Heavy Mineral Distribution and Geochemical Studies of Coastal Sediments at Sonadia Island, Bangladesh

M. Z. Kabir*, F. Deeba, M. G. Rasul, R. K. Majumder, M. I. Khalil and M. S. Islam

Institute of Nuclear Minerals, Atomic Energy Research Establishment, Dhaka-1349, Bangladesh

Abstract

This work attempts to understand the heavy minerals distribution, mineralogical composition and trace elements distribution in beach sands of Sonadia Island, Cox's Bazar district, Bangladesh. Total 14 beach sand samples were collected from the study area to determine the heavy mineral percentage, mineralogical composition and elemental concentrations. The separated minerals were examined by a polarizing petro graphic microscope. About 12.8 – 84.96% heavy minerals concentrations were found in the analysed samples by heavy liquid separation technique. Result of mineralogical composition suggests that garnet is the dominant mineral component followed by ilmenite, magnetite, rutile and zircon. Elemental concentration using XRF techniques reveals the average concentrations of Zr (198.75 ppm), Sr (82.76 ppm), Rb (93.62 ppm), Pb (9.03 ppm), Zn (38.75 ppm), Mn (390.73 ppm), Fe (15127 ppm), Th (3.78 ppm), Cu (18.08 ppm), Co (70.84 ppm), Ti (1598 ppm), Ba (280.47 ppm), Cs (91.62 ppm) and Ni (16.03 ppm). The radioactivity of the study area was found to be 24 and 170 cps. The source of the heavy minerals observed in the Sonadia Island is possibly from the Miocene sedimentary rocks exposed along the Cox's Bazar beach, which have been distributed along the beach by the long shore current, waves and winds.

Keywords: Heavy minerals, heavy liquid separation, radioactivity, XRF, placer deposits, Sonadia Island

1. Introduction

The heavy mineral deposits along the coastal belt of Bangladesh constitute potential resources for Bangladesh. The fore dune deposits also contain noticeable amount of heavy minerals, which are being accumulated within the intertidal zone. This part is very dynamic and exposed subject to wave, current and wind actions. Mineral sands on those deposits contain some important metallic minerals mainly ilmenite, magnetite, rutile, zircon, garnet, monazite, kyanite and leucoxene [1]. The heavy mineral concentration along the recent fore dune deposit of Bangladesh coast ranges from 13% to 70%, which is quite significant [2]. Presence of radioactivity in Cox's Bazar beach of Bangladesh was first reported by Schmidth and Asad [3]. Placer deposits of Bangladesh coast contain several heavy minerals, in which monazite is radioactive mineral because of thorium in its composition [4]. Radioactivity is also observed in the separated zircon assemblages [5].

The islands of Bangladesh are scattered along the Bay of Bengal and the river mouth of the Padma. A huge amount of sediments are also thought to be carried by under currents into the deeper Bay of Bengal and the Indian Ocean. The bottom topography of the Bay of Bengal plays a dominant role in the dynamic processes in the North Bay and Bangladesh coast which results in frequent geomorphological changes in the adjacent coast and islands [6-7].

Sonadia is a small offshore island of about 9 km^2 and is located in the Bay of Bengal on the West side of Cox's Bazar under Kutubjum union of Moheshkhali Island. Though Moheshkhali Island is little far from the active delta formation region, it still receives a lot of sediment and undergoes coastal process which helps re-shape the morphology of the island's coast, especially the south and south-eastern part including Sonadia Island [8]. An intertidal beach and sandy ridge extends along the length of the western side of the Island's length from north-west to south-east. Changes are apparent in the south-eastern coastline of Sonadia Island, which thus gets the characteristics of a sandbar [9]. An intertidal sandy beach and sandy ridge extends for approximately 12.5 km along the length of the western side of Sonadia Island, from north-west to south-east [10]. The Sand bars and sandy shoals occur along the Ghotivanga coastline and extend along the length of the western beach of Sonadia Island.

Consisting of gently sloping low-lying coast unprotected from the sea, Sonadia Island hasformed as a barrier island just south-west of Moheshkhali Island. Natural sandy breakwaters face parallel to the flat coastlines of Moheshkhali. To the east a smallchannel separates the two islands while to the south-east shallow bays separate it by 3.5 km from the mainlandof Cox's Bazar.

The dunes run along the entire coast and are also fringed several hundred meters inward. Wind and waves are the major forces determining the features of the dunes. The western side of the island is sandy and different kinds of shells are found on the beach.

Sonadia Island constitutes a complex and unique geological system on the eastern cliff coast of Bangladesh (Fig.1). Holocene evolution of the island is very different and rather complex than those of the other estuarine or deltaic islands of Bangladesh. Sonadia Island is neither deltaic Bay mouth bar nor estuarine mouth bar but sub maridional bar to the cliff coast and situated within the shallow and wide inner shelf. The present shore face of the area is characterized by the presence of numerous long shore bars along the west coast and barriers are found along the northern coast of Sonadia Island. Geomorphologic study reveals that the Island is largely initiated due to the combined erosional and depositional processes on an open to semi-protected depositional basin under the transgressive shore face [11].

Corresponding author: zafkab_geoaec@yahoo.com

Many investigations have been carried out on different physical and chemical aspects like mineralogical composition of the beach sands [12] and mechanism of heavy mineral deposition in the beach of Cox's Bazar [13], but a few studies have been conducted on Sonadia Island.

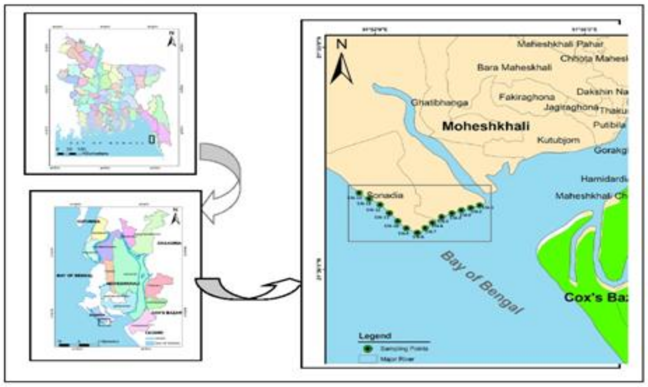

Fig. 1 Location map of the study area

The present study was done with a view to understand the heavy mineral distribution, mineralogical composition and trace element distribution within the beach sediment of Sonadia Island. Several hand auger drilling were made in order to observe the vertical extent of the heavy minerals in the island. During auger drilling, sand samples were taken in order to make laboratory investigation. In the laboratory, physical separation and microscopic techniques were employed to characterize the heavy minerals. A portable Radiation Survey Meter was used to measure radioactivity of the study area. Global Positioning System (GPS) was used to locate the position of sampling points.

2. Materials and Method

The present work incorporates various methods, such as field investigation, heavy mineral separation and mineralogical analysis by microscope and elemental analysis through portable XRF analyzer.

2.1 Field investigation

A geological fieldwork has been carried out at Sonadia Island of Moheshkhali Upazilla. Sandy beach and ridge extends along the length of Sonadia Island from north-west to south-east. The dunes run along the entire coast and are also fringed several hundred meters inward. The average height of the dunes was 1 m while average length and width was 60 m and 38 m respectively. Samples were collected from the dune sand where heavy minerals were relatively concentrated. In the field, Global Positioning System (GARMIN handheld Land GPS) was used to locate the Latitude-Longitude of the survey area. 14 representative samples were collected using hand auger for subsequent laboratory study. Radioactivity counts in cps (counts per second) were recorded by a portable Gamma Ray Spectrometer (Scintrex GRS-500). About 5~10 kg of beach sand samples were taken at each location for subsequent laboratory investigation (Fig. 2). Sampling location, depth, radioactivity at different locations of the collected samples was shown in Table 1.

2.2 Laboratory investigation

Laboratory investigations were carried out through sample treatment for further mineralogical analysis, heavy-liquid separation for separating heavy minerals from raw sand, microscopic study to get mineralogical composition and elemental analysis of the samples.

Table 1: Sampling description at Sonadia Island

Sample code	Longitude	Latitude	Depth (cm)	Radioactivity (cps)
SN01	91.900	21.524	90	40
SN02	91.895	21.523	90	34
SN03	91.893	21.522	152	50
SN04	91.890	21.521	90	80
SN05	91.888	21.520	152	170
SN06	91.885	21.517	60	90
SN07	91.883	21.516	60	60
SN08	91.880	21.514	30	50
SN09	91.877	21.515	60	90
SN10	91.874	21.518	30	90
SN11	91.871	21.521	122	100
SN12	91.868	21.524	60	100
SN13	91.865	21.528	60	120
SN14	91.861	21.529	30	100

2.3 Heavy Mineral Separation

Heavy mineral separation was done to know the percentage of heavy fraction in the raw sand. For the study Bromoform ($CHBr_3$) was used as density separator to separate the heavy from light minerals. The specific gravity of Bromoform is 2.9 at 20^0 C. The minerals that have specific gravity higher than the Bromoform are called heavy minerals. For this purpose 50 gm of raw sand sample was poured with stirring into 100-150 ml Bromoform contained in a wide-mouthed separating funnel. The funnel was fitted with a stopcock, the bore of which is of greater diameter than the inner diameter. The mineral floating on the Bromoform was stirred and the funnel then left until all the heavy minerals had settled. The heavy minerals with some Bromoform were then run from the bottom of the separating funnel into a filter funnel containing a filter paper. The heavy mineral in the filter paper was washed, free from Bromoform using acetone, dried, weighed and finally calculated as a percentage of the weight taken.

2.4 Microscopic study

For identification and counting the percentages of heavy minerals by grain count method, 42 (forty two) grain slides were prepared. For the preparation of slides, the grains were mounted on glass slide using Canada balsam. The glass slide was heated carefully in a hot plate to get required viscosity by avoiding of producing bubbles. Finally the slide was then kept in room temperature for few hours, dried and covered by cover slip. Accessory balsam was washed with xylene (C_8H_{10}) and the grain slide was then ready for optical study. For the study, MEIJI ML 9300 polarizing petrographic microscope was used. For counting the grains under microscope, a magnification was selected such that the numbers of particles in the field of view are in the range of 50-100 grains (Fig. 3). At least 10 separate views were counted on each slide to give a total count per slide of 1000-3000 grains.

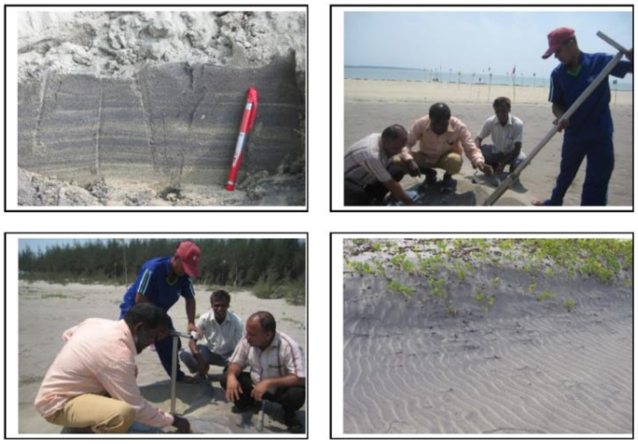

Fig. 2 Sample collection activities in the field

The weight percentage of individual mineral was calculated according to the following equation [14].

$$wt\% = \frac{100(bXc)}{\Sigma(bxc)} x \frac{a}{100}$$

Where *a*, *b* and *c* represents the weight percentage of individual size fraction, number of grains of a particular mineral of interest and specific gravity of a particular mineral of interest respectively.

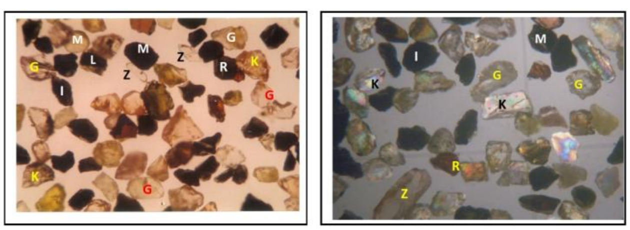

Fig. 3 Photomicrographs of heavy minerals (Ilmenite, Magnetite, Garnet, Zircon, Rutile, Leucoxene, Monazite and Kyanite)

2.5 Elemental analysis of the sample

Elemental analysis of collected samples was performed using a portable handheld XRF analyzer (NITON XL3) for detecting qualitative and quantitative elemental percentage presents in the samples. The analyzer is a single unit, high performance portable x-ray fluorescence (XRF) elemental analyzer.

For elemental analysis, 10 (ten) samples each of 50 gm were dried for 4-6 hours at 105°C in the laboratory drying oven. After then the samples were kept for air dry for overnight at room temperature in a shallow pan. Samples were then crushed into fine powder with an agate mortar and pestle. Then <0.075 mm size was taken using sieve shaker to avoid variations in particle size. The powdered sample was then placed in an XRF sample cup. A circle of polypropylene film was placed on the top of the sample cup. This film on the end of the cup with the indented ring was secured with the collar. The cup was filled with at least 10 gm of the powdered sample and confirmed that no voids or uneven layers were found. A filter paper was placed on the sample disk and a polyester fiber stuffing was put to prevent sample movement. The data were collected using different analytical mode to reveal the percentage of the elements of the samples.

3. Result and Discussion

The heavy minerals weight percentages of various locations for the study area are given in Table 2. The maximum and minimum amount of heavy minerals of the study area by Bromoform separation technique was measured as 84.96% in sample SN05 and 12.8% in sample SN04.

Table 2: Heavy mineral concentration in raw sand measured by heavy liquid separation of the study area

Sampling point	Heavy (%)	Light (%)	Loss (%)
SN 01	20.62	79.20	0.18
SN 02	29.36	70.60	0.04
SN 03	17.00	82.92	0.08
SN 05	84.96	14.90	0.14
SN 04	12.80	87.08	0.12
SN 06	77.20	22.68	0.12
SN 07	14.84	85.04	0.12
SN 08	16.18	83.66	0.16
SN 09	20.04	79.86	0.10
SN 10	34.20	65.76	0.04
SN 11	21.92	78.04	0.04
SN 12	32.62	67.33	0.05
SN 13	62.46	37.50	0.04
SN 14	56.00	43.97	0.03
Average	35.73	64.19	0.08

The heavy mineral assemblage of the study region is governed by the distribution of different types of minerals. The area is characterized by the presence of garnet (33.24% - 62.43%), ilmenite and magnetite together (21.39% - 56.27%), rutile (0.5% - 3.74%), zircon (0.11% - 3.16%), monazite (0.0% - 0.83%), leucoxene (0.57% - 1.81%) and kyanite (0.57% -1.81%). The minerals of the study area like garnet and kyanite may be assigned to the contribution of different high grade metamorphic rocks. Ilmenite, magnetite, zircon and rutile might have been derived from igneous rocks of acidic and basic composition. Table 3 shows the mineralogical percentage of the study area.

The concentrations of different elements measured in the samples by XRF are shown in Table 4. Zirconium (Zr), Strontium (Sr), Rubidium (Rb), Lead (Pb), Zinc (Zn), Manganese (Mn), Iron (Fe), Thorium (Th), Copper (Cu), Cobalt (Co), Titanium (Ti), Barium (Ba), Cesium (Cs), Nickel (Ni) were determined in the samples, where each element's concentration was compared with world average value of that metal. The significance of trace elements in marine sediment is increasingly becoming an issue of global concern and needs proper assessment [15-16].

Table 3: Mineralogical abundance at Sonadia Island

	Mineralogical abundance (%) in heavy fraction								
Sample ID	Ilm & Mag	Gar	Rut	Zir	Mnz	Leu	Kya	Qtz	Others
SN01	21.39	45.32	2.5	0.11	0	1.77	1.77	3.19	19.53
SN02	24.32	56.01	1.82	0.4	0	1.81	1.81	1.94	8.52
SN03	22.9	56.92	1.09	0.11	0	1.31	1.31	4.35	8.09
SN04	21.94	52.06	1.28	0.23	0	1.71	1.71	1.87	14.74
SN05	56.27	33.24	2.03	2.54	0.83	1.32	1.32	0.79	2.43
SN06	54.06	36.53	1.66	1.65	0.09	1.04	1.04	0.79	2.68
SN07	40.59	45.75	2.88	0.32	0	1.36	1.36	0.72	4.9
SN08	24.93	62.43	1.76	0.43	0.23	1.75	1.75	0.61	3.32
SN09	36.13	48.89	3.74	2.22	0	0.57	0.57	0.57	4.22
SN10	29.7	54.69	3.03	1.07	0	1.11	1.11	1.71	5.25
SN11	25.88	57.81	2.05	1.19	0.25	1.22	1.22	3.11	3.37
SN12	30.14	57.37	0.5	0.67	0.12	0.85	0.85	1.25	5.51
SN13	37.12	46.12	1.06	3.16	0.34	0.9	0.9	2.04	4.89
SN14	27.91	56.3	1.29	1.28	0	1.77	1.77	5.27	3.56
Average	32.38	50.67	1.91	1.10	0.13	1.32	3.98	2.02	6.50

Ilm=Ilmenite, Mag=Magnetite, Gar=Garnet, Rut=Rutile, Mnz=Monazite, Leu=Leucoxene, Kya=Kyanite, Qtz=Quartz

The concentration ranges 119-366 ppm for Zr and its average is 198 ppm. The concentration of Sr and Rb are 72-104 ppm and 81-106 ppm with an average value of 82 ppm and 93 ppm respectively. Mn, Ti and Th concentration are found as 309-478 ppm, 1221-1928 ppm and 1.01-9.25 ppm respectively and their average values are 390 ppm, 1598 ppm and 3.78 ppm. Iron is the most abundant metal, and is believed to be tenth most abundant element in the universe. The range of Fe concentration is found 12757-17638 ppm with an average of 15127 ppm. The iron concentration is much higher than average continental crust values [17]. The range of Cu concentration varies from 14.61-21.95 ppm. The average concentration of Cu is 18.08 ppm. The Cu concentration is lower than the average continental crustal value. Pb concentration varies from 7.8-12.15 ppm with an average concentration of 9.03 ppm. The Pb concentration is lower comparing with the coastal sediments and some other marginal marine areas. The concentration of Pb is low due to the dilution of monsoonal rainfall.

The average concentration of Ba and Cs are 280 and 91 ppm. The Ba concentration is lower than average continental crustal value whereas Cs is higher than it. Maximum Zn concentration of the study area is found 70.85 ppm with an average concentration of 38.75 ppm. It is higher than the average continental crustal values. The highest concentration of Zinc is mainly due to input of organic wastes in aquatic environment. Zinc can enter the aquatic environment from a number of sources including industrial discharge, sewage effluent and runoff [18]. The Ni concentration in the study area varies from 2.5 to 30.16 ppm with an average of 16.03 ppm. It is low compared to other coastal sediments. Cobalt is relatively scarce in the earth's crust. The Co concentration varies 99.40 - 49.71 ppm with an average of 70.84 ppm. The Co concentration is higher than the average continental crustal value. The presence of Co in the sediments of the study area is associated with lithogenic origin with little contribution from external sources.

Table 4: Concentration of different elements

	Concentration of elements in samples (in ppm)										
Element	SN01	SN02	SN03	SN04	SN05	SN06	SN07	SN08	SN-09	SN10	Average crustal values
Zr	366.23	257.80	127.47	156.65	178.07	195.72	119.43	141.49	276.55	168.08	237
Sr	76.08	82.21	84.94	74.72	82.52	77.25	104.17	93.91	79.29	72.48	316
Rb	103.94	106.45	81.40	96.01	97.21	86.63	96.38	92.45	88.24	87.46	110
Mn	325.72	357.22	437.48	410.15	411.40	345.61	478.45	414.40	417.25	309.60	78
Ti	1928.3	1445.9	1226.7	1779.7	1660.3	1749.0	1221.4	1461.7	1904.1	1604.7	-
Th	9.25	7.99	1.02	4.30	4.41	1.01	3.23	1.141	3.65	1.83	10.3
Fe	15103.3	12757.0	14616.5	17638.7	15682.8	16597.9	13242.1	15261.7	16560.5	13810.2	-
Cu	19.47	18.076	19.12	21.95	17.61	18.07	16.19	14.61	18.84	16.91	28
Pb	8.18	7.86	9.20	8.58	9.36	7.97	12.15	9.14	8.48	9.40	17
Ba	400	488.01	393.33	0.038	0.041	0.039	400	410	373.33	340	668
Cs	79.37	87.91	90.91	97.31	94.77	97.50	91.99	88.10	96.79	91.58	5.8
Zn	70.85	59.18	29.90	33.94	32.60	36.26	25.23	32.57	35.88	31.12	67
Ni	11.01	2.52	16.92	19.42	27.04	30.16	16.93	8.88	16.44	11.01	47
Co	81.97	49.71	66.87	99.40	72.02	69.73	73.55	78.54	65.62	50.96	17.3

4. Conclusion

As there is no report of presence of significant amount of heavy minerals for being a deposit on Sonadia Island, it can be assumed that the erosion of Moheskhali and Cox's Bazar deposit, through Moheshkhali channel played a role of deposition of heavy minerals on this Island. Ocean current dynamics of the Bay of Bengal is another major factor to know the environment of deposition of these heavy minerals. The source of the heavy minerals observed in the Sonadia Island is possibly from the Miocene sedimentary rocks exposed along the Cox's Bazar beach, which have been distributed along the beach by the long shore current, waves and winds.

Mineralogical composition of heavy mineral concentrates indicates that garnet is the dominant mineral component followed by ilmenite, magnetite, rutile and zircon in heavy mineral composite. The radioactivity of the study area varies from 24 to 170 cps. The minerals like garnet, kyanite may be assigned to the contribution of different high grade metamorphic rocks. The opaque minerals mainly ilmenite and magnetite, rutile and zircon have been derived from igneous rocks of acidic and basic composition.

The concentrations of Zr, Sr, Rb, Pb, Zn, Mn, Fe, Th, Cu, Co, Ti, Ba, Cs, Ni that were studied can be treated as the baseline data of the area where detailed mineralogical and geochemical investigation in trace element level is needed. Extensive field work as well as laboratory works is required on Sonadia Island to identify the presence of any subsurface heavy mineral deposition cycle and their mineralogical percentages.

Acknowledgement

The first author would like to express the sincere gratitude to the Ministry of Science Technology (MOST), Government of the People's Republic of Bangladesh for providing fund for this Research Project for the financial year 2015-2016.

References

1. F. Deeba, M. Z. Kabir, M. M. Zaman, M. Rajib and S. M. Rana, Difference in Grain Size Distribution Among Heavy Minerals of Cox's Bazar, Barchara, Patuartek and Teknaf Fore Dune Deposit, Proceed. of Int. Confer. on Geosci. for Glob. Dev., 26-31 October, 2009, Dhaka, Bangladesh, 24-27 (2009).
2. M. Rajib, M. Z. M. Kabir, F. Deeba, M. M. Zaman and S. M. Rana, Distribution of five major heavy minerals along the recent beach areas of Bangladesh, The J. of NOAMI, **24(1)**, 1-9 (2007).
3. R. G. Schmidth, and S. A. Asad, A reconnaissance survey of radioactive beach sand at Cox's Bazar, Inter. Geol. Report, The Geological Survey of Pakistan, East Pakistan, **3,** 1-15 (1963).
4. M. M. Zaman, M. Z. Kabir, F. Deeba, M. Rajib and S. M. Rana, Finding a new heavy mineral deposit and its mineralogical composition at Sonarpara, Cox's Bazar, The J. of NOAMI, **26(1)**, 17-30 (2009).
5. M. M. Zaman, M. Rajib, M. Z. Kabir, F. Deeba, S. M. Rana, S. M. Hossain, S. A. Latif and G. Rasul, Presence of uranium and thorium in zircon assemblages separated from beach sands of Cox's Bazar, Bangladesh, J. of Sci. Tech. Environ. Informatics. **03 (01)**, 161-169 (2016).
6. M. H. Siddiqui, Land Accretion and Erosion in the Coastal Area, Proceed. of the Nat. Workshop on Bangladesh Coast. Area Res. Dev. and Manage., Dhaka, 3-4 October, 1988.
7. D. K. Barua, The Coastline of Bangladesh-An Overview of Process and Forms, Proceed. of 7th Sympo. on Coastal and Ocean Management, ASCE, Long Beach, CA, 8-12 July, 2285-2301 (1991).
8. M. S. Islam and A. Hoque, Application of Remote Sensing Technique to Study the Landuse Changes of Moheshkhali Island in Bangladesh, J. of Remote Sensing and Environ, **3**, 69-85 (1999).
9. M. E. Hoque, S. R. Chowdhury, M. M. Uddin, M. S. Alam and M. M. Monwar, Grain Size Analysis of a Growing Sand Bar at Sonadia Island, Bangladesh, J. of Soil Sci., **3**, 71-80 (2013).
10. L. A. Molony, Sonadia Island ECA Conservation Management Plan Coastal and Wetland Biodiversity Management Project BGD/99/G31, **5** (2006).
11. A. B. K. Majlis, M. A. Islam, M. H. Khasru and M. K. Ahsan, Protected to Open Basin Depositional System: An Appraisal for Moheshkhali-Kutubdia Coastal Plain (Abstract), Bangladesh Coast: Geology, Hazards and Res., 29-30 May, Dhaka Bangladesh, **3** (2011).
12. M. A. B. Biswas, Some information about mineralogical composition of the beach sands of Cox's Bazar, Bangladesh, Geology and Prospecting, Moscow, 7, 32-38 (1977).
13. M. A. B. Biswas, Mechanism of heavy mineral concentration in the beach sands of Cox's Bazar, Nucl. Sci and appl. **B (12-13)**, 74-83 (1981).
14. E. H. Macdonald, Manual of beach mining practice-Exploration and Evaluation: 2nd edition, Department of Foreign Affairs, Canberra, Australia (1972).
15. A. A. Adeniyi and J. A. Afolabi, Determination of total petroleum hydrocarbons and heavy metals in soils within the vicinity of facilities handling refined petroleum products in Lagos metropolis, Environ. Int., **28 (1-2)**, 79–82 (2002).
16. H. S. Lim, J. S. Lee, H. T. Chon and M. Sager, Heavy metal contamination and health risk assessment in the vicinity of the abandoned Songcheon Au-Ag mine in Korea, J. of Geochem. Expl., **96 (2-3)**, 223–230 (2008).
17. H. Wedepohl, The composition of the continental crust, Geochemica et Cosmochimica Acta, **59**, 1217-1239 (1995).
18. A. B. A. Boxall, S. D. Comber, A. U. Conrad, J. Howcroft and N. Zaman, Inputs, monitoring and fate modeling of antifouling biocides in UK estuaries, Marine Pollu. Bul., **40**, 898-905 (2000).