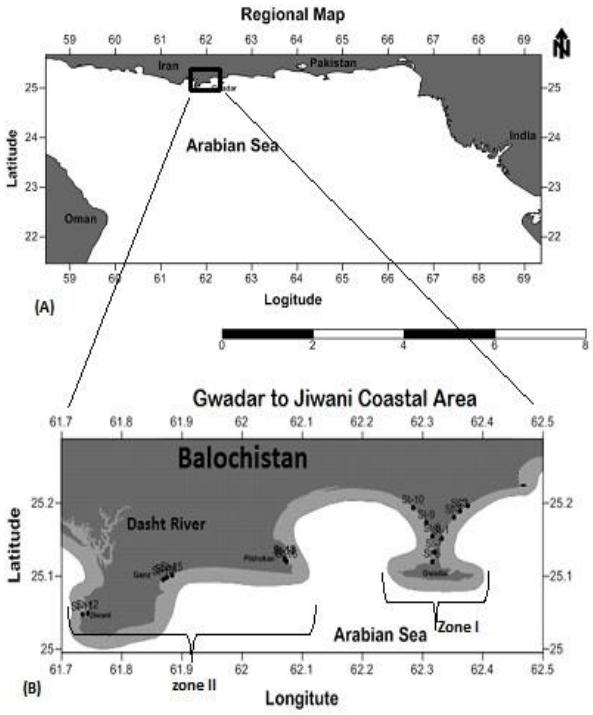


Fig. 1 (A) Map showing study area and (B) sampling points ST-01 to ST-03 and ST-06 to ST-18.

Materials and Methods

The study area is located along the Balochistan coast from Gwadar east Bay (62° 22' 05.57" E, 25° 11' 28.27" N) to Jiwani (61° 44' 22.18" E, 25° 02' 48.65" N) (Fig. 1A). Balochistan coastal area is 600 km long covering all study sites (Fig. 1B). The study area is divided into two zones. Zone-I has two sites (Gwadar east Bay and Gwadar west Bay), and Zone-II has three sites (Jiwani, Ganz, and Pishukan). Each study site is further divided into various stations on the beach for the collection of sediment samples (Table 1).

Six field trips were conducted for the collection of sediment samples from the intertidal zones of each study site. Sixteen sediment samples from all the study sites were collected. About 1000 grams of sediment samples were packed in airtight zip-locked plastic bags and brought to the laboratory for further treatment. Sampling was carried out at the onset of low to moderate tides based on tidal information of the five study sites (Fig. 1). These samples were kept in sunlight for 7 hours and put in the oven at 100°C for 8 hours, for the chemical analysis.

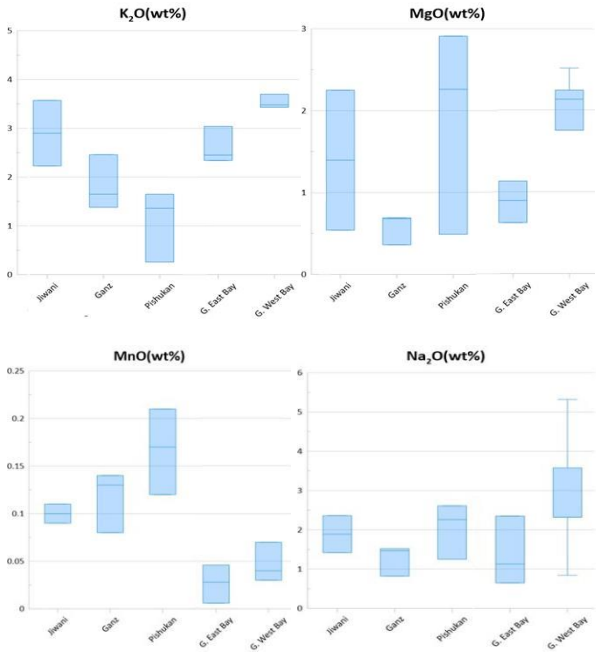


Fig. 2 Box-plots showing the summary of geochemical compositions of sediment samples from Jiwani to Gwadar east Bay. Vertical lines give the range, boxes enclose 50% of the data and illustrate the 25% quartile, median (horizontal bar), and 75% quartile.

The x-ray fluorescence operation was carried out on the XRF model S4-PIONEER WD-XRF. This instrument was manufactured by Bruker-AXS; Germany. It was fully controlled by software known as SpectraPlus. The GeoQuant and OilQuant were two other sub-packages attached to it for the measurement of various geological and oil samples.

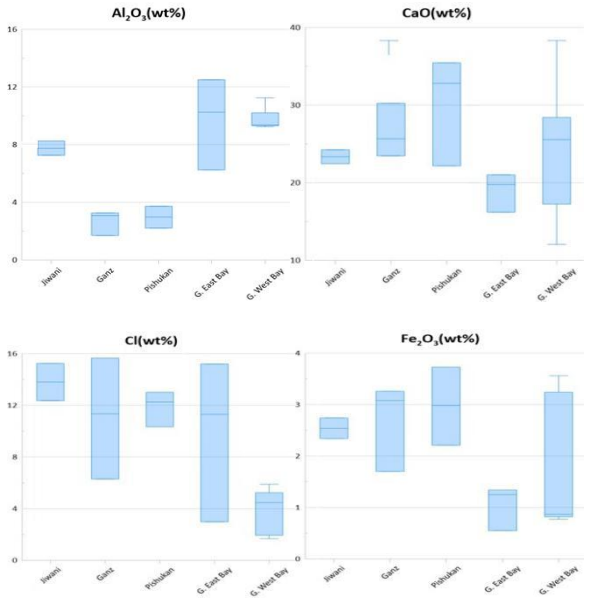


Fig 3. Box-plots showing the summary of geochemical compositions of sediment samples from Jiwani to Gwadar east Bay. Vertical lines give the range, boxes enclose 50% of the data and illustrate the 25% quartile, median (horizontal bar), and 75% quartile.

The samples were grinded in a grinding mill to prepare the fine powder of the sample. The powdered samples were put in the oven at 105°C to remove the

atmospheric water. Ten grams of this oven-dried powdered sample was taken and homogenized with 3 grams of a wax that is used as a binder. Finally, 10 grams of this mixture was taken and pressed up to 25 N (Newtons) to prepare a rounded pressed pellet. These pressed pellets were then put in a steel cup of the sample magazine of the instrument. Through software, these cups, along with prepared pellets were sent one by one into the sample chamber of the machine, and the analyses were performed. As, each element is irradiated at a particular voltage and current, so for this reason, the minimum and maximum voltage and current were set as 15 - 60Kv and 20-150mA respectively. All the samples were analyzed for major oxides and trace elements.

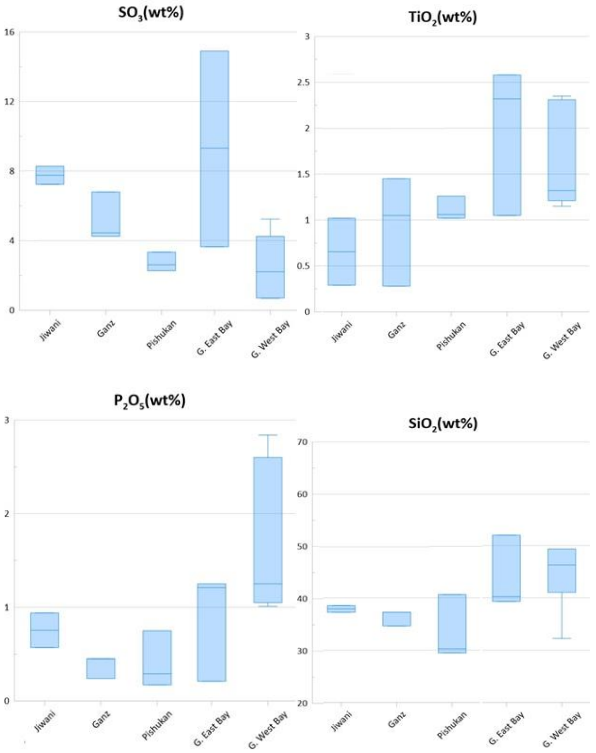


Fig. 4 Box-plots showing the summary of geochemical compositions of sediment samples from Jiwani to Gwadar east Bay. Vertical lines give the range, boxes enclose 50% of the data and illustrate the 25% quartile, median (horizontal bar), and 75%quartile.

Results and Discussion

Major and Minor Elements abundance in Zone-I and Zone-II

Results of major and minor elements abundance of sediment samples of Zone-I in Gwadar east Bay coastal beach are SiO_2 > CaO > Cl > SO_3 > Al_2O_3 > K_2O > TiO_2 > Na_2O > Fe_2O_3> P_2O_5 > MgO > MnO with average values of 43.86± 7.07 wt%, 19± 2.49 wt%, 9.826± 6.24 wt%, 9.29± 5.63 wt %, 9.66± 3.17 wt%, 2.61± 3.17 wt%, 1.98± 3.17 wt%, 1.375± 0.716 wt%, 1.0466± 0.353 wt%, 0.89± 0.4811 wt%, 0.88± 0.207 wt% and 0.026± 0.016 wt% respectively. While average major and minor elements in Gwadar west Bay coastal beach are SiO_2 > CaO > Al_2O_3 > Cl > K_2O > Na_2O > SO_3> MgO > Fe_2O_3 > P_2O_5 > TiO_2 > MnO with average values 46.628± 11.77 wt%, 24.32 ± 10.18 wt%, 9.874 ± 0.86 wt%, 3.842 ± 1.924 wt %, 3.242± 1.17 wt%, 2.876± 1.67 wt%, 2.616± 2.07wt%, 1.882 ± 0.67 wt%, 1.852 ± 1.42 wt%, 1.75 ± 0.89 wt%, 1.668 ± 0.61wt % and 0.048± 0.02 wt% respectively.

Major and minor elements abundance in Zone-II were recorded as SiO_2 > CaO > Al_2O_3 > Cl > Fe_2O_3> Na_2O > TiO_2> MgO> K_2O > P_2O_5 > MnO, SiO_2 > CaO > Al_2O_3 > Cl > SO_3 > Fe_2O_3 > K_2O > Na_2O > TiO_2 > MgO > P_2O_5 > MnO and SiO_2 > CaO > Cl > Al_2O_3 > SO_3 > K_2O > Fe_2O_3 > Na_2O > MgO > P_2O_5 > TiO_2> MnO respectively. In all areas of Zone-II, the highest values of SiO_2 (37.89± 0.92 wt%, 36.37 ± 1.53 wt%, and 33.45±6.24 wt%) was found in Jiwani, Ganz, and Pishukan. The lowest value in major elements is MnO which 0.1667± 0.036 wt%, 0.1166 ± 0.026 wt%, 0.1± 0.014 wt%in Pishukhan, Ganz, and Jiwani respectively.

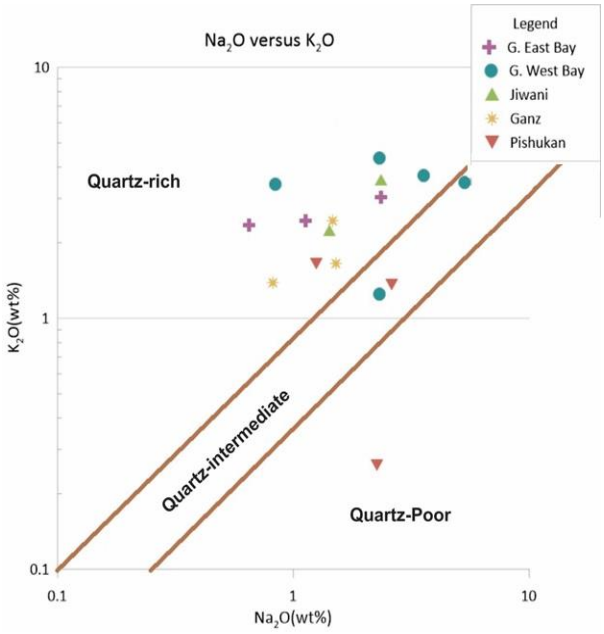


Fig. 5 Plot of Na_2O versus K_2O (Crook, 1974)

Trace Elements Abundance in Zone-I and Zone-II

The average trace metal levels in zone-I (Gwadar east Bay) were in the order Cr > Sr > Zr > Eu > Cu > Ni > Zn with values 843.66± 578.35 ppm, 581.33± 46.46 ppm, 341± 83.59 ppm, 114 ppm, 60.6± 587.36 ppm, 53.66± 18.23ppm, 44 ppm respectively, Gwadar west Bay has average trace metal levels in this way Cr > Sr > Zr > Ni > Cu > Zn > Eu having an average level 978.75± 298.07 ppm, 810.2± 226.76 ppm, 202.6 ± 79.76 ppm, 64.44 ±20.18 ppm, 61.6 ±8.20 ppm, 51 ±4.24 ppm, 44ppm, respectively.

The average abundance levels in Zone-II were as Sr > Cr > Zr > Cu > Ni > Zn, Cr > Sr > Zr > Eu > Ni > Zn

and Sr > Cr > Zr > Eu > Cu > Ni > Zn respectively. The highest average value of Sr 1430± 674.69 ppm and 1228.5± 765.79 ppm were found in Pishukhan and Jiwani, respectively. Similarly, the highest value of Cr 1070± 588.98 ppm was recorded in Ganz. At the same time, Zn was found to be the lowest level as, 502.66 ± 331.13 ppm, 46 ppm, 53 ppm in all areas of Zone II, respectively.

Table 1 Comparison of beach sediment samples from Gwadar to Jiwani coastal area of the present study to crustal average (concentration is in wt %). Average abundance of elements in the crust from Taylor, 1964.

Major Elements	Reference Crustal Average (Taylor, 1964)	Average G.East Bay	Average G.West Bay	Average Pishkukan	Average Ganz	Average Jiwani
SiO_2	60.976	43.86	46.63	33.45	36.37	37.89
CaO	5.004	19	24.32	30.14	26.45	23.35
K_2O	3.028	3	3.242	1.09	1.83	2.9
Al_2O_3	15.734	9.66	9.874	12.75	13.66	7.76
TiO_2	0.978	1.98	1.668	1.113	0.926	0.655
Fe_2O_3	2.96	1.04	1.852	2.97	2.68	2.54
MgO	3.652	0.882	1.882	1.886	0.576	1.395
Na_2O	3.152	1.375	2.88	2.04	1.27	1.89
Sampling Stations		3	5	3	3	2
		Zone-I		Zone-II		

Variations of Major and Minor Elements between Zone-I and Zone-II

Results of the targeted area in Zone-I and Zone-II showed that major and minor elements SiO_2 (silicon dioxide), CaO (calcium oxide), Al_2O_3, (aluminum oxide) and Cl (chlorine) are in high concentrations. SiO_2 and Cl are highly enriched in Zone-I (Gwadar east and west Bay) as compare to Zone-II (Pishukhan, Ganz, and jiwani), while CaO and Al_2O_3 contents are higher in Zone-II as compared to Zone-I.

When these results were compared with the other similar areas, it was observed that SiO_2 was in much lower concentration than in the coastal sediments of western Yamaguchi Prefecture, Japan (Malick et al., 2012) and average crustal abundance values of 60.98 wt% (Taylor 1964, Table 1).

Variation of Trace Elements between Zone-I and Zone-II

The results of the present study indicated that a higher concentration of Cr (chromium), Sr (strontium), and Zr (zirconium) are found in the coastal sediments of two zones. However, Zone-II (Pishukhan, Ganz, and Jiwani) is highly enriched in these elements as compared to Zone-I (Gwadar east and west Bay). At the same time, the slightly higher concentration of Cu (copper), Ni (nickel), and Zn (zinc) are observed in Zone-II. Only Eu (europium) has a higher content in the sediments of Zone-1. When these results were compared with previously reported values of Cr (chromium), it was much higher than those recorded in coastal sediments of Bay of Bengal, Alang-Sosiya coast intertidal Gulf of Manner and east coast of Tamilnadu, India (Selvaraj et al., 2004; Reddy et al., 2014; Kumar et al., 2016), Mediterranean Sea coast, Egypt (El-Sorogy and Attiah, 2016), western Yamaguchi Prefecture, Japan (Malick et al., 2012) and average crustal values 100 ppm (Taylor, 1964). However, the values are slightly lower than the Gulf of Govatr Iran (Bazzi, 2014).

Sr values were much higher than those found in coastal sediments of western Yamaguchi Prefecture, Japan (Malick et al., 2012). Gulf of Govatr Iran (Bazzi, 2014), Mediterranean Sea coast, Egypt (El-Sorogy and Attiah, 2016) Bay of Bengal, India (Selvaraj et al., 2004, Table 2) and average crustal values 375 ppm (Taylor, 1964). Zr Value was found much higher than reordered in Sediments of the Mediterranean Sea coast, Egypt (El-Sorogy and Attiah, 2016, Table 2), and average crustal values 165 ppm (Taylor, 1964). Cu values were found within the range of those values, that were recorded in coastal sediments of Gulf of Govatr Iran (Bazzi, 2014) and higher than western Yamaguchi Prefecture, Japan (Malick et al., 2012, Table 2) and average crustal values 55 ppm (Taylor, 1964), while lower than Alang-Sosiya coast intertidal Gulf of Manner and east coast of Tamilnadu, India (Kumar et al., 2016). One of the reasons of higher values of Sr, Zr, and Cu is the last glacial time (18000 years BP), when the sea level was about 120 m below the present level and hence the shelf area was approximately 100 m lower than the present depth. At that time, rivers used to fall on the shelf directly, and significant placer minerals brought by them may have accumulated there. Currents and waves deposited and dispersed the minerals along the coastline during the past transgression and regression action. Sea level rise effect to move the beaches and some of their placer minerals towards the land (Khan, 1999).

Ni values were slightly higher than those recorded in coastal sediments of Bay of Bengal, east coast of Tamilnadu, India (Seivaraj et al., 2004; Kumar et al., 2016) and western Yamaguchi Prefecture, Japan (Malick et al., 2012). While much fewer values of Ni and Zn are found in Alang-Sosiya coast intertidal Gulf of Manner and east coast of Tamilnadu, India (Kumar et al., 2016), Mediterranean Sea coast Egypt (El-Sorogy and Attiah, 2016) and slightly lower and comparable with crustal average values of Ni 75 ppm and Zn 70 ppm (Taylor, 1964). Eu concentration was found higher in Zone-1 and also much higher than the crustal average of 1.2 ppm (Table 2).

Table 2 Comparison of beach sediment samples of the Makran coastal area of the present study to other parts of the World. (concentration is in ppm). Average abundance of elements in the crust from Taylor, 1964.

Trace Element	This Study	Gulf of Govatr Iran	Coastal Bay Of Bengal	East Coast of Tamil Nado India	Mediterranean Sea Coast	Western Yamaguchi Prefecture Japan	Alang-Sosiya Coast Intertidal Gulf of Manner
		Bazzi, 2014	Selvaraj, 2004	Kumar, 2016	Sorogy, 2016	Malick, 2011	Reddy, 2014
Cr	390-1510	15-10000	57	38.1-312.6	0.23-0.29	7.0-20.0	290.18±63.18
Cu	43-103	6.2-101				3.0-6.0	214.41±53.47
Ni	34-90	14.9-109	30	23.9-44	706.91-894.17	6	172.53±47.68
Sr	543-2200	251-2380	20		118.81-178.22	954-1354	
Zn	43-63	13-174	26-87.3		298.50-349.11	5.0-24.0	1222.18±147.06
Zr	132-845				0.21-0.37		

Comparison with previous studies and crustal average values revealed that most sediment samples of the present study contain an elevated concentration of trace metals which may indicate the influence of anthropogenic activities in the study area (Zone-I and Zone-II). It has been recognized for many years that the concentrations of metals found in coastal areas, whether they are in the dissolved or particulate phases are derived from a variety of anthropogenic and natural sources (Burridge et al., 1999). The major part of the anthropogenic metal load in the sea and sea bed sediments and organisms have a terrestrial source from mining and intensive aquaculture and municipal wastewaters, fishing villages, harbour activities, urban and agricultural runoff along major rivers and estuaries and bays (Tarra-Wahlberg et al., 2001; Akif et al., 2002).

Variations of Enrichment Factor between Zone-I and Zone-II

Further investigation of sediment samples was carried out by enrichment factor (EF) to find out the metal concentrations in the samples. The calculation of enrichment factor is one of the most preferred approaches to assess the anthropogenic effects on sediment quality. Enrichment factors (EF) were calculated to compare concentrations with average continental crust (Taylor, 1964). The following formula was used for calculating the Enrichment Factor for a given element X (Birkeland, 1999).

$EF_x = [X_{sample}]/ [X_{standard}]$

An enrichment factor (EF) value of 1 means that a particular element is of natural origin. This standard is used in average continental crust, including coastal area (Taylor, 1964). An enrichment factor of less than 1 indicates a depletion of that element in the sediments relative to the concentration of that element in a given standard due to either mobilization or loss of this element relative to the reference element or an overestimation of the reference element contents; an EF value of greater than 1 indicates enrichment of that element in that sediments relative to the concentration of that element in a given standard. An EF value above 1.5 indicates that there are both the natural process and anthropogenic impacts on the sediments (Hung and Hsu, 2004; Fang et al., 2009; Duan et al., 2010; Fernandes et al., 2011). An EF value between 1.5 to 2 indicates shortage to low enrichment; an EF value between 2 to 5 shows a moderate enrichment; an EF value between 5 to 20 specify a significant enrichment, and EF value between 20 to 40 has a very high enrichment and if EF is greater than 40, it relates to extremely high enrichment (Lianfeng et al., 2010; Feng et al., 2011; Cukrov et al., 2011).

The results show that mostly major and minor elements are in depletion direction. A moderate to significant enrichment in CaO results indicate that the main source is carbonate minerals such as calcite and dolomite (Brems et al., 2016).
Zone-I has a deficiency of low enrichment in TiO_2 as compared to the Zone-II which has depletion. Some Ti-oxide elements enhance the TiO_2 content by weathering after the deposition of sediments. In particular, ilmenite leached iron through weathering, thus upgrades the ilmenite's TiO_2 content (Force, 1991).

Although the high enrichment factor is the first indication of a potential anthropogenic contribution in an element, enrichment is also observed by some natural sources (Atgin et al., 2000). Metal enrichment had occurred along the Makran coast, especially over the last one or two decades. According to EF values,

Cr is in significant enrichment, and Sr is in moderate enrichment.

The trend indicates that the two elements Cr and Sr, have a common origin. It seems that exposed rock in this region appears to have undergone weathering and dissolution process and rain brought sediments here through streams. This is the leading cause of the metal chromium and strontium enrichment in sediments.

On the other hand, anthropogenic origin, the impact of human and environmental pollution is caused by marine vessels. These elements dissolve in water and are associated with carbonates, which are absorbed and deposited in the sedimentary basin. The most important factors increasing the concentrations of these elements are painting, refueling, and oil change in fishing boats of wastewater.

Coefficient Correlations

Correlations Coefficient was derived using the result of sediment samples of Gwadar east Bay, which indicates that SiO_2 has a negative correlation with the mostly major elements reflects silica dilution due to elevated quartz contents. A positive correlation between Al_2O_3 and K_2O suggests that K_2O abundances are controlled by variation in K-feldspar contents. Positive correlation of Al_2O_3 and Na_2O also suggests significant sodic plagioclase content. Positive correlations were found between Al_2O_3 and Cu, Zn suggesting that the abundances of these elements are controlled by the silt and clay fractions present in the sediments. Trace elements with a significant negative correlation of SiO_2 with Zn and Cu, reflecting the significant quartz dilution in the sediments.

The correlation coefficient of Gwadar west Bay shows the strong and positive correlations seen between Sr and CaO. It suggest that strontium is associated with CaO in biogenic carbonate material. Trace element Sr has a significant negative correlation with SiO_2 showing the significant quartz dilution in the sediments.

The coefficient correlation of major and minor elements of Jiwani's results indicate the significant correlation among "SiO_2, Al_2O_3, Fe_2O_3, MnO, P_2O_5, Cl, TiO_2" and negative correlation coefficient between "SiO_2, TiO_2, Al_2O_3, Fe_2O_3 and CaO, MgO, Na_2O, K_2O, SO_3". Trace elements have significant positive correlation among "Zr, Cr, Cu, Eu, Ni, Zn" and significant negative correlation of Sr with "Zr, Zn, Cr, Cu, Eu, Ni".

Results of Ganz has significant correlation in the major and minor elements among the "SiO_2, TiO_2, Fe_2O_3, MgO, MnO" and negative correlation exists between "SiO_2, TiO_2, and Al_2O_3, SO_3". Trace elements show significant correlation among the Zr, Cr, Cu, Eu, Ni, Sr. Negative correlation is also present between Cu and Zn.

Major and minor elements in Pishukan's result show that SiO_2 has negative correlation with the major elements "TiO_2, Al_2O_3, Fe_2O_3, CaO, MnO" and reflects silica dilution due to elevated quartz contents. However, a positive correlation between Al_2O_3 and K_2O suggests K_2O abundances due to variation in K-feldspar contents. The positive correlation between Al_2O_3 and Cu, Zn indicates that abundances of these elements due to limited silt and clay fractions present in sediments. A positive correlation between Sr and CaO provided the information that strontium is associated with CaO in biogenic carbonate material. SiO_2 has a strong negative correlation with Zr and Sr providing significant quartz dilution in the sediments.

Figures 2 to 4 illustrated the geochemical composition of sediment samples from the Gwadar east Bay to Pishukan in the summarized form. Mostly major sampling areas indicated that SiO_2, SO_3, Al_2O_3, CaO, and Cl are in higher concentrations. Whereas the range of contents of MgO, K_2O, and MnO of sediment samples of Zone-II are broader than that of Zone-I. The range of sediment samples of contents of Na_2O, CaO, SO_3 and P_2O_5 of Zone-I is broader than that of zone-II. Some elements like Cl, Fe_2O_3 are different from similar ranges. Sediment samples from Gwadar east Bay showed the highest concentration of SiO_2 elements.

Chemical Maturity

Clastic sedimentary body shows the chemical maturity in the compositional state wherein quartz is abundant and trace or absence of less resistant particles such as lithic fragments, detrital carbonates, and feldspars (Blatt et al., 2004). Examination of sediment samples on a ternary graph revealed its distribution into three areas which consist of a mixture of terrigenous detritus (expressed by SiO_2 and Al_2O_3) and biogenous material (expressed by SiO_2 and CaO), CaO*2- SiO_2- Al_2O_3*5 (Brumsack, 1989). Three sides of the ternary graph represent CaO, SiO_2, and Al_2O_3 which represent calcium carbonate, biogenic silica, and/or quartz and clays respectively. Overall Gwadar west Bay and Jiwani's sediment samples are intermediate in the area of carbonate and in between SiO_2 and CaO line, displaying the variation in contents of carbonate in addition to biogenic silica and quartz. Gwadar east Bay samples are sedimentary layers made of a unique mixture of mud and sand and may have deposited in this area through tides. Gwadar west Bay Sediment sample shifted toward the SiO_2 indicates higher silica content. Coarse grains of quartz-rich sediments are indicated in this region by this surplus of silica rather than biogenic silica.

Quartz is more laborious than feldspar on the Mohs' Scale (Mosquera and Sanchez, 2008). Feldspar belongs to a group of minerals that contain aluminium and silica ion and quartz belong to the mineral that consists of silicon and oxygen (Burat et al., 2007). Feldspar is more commonly found than quartz. Sediment samples

of Zone-I between $K_2O + Na_2O + Al_2O_3$ (indicating the Feldspar content) versus SiO_2 (indicating the quartz content) show a high degree of maturity, which may reflect the rich weathering in source areas. On the other hand, sediment samples from the Zone-II (Ganz and Jiwani) show a lower degree of chemical maturity.

The graph Na_2O / K_2O is used for the quantity of quartz in the sample (Crook, 1974). This graph shows that the sediment samples of Ganz, Jiwani, and Gwadar east Bay are in the Quartz rich field (Figure 5). However, sediment samples from Gwadar West Bay and Pishukan are in the quartz-rich to the intermediate domain.

Provenance of minerals

The primary sources of sedimentation are small streams along the Makran coast rivers. Other sources are coastal erosion through wave action and dust from the arid continental area of sedimentation on this coast. According to Bourget et al. (2010), turbidites are deposited along the Makran coast even at mid and late-Holocene sea-level high stands but with reduced frequency and thicker turbidites compared with the glacial and early Holocene. During the rising sea levels of the early Holocene, much of the terrestrial material contributed mainly by rivers was stored on the shelf and was only occasionally transferred to the deep sea. This trend to thicker and coarser turbidites became enhanced after the mid-Holocene humid period when the decrease in vegetation leads to enhanced erosion (Bouget et al., 2010).

Calcium oxide (CaO) has a strong concentration in both zones of the study area. Potassium oxide (K_2O) has an average concentration in the Zone-1. Titanium dioxide (TiO_2) has more than average concentration in Zone-1 and average concentration in Zone-II. Ferric oxide (Fe_2O_3) has an average concentration in the Zone-II. zirconium (Zr), chromium (Cr), europium (Eu), strontium (Sr) are in intense concentration in both zones, and copper (Cu) shows the average concentration in both zones.

Conclusion

Surficial sediment samples were investigated by dividing the area from Jiwani to Gwadar into two zones. The Research demonstrated that most of the sampling areas of Zone-I indicate that calcium oxide (CaO), potassium oxide (K_2O), titanium dioxide (TiO_2), zirconium (Zr), chromium (Cr), europium (Eu), strontium (Sr) and copper (Cu) has higher or average concentrations. In contrast, Zone-II indicates that calcium oxide (CaO), titanium dioxide (TiO_2), ferric oxide (Fe_2O_3), zirconium (Zr), chromium (Cr), europium (Eu), strontium (Sr), and copper (Cu) has higher or average concentrations. CaO, Al_2O_3 are much more enriched in Zone-II than Zone-I. High CaO content indicates the presence of a high value of shell material. Ganz, Jiwani, and Gwadar east Bay are in the Quartz-rich field, and the rest of the area is in the quartz-rich to an intermediate domain. Gwadar west Bay and Jiwani have high a degree of maturity which may be due to rich weathering in source areas, and Ganz and Pishukan have a low level of chemical maturity. Gwadar east Bay samples show that the sedimentary layer form by a mixture of mud and sand. Gwadar west Bay and Jiwani have carbonate. Trace elements Zr, Cr, and Sr are more than globally crustal average value in the all major sampling sites, Cr and Sr may be of anthropogenic source in this region. A positive correlation between Al_2O_3 and K_2O suggests that abundances of K_2O are controlled by variation in K-feldspar contents. Positive correlation of Al_2O_3 and Na_2O also suggests significant sodic plagioclase content is in Gwadar east bay. SiO_2 has a strong negative correlation with Zr and Sr, which shows significant quartz dilution in Pishukan sediments.

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