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Research Article

HEAVY MINERAL DISTRIBUTION AND GEOCHEMICAL STUDIES OF DAMIATTA AND ROSSETA NILE BRANCHES, EGYPT

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ABSTRACT
The main objectives of the present study are to understand the heavy mineral and trace elemental distribution within the two Nile branches. A total of 20 stations had been collected to identify the percentage of heavy minerals. In the present study area and most of the sediments are medium and fine grained, indicates fresh water and beach environment and most of the grains are positively skewed. The study contained a high percentage of opaques followed by amphibole, pyroxene and epidote and others in rare amounts as garnet, rounded and broken zircons and others. The study contained a high percentage of opaques followed by amphibole and pyroxene and others in rare amounts as garnet, rounded and broken zircons and others. Overall from the geochemistry studies, it is observed that Fe, Mn, Zn and Cr are more dominant.

Keywords: *Sediment Types, Heavy Minerals, Geochemistry, Two Nile Branches*

INTRODUCTION
A placer deposit is the result of flowing water, particularly streams and rivers, causing an accumulation of mechanically segregated are minerals. The erosion of weathered rocks and minerals results in the concentration of the more resistant and higher specific gravity (density) minerals (2.89). Placer deposits can be broadly classified on the basis of mode of origin and transportation. The area of study lies on a few km to the north of Cairo composed of the two branches of the Nile (Figure 1). The Rosetta arm lies on the west and the Damiatta on the east.
The Rosetta Nile branch extends north of El-Khairiya barrage for about 160 km and it opens finally into Rosetta estuary through the gates of Edfina barrage. It varies in width from 250 to 800 m with an average of 500 m. The widest parts lie opposite to Kafer El-Zayat and Dessuq cities. The Damiatta Nile branch extends north of El-Khairiya barrage for about 170 km and it opens finally into Damiatta estuary at Ezpt El-Bourg. It varies in width from 180 to 200 m. The bottom sediments the two branches range from sandy silt in the first half to silty clay in the north part (Draz, 1983). The sediments in river Nile contain heavy minerals like amphibole, pyroxene, epidote, garnet, rutile, zircon and tourmaline (Abu El-Enain *et al.*, 1997; Lotfy, 1997, 1997, 2002 and Abd El-Monsif, 2009). In natural aquatic ecosystems, metals occur in low concentrations, this situation has arisen as a result of the rapid growth of population, increased urbanization, expansion of industrial activities, exploration of natural resources, extension of irrigation and other modern agricultural practices as well as the lack of environmental regulations. In the present study, the sediments were analyzed for their content of eight trace metals, to reveal the concentrations of these pollutants. Attention was paid to the effect of the different waste discharge on the levels of these elements.

MATERIALS AND METHODS
A total of 20 stations and each station have two sediment samples (one from east and other from west beach and the average is taken between them) were collected from Rosetta and Damiatta Nile branch (Figure 1 and Table 1), by using a grab sampler during March and April 2014. The samples were dried in an oven at 60ºC to remove the moisture. Sieving was carried out, using graphic (Folk, 1968; Blott and Pye, 2001). From the mounted slides the individual (>300 grains) minerals were counted by using the line method described by Galehouse (1969). Various diagnostic properties of heavy minerals provided in the Milner (1962) and Rothwell (1989) are utilized for easier identification.

For total digestion the geochemical analytical procedure suggested by Tessier *et al.*, (1979) were followed. The solution of samples was finally analyzed for total Fe, Cu, Mn, Zn, Pb, Ni, Cr, and Cd on a Perkin Elmer Graphic Furnace HGA 800 (Pollution Lab. Nation. Instit. of Oceano. And Fish.).

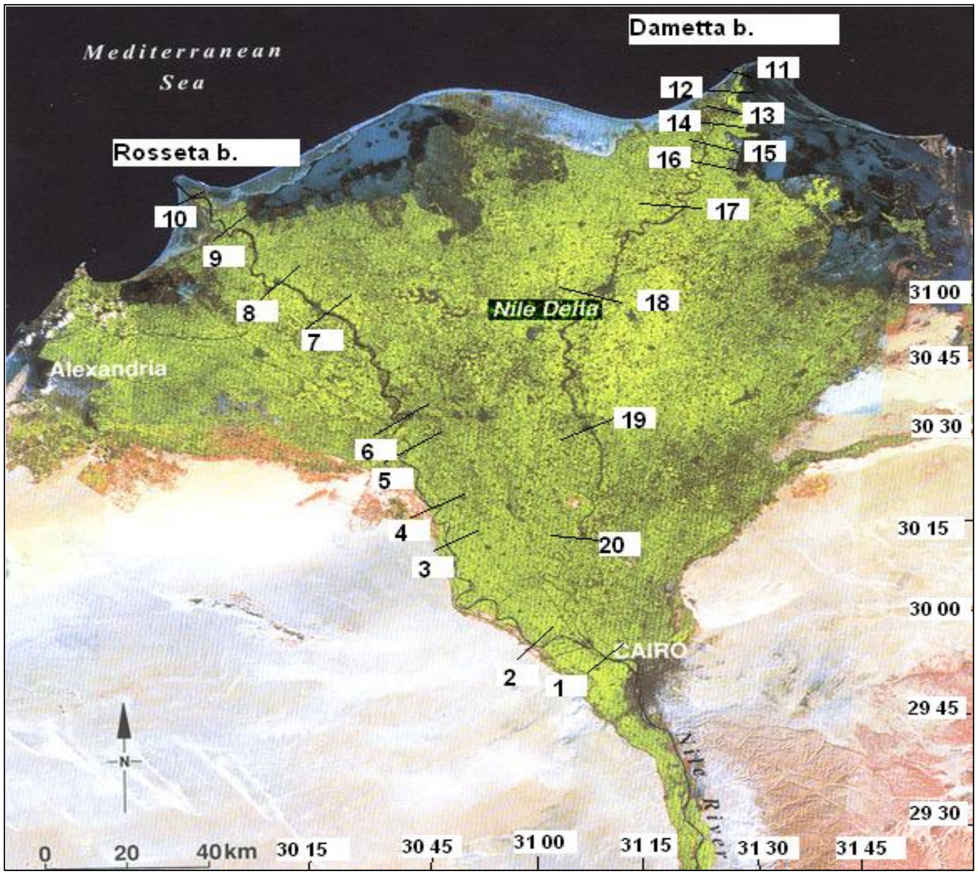

Figure 1: Map Showing Sectors Location at Nile Branches

RESULT AND DISCUSSION

Grain Size Analysis

The result of the grain size parameters of the graphic method (Folk, 1968) such as mean (Mz), standard deviation (σ), skewness (Sk), and kurtosis (K) has been calculated (Table 2).

Mean Size

The mean reflects the overall average size of the sediment as influenced by source of supply and environment of deposition. In the study area, mean size value of Rosseta Nile branch ranges from 0.9φ to 5.6φ indicating a prominent distribution of coarse to fine sediments in this zone (Figure 2), then the mean sizes of the southern zone are coarse to medium grains. In the station of Damiatta Nile branch, mean value ranges from -0.5φ to 4.4φ indicating a prominent distribution of coarse to fine sand size in this area and the coarse grains increase around the Faraskour dam. The fine sand indicate the depositional environment either in suspension, it can be transported by longshore current

Standard Deviation

Standard deviation measures the sorting or uniformity of the particle size distribution. Accordingly, in the study region of Rosseta and Damiatta branches sorting values range from 0.5φ to 2.2φ and from 1.2φ to 2.6φ, respectively (Figure 3) indicates moderately well sorted to very poorly sorted nature may be due to the addition of sediment of different grain size from the reworking of beach ridges or by alluvial action and the prevalence of strong wave convergence throughout the year. Generally, the sample shows general trend of moderately well sorted southwards and very poorly sorted northwards.

Table 1: The Station Number and Station Name

Station Number	*Station Name*
1	El-Kanater
2	El-Rahawy
3	Tamalay
4	Sabal
5	Kom Hamada
6	Kafr El-Zayat
7	Desuq
8	Fowa
9	Rosetta city
10	Rosetta Estuary
11	Ezpt El-Bourg
12	El-Khayata
13	El-Ratma
14	Damiatta city
15	North Faraskour dam
16	South Faraskour dam
17	El-Serw
18	Talkha
19	Zefta
20	Benha

Table 2: Grain Size Parameters in Phi (Φ) for Sediment Samples

St.	Rosseta Branch				St	Damiatta Branch			
	Mz	Σ	Sk	K		Mz	σ	Sk	K
1	5.7	1.7	0.0	1.2	**11**	3.8	1.2	-0.7	0.4
2	2.7	1.4	-0.2	1.4	**12**	3.9	2.0	0.3	1.2
3	1.3	0.6	-0.1	1.6	**13**	-0.5	1.2	0.8	1.7
4	2.1	0.5	-0.3	1.2	**14**	2.2	2.3	-0.2	1.7
5	1.7	1.0	-0.3	1.5	**15**	3.6	2.3	0.5	1.3
6	3.5	1.6	0.9	2.9	**16**	3.2	1.5	0.6	1.3
7	0.9	1.9	0.0	0.7	**17**	3.3	2.6	0.2	1.1
8	3.6	2.2	0.5	1.9	**18**	4.4	2.1	0.5	1.1
9	2.4	0.8	0.2	0.5	**19**	3.8	1.9	0.3	1.2
10	2.4	0.5	-0.1	1.2	**20**	3.7	1.3	0.6	1.2

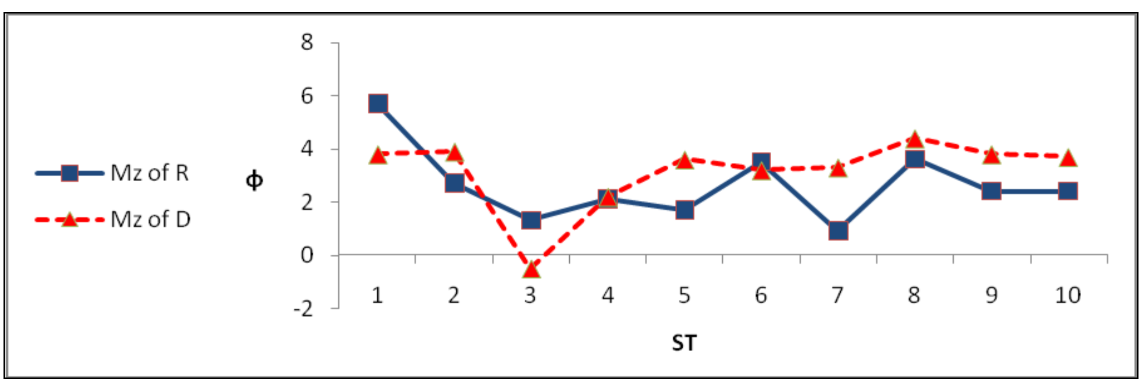

Figure 2: Distribution of Mean Sizes (φ) of the Rosseta and Damiatta Nile Branch Sediments from North to South

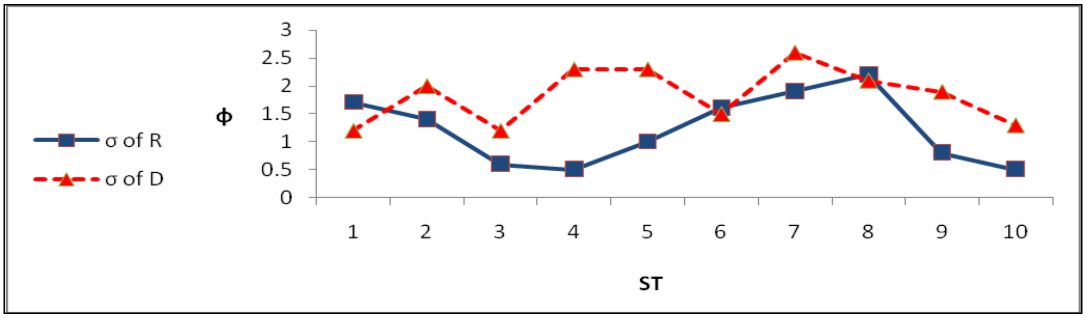

Figure 3: Distribution Standard Deviation (φ) of the Rosseta and Damiatta Nile Branch Sediments from North to South

Skewness

Skewness measures the asymmetry of the distribution. In general, the skewness values of these sediments vary from negatively to positively skewed (from -0.3 to 0.9 of Rosseta branch and from -0.7 to 0.8 of Damiatta branch, Figure 4). It implies the prevalence of high and low energy environments in different wave directions, entailing a mixed distribution of coarse and fine sediments. Due to washing and backwashing of waves, coarser sediments are retained and get entrapped amidst finer sediments.

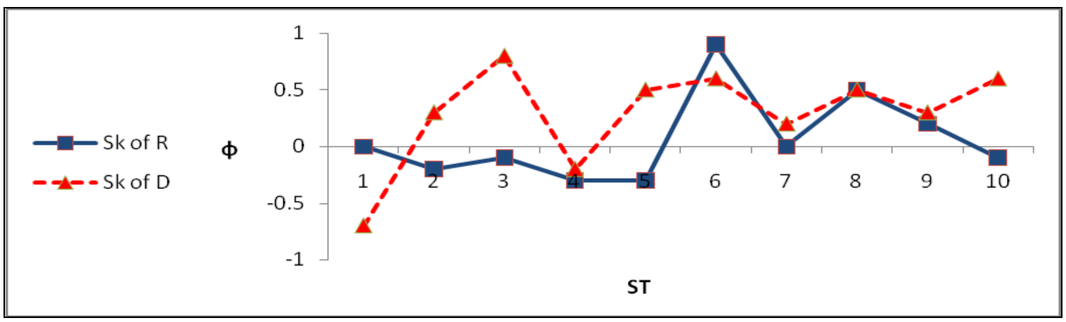

Figure 4: Distribution Skewness (φ) of the Rosseta and Damiatta Nile Branch Sediments from North to South

Kurtosis

The graphic kurtosis in the qualitative measure of the part of sediments already sorted elsewhere in a high energy environment and later transported and modified by another type of environment (Folk, 1968). But the moment kurtosis is an index of mixing of two-end populations (Thomas *et al.*, 1972). The graphic kurtosis study shows that the area is leptokurtic to platykurtic in nature indicates multiple environment i.e. one derived from riverine/aeolian environment and the other primarily derived from marine environment (Figure 5).

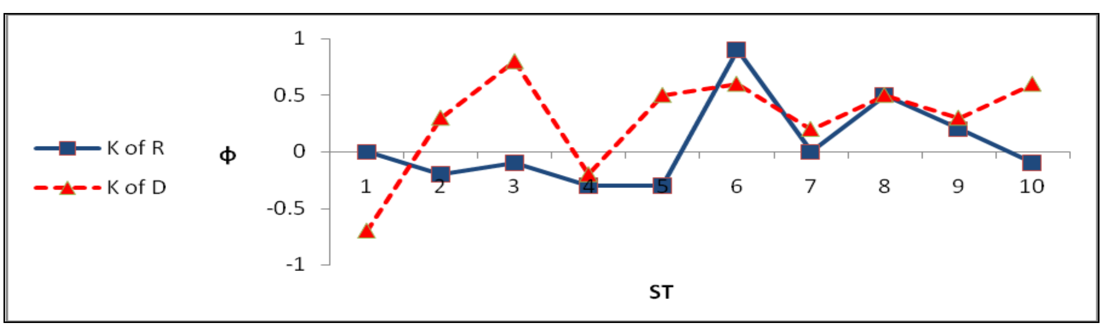

Figure 5: Distribution Kurtosis (φ) of the Rosseta and Damiatta Nile Branch Sediments from North to South

The moment kurtosis values are found to vary from 0.5 to 2.9 in the sediments of Rosseta branch and from 0.4 to 1.7 in the sediments of Damiatta branch. This uneven nature clearly designates the mixing of two-end populations. This is also attributable to the widely varying nature of sediments and change in gradients of the coastline.

Depositional Environment

Bavarian Plots

In the present study, various textural parameters obtained through both graphic and movement methods have not shown many variations. Several earlier workers like Moiola and Weiser, (1968), Hails and Hoyt, (1969), Jaquet and Vernet, (1976), Rajamanickam and Gujar, (1984) and Rajamanickam and Gujar, (1993) have also expressed similar views.

The bavarian plot of mean vs. standard deviation (Figure 6) shows that the sediments of poorly sorted irrespective of their coarseness or fineness. This emphasizes the fact that sorting is independent of grain size and that sorting deteriorates in both coarse and fine sediments. The plot of mean vs. skewness (Figure 7) shows that the skewness values vary from positive to negative with increasing mean sediment size. The scatter plot of mean vs, standard deviation (Figure 8) shows a distinct group. It indicates a poorly sorted as mean size decrease. The scatter plot of standard deviation vs. skewness (9) also helps to characterize as a separate cluster. The study region shows the influence of fluvial and beach environment.

Heavy Minerals

Table 3: Heavy Minerals Weight % in the Study Area

Rosseta Nile Branch Stations		*Damiatta Nile Branch Stations*	
Stations	Heavy m.%	Stations	***Heavy m. %***
1	11.51	11	***21.3***
2	15.41	12	***19.1***
3	18.41	13	***21.5***
4	16.6	14	***19.6***
5	16.6	15	***20.1***
6	20.33	16	***15.8***
7	16.1	17	***19.6***
8	15.41	18	***14.6***
9	19.6	19	***18.9***
10	23.3	20	**12.9**

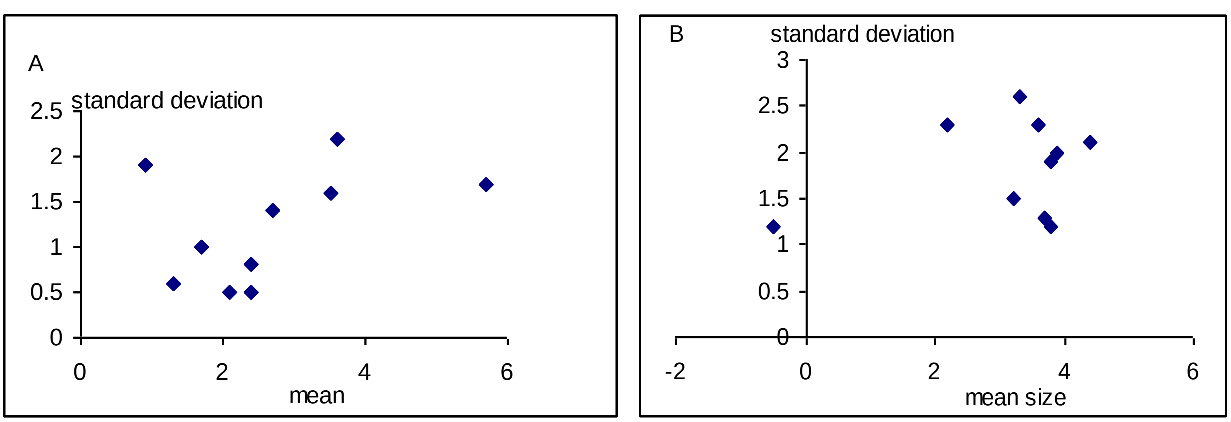

Figure 6: Mean vs. Standard Deviation (A- Rosseta b., B- Damiatta b.)

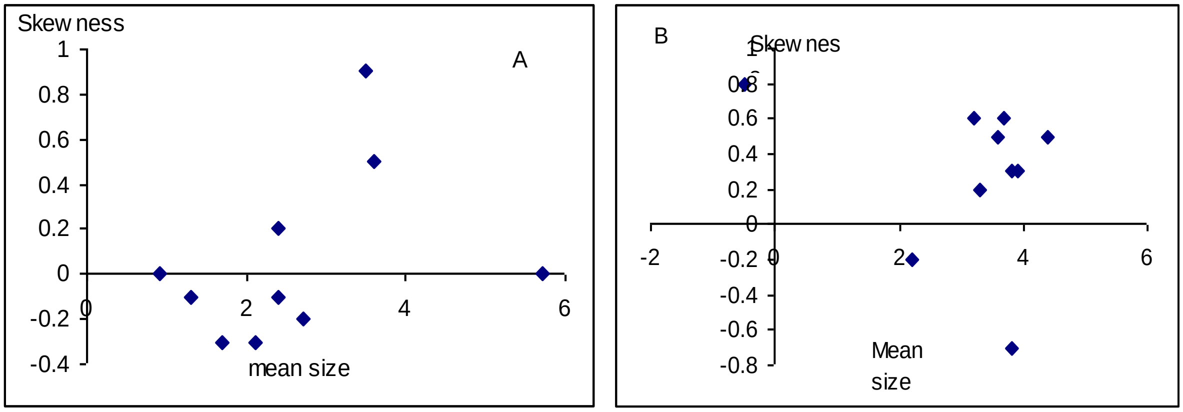

Fig. 7: Mean vs. Skewness

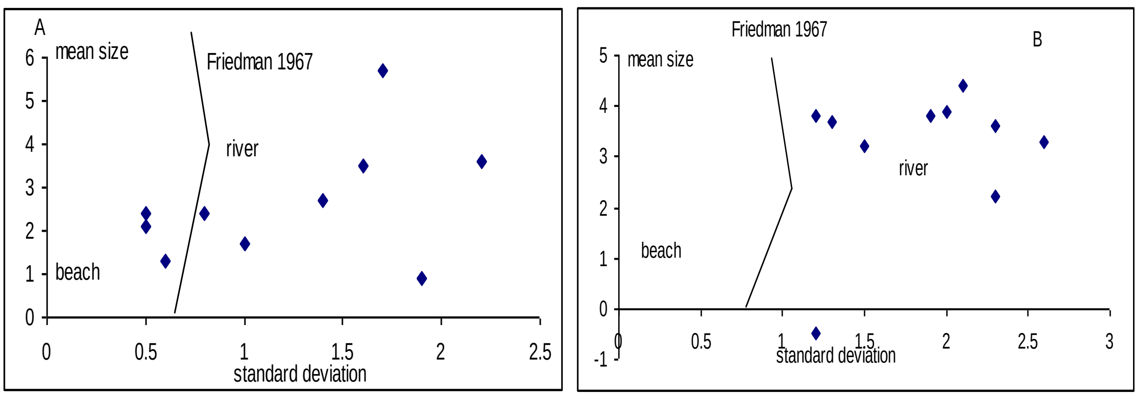

Figure 8: Mean vs, Standard Deviation

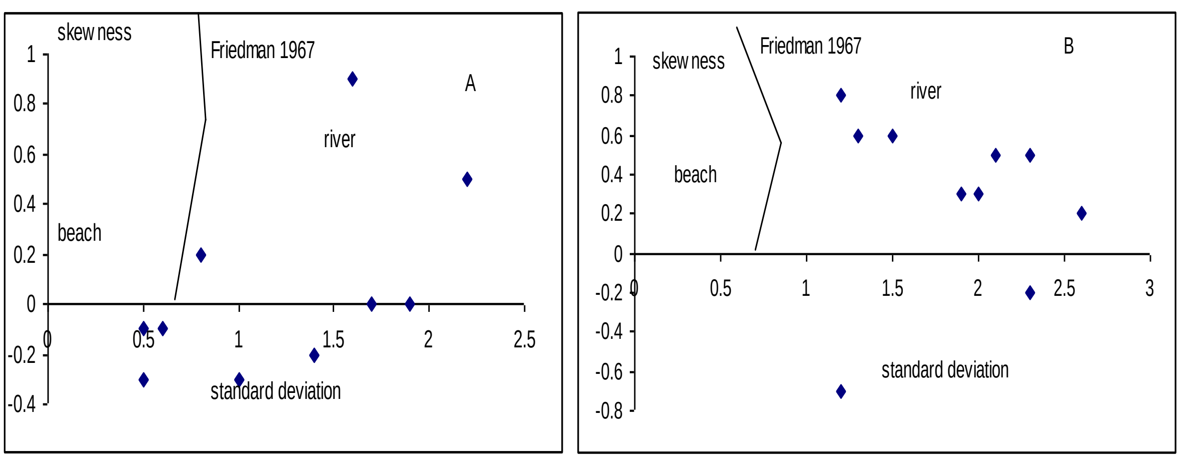

Figure 9: Standard Deviation vs. Skewness

The heavy minerals weight percentages of various locations for beach of the study are given in Table 3. In the study region, the fine sand receives more number of heavies. Based on heavy mineral distribution, it is observed that from stations 3, 6, 9 and 10 of Rosseta branch and from 14, 16, 18 and 20 of Damiatta branch records appreciable amount of heavies in the finer sediments. This enrichment in the finer grade in mainly due to selective removal of light minerals leaving behind coarser light minerals and heavy density minerals in HIL ratio (Frihy and Komar, 1991) for the different fractions (0,149-0.063mm) shows a gradual increasing trend towards finer size.

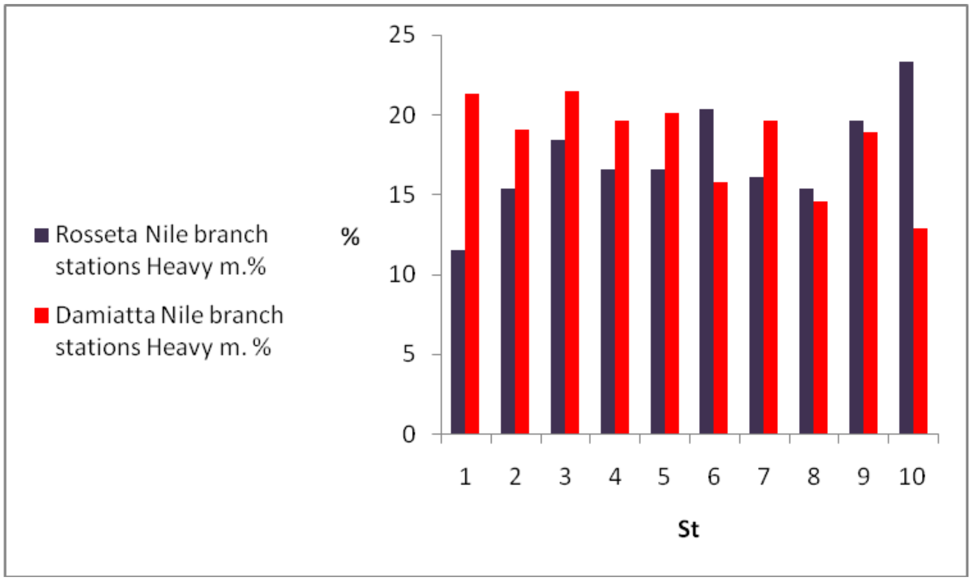

Figure 10: Heavy Mineral Weight % of Rosseta and Damiatta Nile Branch Sediments

At the station 3, 6, 9 and 10 in Rosseta branch and the station 12, 14, 16, 18 and 20 in Damiatta branch, the heavy weight percentage is very less in amount. The beach environment of the study area is more amounts of opaques, pyroxene has contained a high percentage of orthopyroxene (hypersthene) and monoclinic pyroxene (violet brown augite and diposide), amphibole (rounded prismatic hornblende) and epidote (yellowish green to green, rounded to sub-rounded with clear pleochrism) and lesser amount of garnet (colorless and pink), kaynite, apatite, rutile, zircon and tourmaline is noticed. The heavy mineral assemblage of the study region is governed by the distribution of different type of minerals. However, the assemblage is restricted to the dominance of few selective minerals like garnet, zircon, rutile, tourmaline and others.

The study area is characterized by a suite of opaques (19.63-39.10%), pyroxene (22.48-30.30%), amphibole (27.48-37.27%), epidote (4.17-8.11%), garnet (0.26-1.50%), apatite (0.41-1.24%), rutile (0.15-1.01%) and zircon (0.26-0.93%) minerals. Based on heavy minerals, an attempt has been carried out to find their parent rocks in the provenance. The mineral like hyperthenes, garnet and kyanite may be assigned to the contribution of different high grade metamorphic rocks. The opaques (mainly ilmenite and magnetite), zircon euhedral and rutile might have been derived from igneous rocks of acidic and basic compositions of the eastern desert. Similarly, the rutile, rounded zircon and the remaining above said minerals having roundness in the range of sub-rounded nature, etching, over growths, out growths, etc., can be related to the ancient sediments which have undergone the recycling. When comparing the different rock types and the mineral assemblages of the study area, it is suggested that along with the high rank metamorphic, acidic and basic igneous rocks, reworked sediments and the low rank metamorphic rocks are expected to provide a significant contribution in these environments. From this, it may be concluded that along with the contribution of the minerals from the rock types of upper Egypt and other south countries and transported by Nile water during the seasons of flood.

Trace Elements

Analyses of trace metal distributions in the study area indicate that metal concentrations in sediments are controlled by variations in the reactivity of different particle types and sizes, and natural sources. Geochemical analyses for Fe, Cu, Mn, Zn, Pb, Ni, Cr and Cd were carried out and their mean concentration is listed in Tables 4 and 5 and Figure 11.

Tables 4: Results of Trace Element Geochemistry in the Rosseta Nile Branch Sediments (ppm)

Stations	Fe%	Cu	Mn	Zn	Pb	Ni	Cr	Cd
1	4.8	39.5	1124.9	87.6	56.4	59.6	127.2	5.4
2	4.96	79.6	1280.1	126.4	31.6	80.9	140.4	9,5
3	9.92	65.5	600.1	208.7	84.1	76.6	93.2	8.8
4	4.88	50.5	801.6	170.6	34.5	38.4	409.2	11.9
5	4.93	70.7	1709.7	220.6	85.3	76.3	390.3	9.3
6	5.03	40.5	920.7	156.6	54.4	87.6	227.9	10.3
7	4.83	79.6	1450.7	310.6	148.2	76.6	442.9	10.6
8	4.92	250.7	1107.6	134.5	185.6	66.8	162.9	71.9
9	4.72	88.8	1125.2	348.8	332.6	91.2	145.5	61.3
10	4.66	230	924.6	520.3	87	130.6	130.6	7.5

Table 5: Results of Trace Element Geochemistry in the Damiatta Nile Branch Sediments (ppm)

Stations	Fe%	Cu	Mn	Zn	Pb	Ni	Cr	Cd
11	4.81	22.8	138.3	65.1	18.7	70	292.6	9.5
12	4.08	64.7	1267	243.9	82.3	82.2	128.3	11.9
13	4.91	60.5	750	226	34.5	76	128.7	7.7
14	4.83	68.3	800.4	148.6	60.7	76.6	130.7	9.3
15	4.77	77.3	1189.0	240.6	46.9	73	106.1	61.3
16	4,96	65.9	1702.6	152.8	38.2	78.3	114.4	9.8
17	4.97	125.5	2488	404.2	47.5	38.1	118.8	6.6
18	4.95	214.4	613.2	317.8	62.9	82.1	99	12.2
19	9.93	145.4	830.2	287.7	51.8	86.3	168	8.7
20	4.69	99.3	742.6	1200	17.1	66.3	116.5	6.1

Iron (Fe)

Iron is the most abundant metal, and is believed to be the tenth most abundant element in the universe. The range in sedimentary iron values between 4.64 and 9.93% with an average of 5.01% in the beach stations of the two branches.

The highest concentration was observed at station 3 (Rosseta b.) and station 19 (Damiatta b.) (Table 3 and Figure 11) and the lower concentration was in station 10 (Rosseta B.) and station 20 (Damiatta b.) northwards. The iron in the study area was relatively low than the average continental crust values (Wedepohl, 1995).

Copper (Cu)

Copper content varies in study area stations from 22.8 to 250.7 ppm with an average of 96.99 ppm. The highest concentration was observed in station 8 (Rosseta b.) and station 18 (Damiatta b.), northwards and the lowest was observed in the station 1 (Rosseta b.) and station 11 (Damiatta b.), southwards. The higher concentration of Cu in the north on the two branches .t due to the high accumulation of the organic matter and Fe-Mn oxyhydroxides produce simultaneous accumulation heavy metals in sediments (Ottosen *et al.*, 2006).

In particulate contamination derived from boating activities, and in particular, paint chips or flakes resulting from the annual cleaning (e.g. pressure-hosing) or, less frequently, complete scraping (shot blasting, sanding, stripping) of automobiles (Turner *et al.*, 2008).

Cu probably entered the basin of deposition largely structurally combined in the lattice of clay minerals (Goldshmidt, 1964).

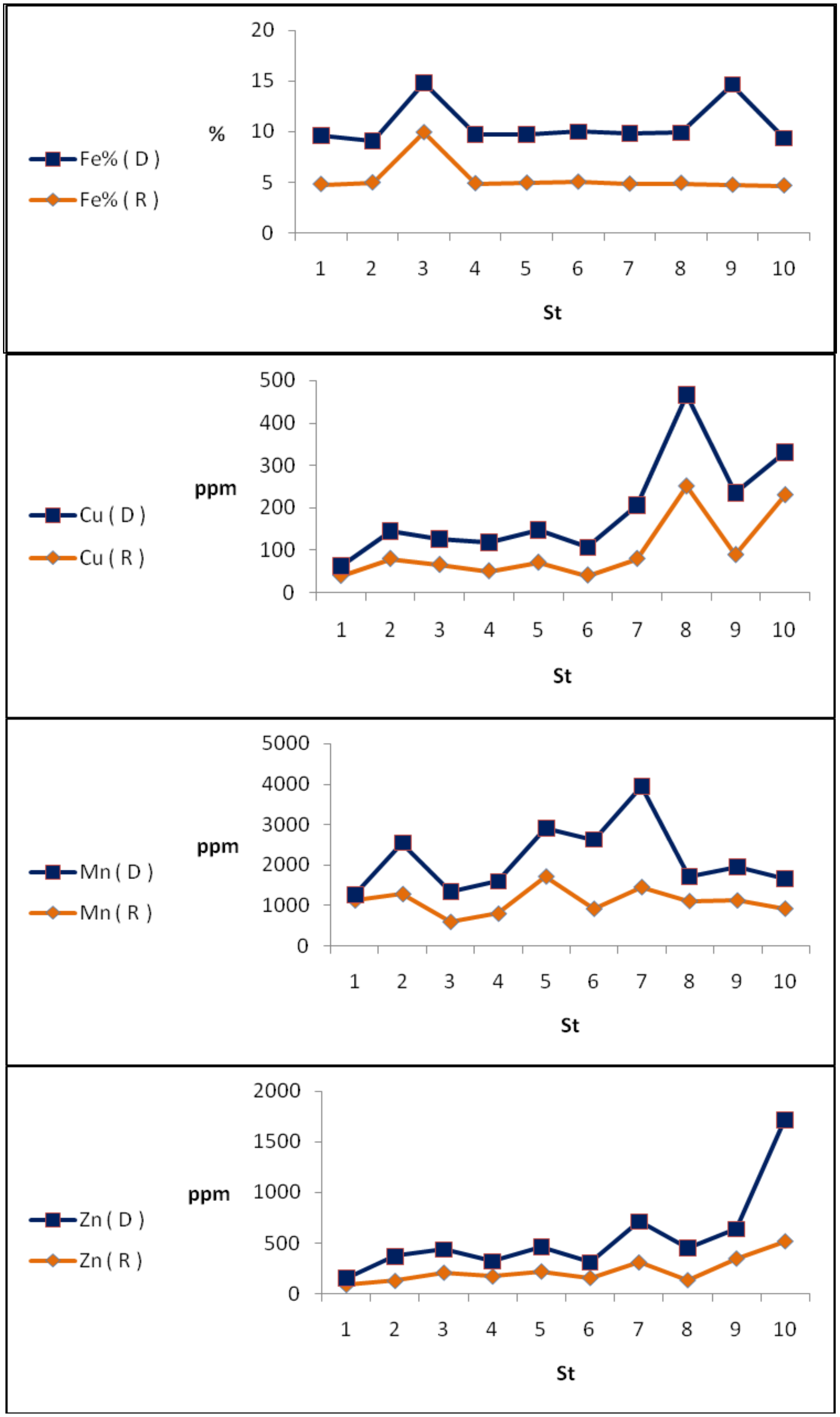

Figure 11: Distribution of Trace Elements (Fe %,Cu, Mn and Zn) Geochemistry in the Rosseta (R) and Damiatta (D) Nile Branch Sediments (ppm)

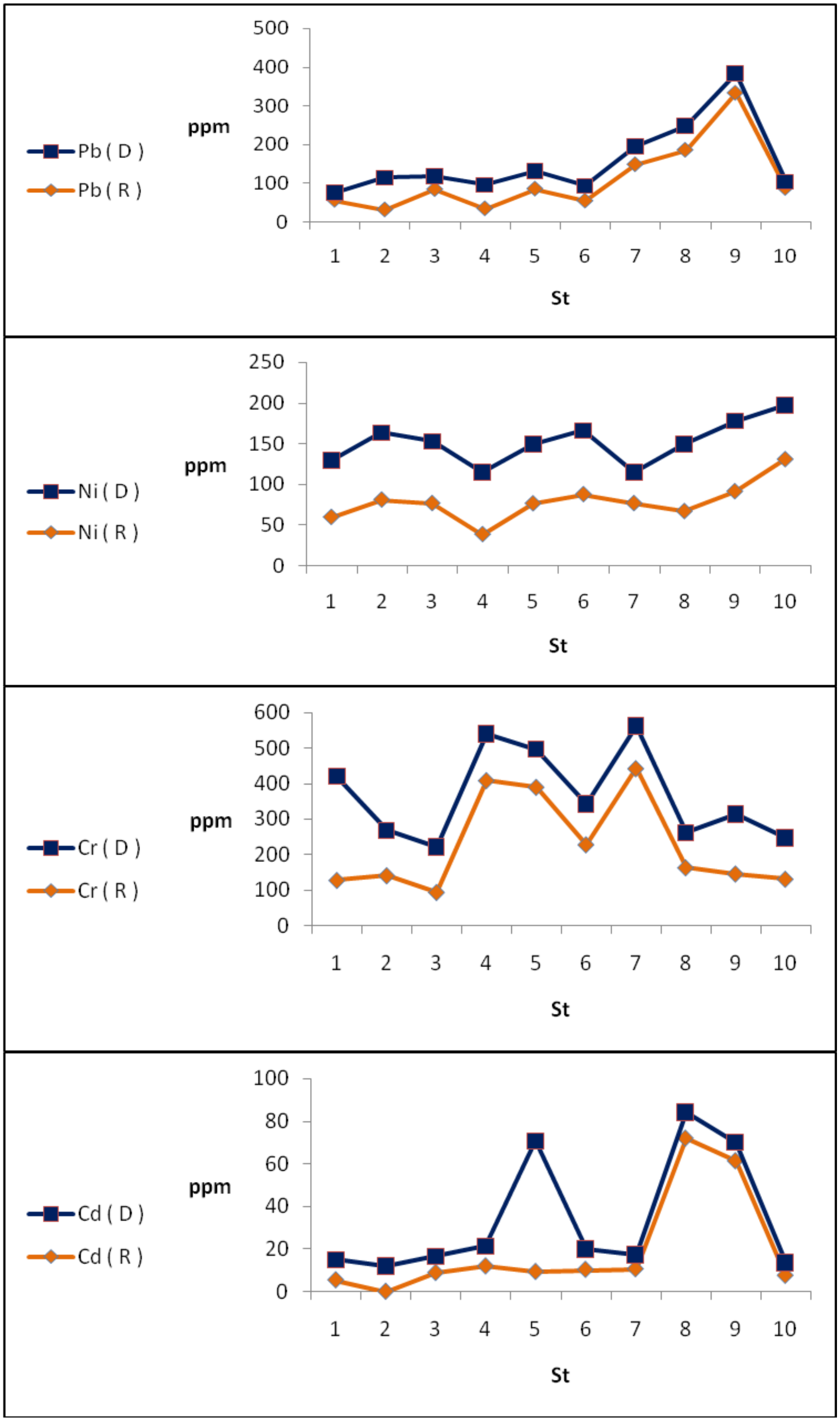

Figure 12: Distribution of Trace Elements (Pb, Ni, Cr and Cd) Geochemistry in the Rosseta (R) and Damiatta (D) Nile Branch Sediments (ppm)

Manganese (Mn)

Manganese is very common compound that can be found everywhere on earth. Manganese in the study area ranges from 600.1-2489 ppm. The highest concentration was observed at station 5 and 7 which are in middle of Rosseta b. and station 16 and 17 which are in middle of Damiatta b. The lowest concentration was observed at station 3and 4 of Rosseta b. and 13 and 14 of Damiatta b. (Table 3 and Figure 11). The Mn concentration was relatively lower than the average continental crustal values. Manganese is relatively abundant with an average upper crustal abundance of 600 mg kg^{-1} and bulk continental crust average of 1400 mg kg-¹ (McLennan and Taylor, 1996). It's indicating the manganese in sediments is only from the lithogenous origin. The concentration was low at northern part and relatively high in middle and southern part. This is due to the grain size effect in the marginal river sediments, where the fine grain sediments accumulate there will be high concentration of metals. This is well supported by the grain size, fine sediments were high at middle and southwards.

Zinc (Zn)

Zinc occurs naturally in air, water and soil, but zinc concentrations are rising unnaturally, due to addition of zinc through human activities. The concentration of zinc varies from 65.5 to520.3 ppm with an average of 224.55 ppm in beach sediments. The highest concentration was observed in station no. 9 and 10 (Rosseta b.) and station 17 and 18 (Damiatta b.) and the lowest observed in south part of the two branch. The concentration was relatively higher than the world average soils. The highest concentration of zinc is mainly due to input of organic wastes in aquatic environment, which comes from municipal sewage, and dumping materials contributes to the zinc increase in sediments (Alagarsamy, 2006). Zinc can enter the aquatic environment from a number of sources including industrial discharges, sewage effluent and runoff (Boxall *et al.*, 2000). Zn probably incorporated within ferromagnesium heavy minerals (amphiboles and pyroxenes) as well as combination in the lattice structure of montmorillonite (Goldshmidt, 1964).

Lead (Pb)

From Table 3 and Figure 12, the lead content varies from 17.1 to 317.8 ppm with an average of 78.02 ppm. The highest concentration of Pb was observed in station 9 (Rosseta b.) and station 12 and 18 (Damiatta b.) and the lowest content were observed in all the remaining stations. Lead values in bay, estuarine and other sediments have been much altered by activities (Alagarsamy, 2006). This Pb concentration was lower than the beach sediments and some other marginal marine areas. The concentration of Pb was low due to the dilution of seasonal rainfall. The higher concentration of Pb indicates the contamination in sediments, when compared with the world average crustal values (Wedepohl, 1995). Pb absorbed generally within iron oxide minerals in addition to its association with Rb in the lattice structure of feldspars (Goldshmidt, 1964).

Nickel (Ni)

Nickel is a compound that occurs in the environment only at very low levels and is essential in small doses but it can be dangerous when the maximum tolerable amounts are exceeded. The nickel concentration in the study area varies from 38.1 to 91.2 ppm with an average 73.5 ppm. The nickel content was relatively high with compared to other coastal and average sediments. This is due to the seasonal effect and fresh water input has diluted the concentration in the river sediments. In the study area, nickel concentration is trend to increase the north side of stations. Ni is usually incorporated within pyroxenes and in chlorite which is an important weathering product of ultrabasic rocks (Goldshmidt, 1964).

Chromium (Cr)

Chromium one of most important trace metals at the aquatic environment. The chromium concentration in the study area varies from 93.2 to 442.9 ppm with an average of 184.01 ppm, the contamination factor of Chromium is >4 also indicates the chromium contamination is relatively higher in sediments, when compared with the world average crustal values (Wedepoll, 1995). The highest value was observed in station no. 4, 5, 6 and 7 in the Rosseta branch sediments and station no. 11 and 20 in the Damiatta branch sediments and the lowest at remaining stations. The enrichment of chromium is mainly due to the dumping of enffluents from the nearby industries of the study area. The anthropogenic influence in the marginal river sediment which is due to the occupational exposure of numerous processes including chrome colors and dyes, cement, tanning agents, anticorrosive agents, welding fumes, lubricating oils and gasses, cleaning materials, textiles and fures, tend to increasing the chromium concentration. Cr also shows higher concentrations in the ultra basic minerals (pyroxenes), (Goldshmidt, 1964).

Cadmium (Cd)

Meanwhile, the river branches water close to the mouse of the agricultural drains are highly enriched with cadmium. The study area results show that the cadmium variation is from 5.4 to 71.9 ppm with an average of 17. 48 ppm, the chromium concentration is relatively higher in sediments, when compared with the world average crustal values (Wedepoll, 1995). The highest value was observed in station no. 8 and 9 in the Rosseta branch sediments and station no. 15 and 18 in the Damiatta branch sediments and the lowest at remaining stations. Cadmium also show positive correlation with lead and zinc indicating the anthropogenic influence in the marginal river sediments which due to the occupational exposure of numerous processes including dyes, cement, tanning agents, anticorrosive agents, welding fumes, lubricating oils and gasses, cleaning materials, textiles and fures.

Discussion

Based on the heavy minerals studies, it is clearly observed that the coastal region between Kom Hamada and El-Kanater at Rosseta branch and between North Faraskour dam and Benha at Damiatta branch is lesser percentages of heavy mineral distribution than the other coastal regions. Opaque minerals are slightly higher than the non opaque minerals in this region. Only selective minerals like pyroxene, amphibole and epidote are dominated. The lesser percentages of garnet, kaynite, apatite, rutile, zircon, tourmaline, etc., are noticed. A large quantity of sediments is supplied by the major Nile River the south region and is constantly moved by the waves either towards the north depending on the angle of wave approach with respect to the coast, the rate of sediment transport varies from time to time along the river Nile and the maximum value takes place during the flood season. The percentage distribution of the total heavy mineral concentration by weight with respect to station to station of individual grain sizes exhibit in study area environments display hardly any significant trend. This may be due to the fact that these environments are influenced by different factors in different times at a particular point (Lotfy, 1997).

Overall, all from the geochemistry studies it is observed that the Fe, Cu, Zn, Pb and Ni are more dominant and higher concentration northwards of two branches. Mn and Cd are more concentrated in the mid stream of the two branches sediments, and Cr are more dominant and higher concentration southwards of Damiatta branch and in mid-stream of Rosseta branch.

Hanamgond and Nayak (2011) the concentration of heavy metals/elements is controlled by the particle size. It is reported that, adsorption of heavy metals is inversely related to the particle size, where finer particles due to their high specific area, adsorb more heavy metals. The available minerals and their chemical weathering/leaching effect mainly influence the distribution of elements in both the grain size fractions.

The finest grain-size fraction River Nile branch sediments point out to a continuous enrichment in heavy metals due to the active surface of Fe-oxides and clay minerals (Förstner and Wittman, 1981). Metal sorption reactions of metals in different competing clay minerals studied by Rybicka *et al.,* (1995) show the highest Pb enrichment for smectite and illite. Several environmental studies use clay mineral associations in sediments to trace the sediment transport in the estuarine and river environment (Irion and Zöllmer, 1990, Pandarinath and Narayana, 1992 and Wijayananda and Cronan, 1994).

The levels of metals in the study area did not follow the same pattern of unpolluted sediments of inland water (Salomons and Förstner, 1981), but show higher levels of Cu, Mn, Zn, Pb and Cd, and lower values of Fe, Ni and Cr.

Conclusion

In the study area most of the sands are fine and medium grained indicates beach environment and most of the grains are positive skewed with very platykurtic to leptokurtic indicates multiple environments. Most of the grains are moderately well sorted to very poorly sorted may be due to addition of sediments of different grain size from the reworking of beach edges or by fluvial action.

The heavy mineral of the study area is governed by the distribution of different type of minerals. However, the assemblage is restricted to the dominance of few selective minerals like garnet colorless, garnet pink, kaynite, apatite, rutile, zircon, tourmaline, etc. The study region contained a high percentage of orthopyroxene (hypersthene) and monoclinic pyroxene (violet brown augite and diposide), amphibole (rounded prismatic hornblende) and epidote (yellowish green to green, rounded to sub-rounded with clear pleochrism).

From the geochemistry studies, the Fe, Cu, Zn, Pb and Ni are more dominant and higher concentration northwards of two branches. Mn and Cd are more concentrated in the mid stream of the two branches sediments, and Cr are more dominant and higher concentration southwards of Damiatta branch and in mid-stream of Rosseta branch. The concentration of heavy metals/elements is controlled by the particle size, where finer particles adsorb more heavy metals. The available minerals and their chemical weathering/leaching effect mainly influence the distribution of elements in both the grain size fractions. The higher concentration of heavy metals in the north of the two branches is due to the high accumulation of the organic matter and Fe-Mn oxyhydroxides produce simultaneous accumulation heavy metals in sediments. There is anthropogenic input in the study area.

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