

# Heavy Minerals in Sands along Brahmaputra (Jamuna) River of Bangladesh

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## Abstract

Sands along Brahmaputra River of Bangladesh have long been considered to be a source of heavy minerals (HMs) since it traversed a long way through various terrains. An attempt has been made under this research work to determine the kinds and amounts of heavy minerals in the sands sourced from the river system. Samples from 14 locations along Brahmaputra River covering 30 km distance from upstream to downstream of the river are found to contain different heavy minerals concentration with a range of 7.92 - 25.16 weight% with the remaining of the sample comprising silicate and aluminosilicates. Mineral characterization from peak positions in diffractogram of X-ray Diffraction (XRD) evaluate quartz, feldspar and mica are major categories light mineral while rutile, magnetite, ilmenite, zircon, monazite, garnet, uranium arsenide and uranium fluoride are the major types heavy minerals. Ilmenite and rutile are main contributors of total heavy mineral (THM). Titanium bearing minerals ilmenite and rutile contributes 26.22% - 31.01% and 14.57% - 23.50% of THM. In the present study area, most of the sands are found to be fine and medium grained as obtained from the particle sizes analysis using 18- to 230-mesh.

## Keywords

Heavy Minerals, River, Sand, Bangladesh

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## 1. Introduction

Minerals are the composite of different elements and occur naturally as crystalline inorganic substances in sediments. Mineral sediments, sands and mud are weathered from mountain belts, transported by rivers, glaciers or wind and deposited. Minerals are classified into two types on the basis of its density such as light minerals (specific density less than  $2.9/10^3 \text{ kg}\cdot\text{m}^{-3}$ ) and heavy minerals (specific density greater than  $2.9/10^3 \text{ kg}\cdot\text{m}^{-3}$ ) [1]. The erosion of weathered rocks and minerals results in the concentration of the more resistant and higher specific gravity (density) minerals ( $2.9/10^3 \text{ kg}\cdot\text{m}^{-3}$ ).

The Brahmaputra River originating in Tibet and flowing through Tibet and the north-eastern part of India enters Bangladesh in Kurigram District. The immense amount of sediment carried by the Brahmaputra River, derived from intense erosion of the Himalayas (in the north), is delivered to the Bay of Bengal. During transportation sandy materials laid down on the bed of the river, forming sand bars. The thickness of sand deposits up to gravel bed is 44 m [2]. For economic exploitation of mineral sands, it is necessary to identify the minerals present, quantify total reserves of sand deposits, determine the contents and quality of economic minerals, and find the market demands in the country and abroad. Non-marine alluvial sand placer deposits are also known to be sources of heavy minerals (HMs), e.g. Gbangbama deposit in Sierra Leone [4], central Kalimantan, Borneo, Indonesia [3]. Compared to HM sand accumulations in beach sand deposits, the concentration of HMs in river sands is generally lower, with as little as 5% - 10% total HMs [4]. Heavy mineral river deposits may be prominent in Bangladesh as the river and drainage systems within Bangladesh are extensive, carrying large quantities of sandy sediments to the coastal regions, e.g. the Brahmaputra River carries an estimated  $(7.35 - 8.00) \times 10^8$  tone of sediment per year [5] [6]. The alluvial sediments contain both light and HMs with the HMs generally deposited on the bed of the river systems forming HM-rich sand bars.

Heavy minerals, having higher specific gravity, occur in all sands. Some sands contain large enough concentrations of valuable heavy minerals to serve as commercial sources of these minerals. The kinds and amounts of heavy minerals occurring in Brahmaputra River are of great interest to warrant commercial exploitation. An attempt has been made through this study to know the heavy minerals concentration together with individual heavy mineral quantification along Brahmaputra River in Bangladesh.

## 2. Materials and Methods

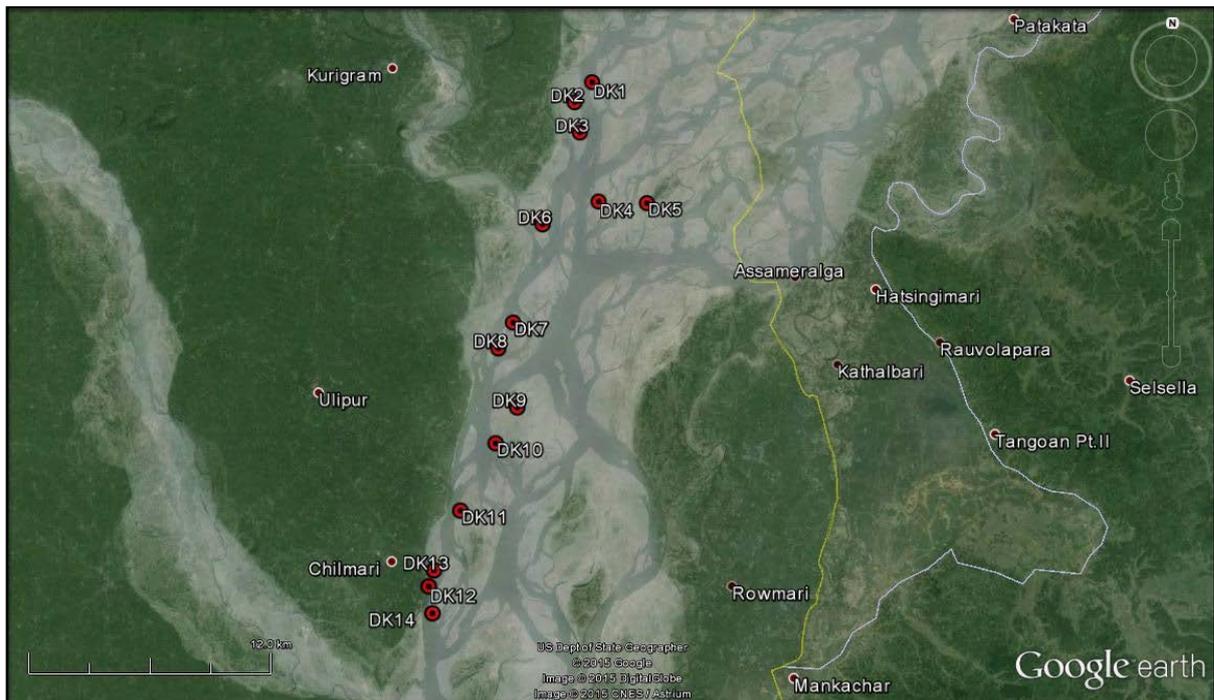
### 2.1. Study Area

The present study area covers Kurigram sadar, Ulipur and Chilmari Upazila of Kurigram district which is traversed by Brahmaputra (Jamuna) river ( $25^{\circ}48'26''$ ;  $89^{\circ}45'09''$  -  $25^{\circ}33'32''$ ;  $89^{\circ}41'01''$ ). The study area covers stable sand bars in an area of  $30 \text{ km} \times 4 \text{ km}$  from upstream to downstream of the Brahmaputra River in the Kurigram district, north-eastern Bangladesh (Figure 1).

### 2.2. Sample Collection and Analysis

The present study covers about  $30 \text{ km} \times 4 \text{ km}$  area from which 14 successive locations were selected and numbered as DK<sub>1</sub>-DK<sub>14</sub>. From each location two samples were collected from sand bar ("chars") and river bed found in the study area. The sample locations were recorded in terms of degree-minute-second (latitudinal and longitudinal position) using a hand-held global positioning system (GPS) (Model: Magellan-Map-410) unit. Each location is separated by a distance of approximately 2 km (approximately 1 minute in co-ordinate system). The samples were collected at the depth of 0 - 5 cm by plastic spade during summer period of 2014 and collected samples were packed in polyethylene bags. Each sample has the weight of about 2 kg. The collected samples were air dried at room temperature in open air.

Preparation and preliminary analysis of sediment samples were carried out as per the procedure given in Carver [7] and Solai *et al.* [8]. Heavy mineral separation was carried out using heavy liquid bromoform of 2.89 specific gravity as per the standard procedures outlined by Milner [9]. The total heavy mineral percentages (THM) were calculated. Using a hand magnet, magnetic minerals (magnetite) were separated from the heavy mineral fractions and the weight percentage was estimated. The samples were also examined to measure their granulometric fractions such as contents of sand, silt and clay. Using an ASTM sieve, about 100 g of sediment was taken for separation of sand, silt and clay fractions by sieving.



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

For mechanical separation 10 kg raw sand samples were dried in the sun to remove moisture. Separation of heavy and light minerals was carried out depending on specific gravity/density of the minerals using laboratory shaking table. For each sample, heavy minerals fraction obtained after density separation dried in burner. Magnetite, ilmenite, rutile and zircon mixed with others were separated using Induced Roll Magnetic Separator (IRMS) applying fixed magnetic intensity at 0.5 amp, 2.5 amp, 5.5 amp, and 7.5 amp condition, respectively.

Powder X-ray Diffraction (XRD) is a versatile technique that can be used to identify any crystalline substances, such as most minerals. It can also be used to quantify the proportions of different minerals or indeed many other substances when they are present in a mixture. Powder X-ray diffraction analysis is seemingly the perfect technique for crystalline-mixture analysis, since each component of the mixture produces its characteristic pattern independently of the others, making it possible to identify the various components by unscrambling their superposed patterns. An X-ray beam of known wavelength is focused on a powdered sample and X-ray diffraction peaks are measured using a detector. In the present study X-ray diffraction technique has been utilized to discern these properties. The phase identification was performed using Philips X'Pert Pro multipurpose X-ray diffractometer which uses copper  $K\alpha$  radiation. X-ray generator operated at 40 kV and 30 mA, and all scans were run at a speed of  $2^\circ$  per minute, from  $10^\circ$  to  $70^\circ$ , with a continuous step size of 0.02.

### 3. Results and Discussion

#### 3.1. Heavy Mineral Separation Analysis

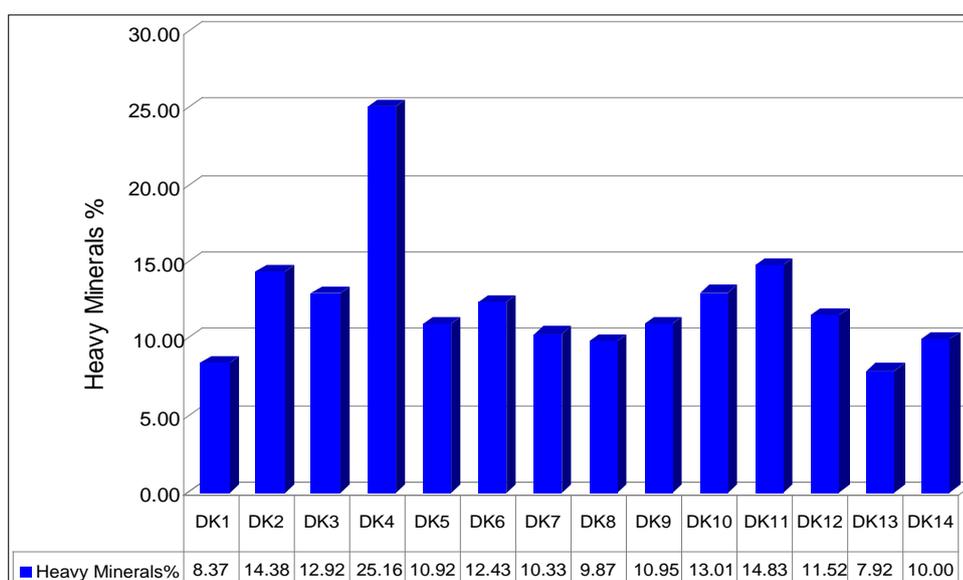
The heavy mineral separation analysis has been carried out to know the total heavy mineral (THM) weight percentage in the present samples. Weight percentage of separated heavy minerals in most of the samples varied from 8% to 15%, while in one sample it reaches to 25%; similar THM value is reported for Brahmaputra river sand [10]. The THM percentage is varied greatly from site to site. It is minimum in DK<sub>13</sub> and it is maximum in DK<sub>4</sub> (Figure 2). Other sites are having intermediate values.

Average THM value in the sand samples of the study area is 12.40% while low (within 10%) THM percentage is encountered in four locations. These values of THM are higher than the other river of Bangladesh as observed in someshari river [11]. The actual sorting and concentration of heavy minerals takes place due to the actions of two principal agents *i.e.* action of waves/currents and wind. Mechanical separation of raw sand using Induced

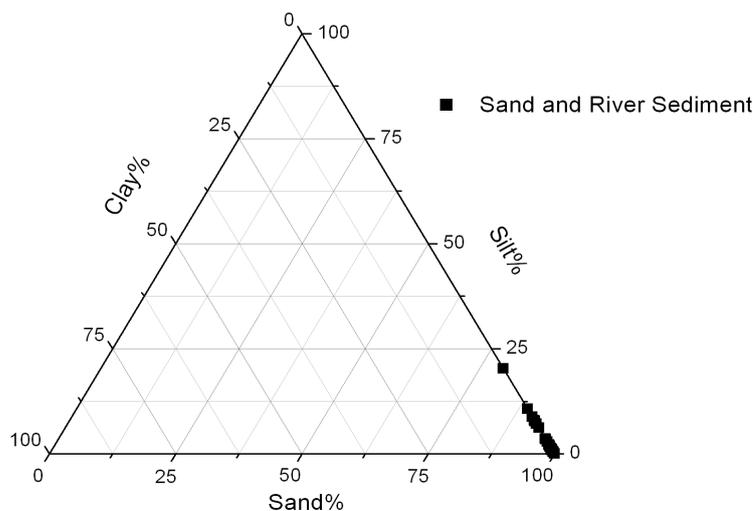
Roll Magnetic Separator (IRMS) resulted to separate magnetite, ilmenite, rutile and zircon mixed with other minerals. Separation of samples DK<sub>1</sub>, DK<sub>8</sub> and DK<sub>12</sub> reveals that ilmenite and rutile are main contributors of total heavy mineral (THM). Titanium bearing minerals ilmenite and rutile contributes 26.22% - 31.01% and 14.57% - 23.50% of THM.

### 3.2. Granulometric Analysis

Granulometric analysis has been carried out to know the content of sand, silt and clay (%) in the present sediments. Percentage of sand, silt and clay (%) content of the samples are presented in **Figure 3**. Sand is the main constituent in all the sampling locations, which varied from 91.87% to 99.74%. Silt content is the least constituent which varied from 0.03% to 7.98%. In the samples studied, the heavy minerals occur predominantly in the 60- to 200-mesh sieve grade (**Table 1**). 75% - 90% heavy minerals of THM occur in 60- to 120-mesh while some heavy mineral grains are finer but most of the samples contain negligible amounts of material of this grain size. In a given sample, the heavy minerals are primarily finer grained than the average grain size of the whole sample.



**Figure 2.** Heavy minerals weight% in the sand sample of the study area.



**Figure 3.** Distribution of sand, silt and clay (%) content in sediment samples of the study area.

### 3.3. X-Ray Diffraction

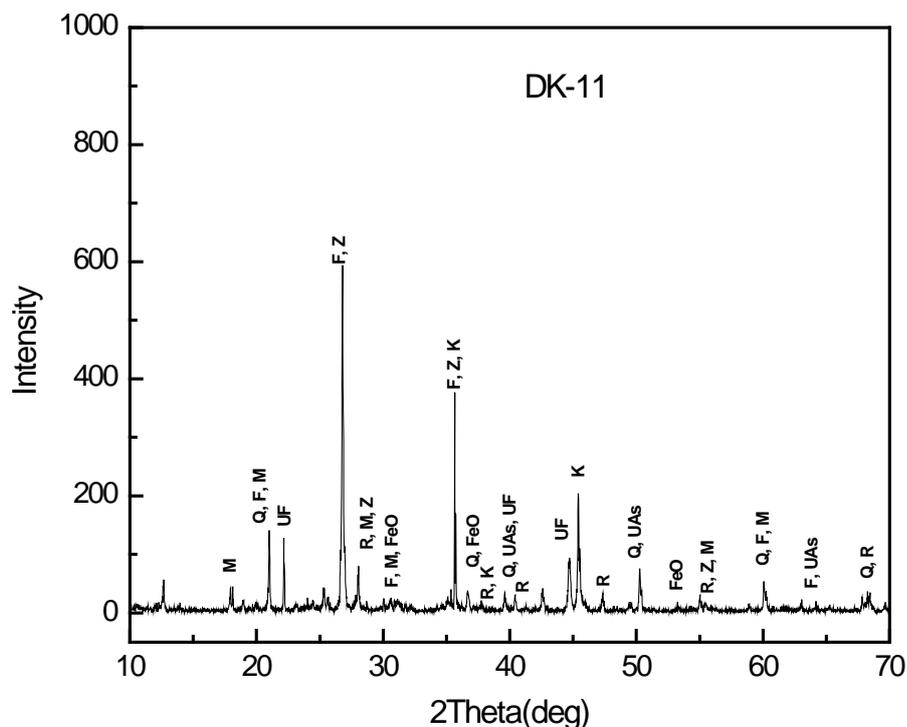
X-ray diffraction is a unique analytical tool for the analysis of geological samples. It is the most important and informative technique for identification and characterization of minerals in the sediments. The XRD spectra were recorded for all the sediment samples to determine the mineralogical composition. A representative diffractogram is shown in **Figure 4** along with name of the minerals present.

The XRD pattern (**Figure 4**) indicates that the compositions are of single-phase structure since no ambiguous reflections other structure is evidenced. Analyzing the XRD patterns we notice that the position of the peaks comply with the reported value. All diffraction peaks of the studied samples are compared to the reported structure for relevant base sand samples. The observed peaks at 2 theta value of 18.37, 21.24, 23.86, 26.97, 29.01, 30.10, 35.42, 36.95, 38.43, 39.62, 40.64, 44.24, 46.10, 47.81, 50.53, 53.43, 55.30, 60.28, 63.68, 68.55 confirmed that the sand is mainly containing Quartz, Monazite, Feldspar, Uranium Fluoride, Rutile, Zircon, Hematite, Kyanite, Uranium Arsenide. Observed peak positions were matched against the International Centre for Diffraction Data (ICDD) Joint Committee on Powder Diffraction System (JCPDS) card database.

The Brahmaputra drains the Tibetan Plateau of China and is dominated by upland tributaries originating in the Himalayas. The Brahmaputra flows through various rock types including Precambrian metamorphics (high-grade schists, gneisses, quartzites, metamorphosed limestones), felsic intrusives, and Paleozoic-Mesozoic sandstones, shales and limestones [12]. From the heavy mineral assemblage study of the Brahmaputra-Jamuna River sand, it can be postulated that there are several types of source rock complexes are exist in the specific source area

**Table 1.** Grain size distribution and weight% of heavy minerals.

Heavy Mineral	Wt%			
	60-mesh	120-mesh	200-mesh	Pan
Ilmenite	8.79 - 25.72	54.76 - 63.27	13.50 - 19.45	5.33 - 8.02
Rutile	11.33 - 55.82	36.03 - 62.42	7.12 - 22.00	1.00 - 4.26
Zircon + others	15.25 - 53.03	42.21 - 73.41	4.51 - 11.00	0.10 - 0.40



**Figure 4.** The representative XRD pattern of the sand sample. M = Monazite, Q = Quartz, F = Feldspar, UF = Uranium Fluoride, R = Rutile, Z = Zircon, FeO = Magnetite, K = Kyanite, UAs = Uranium Arsenide.

mainly Lesser Himalayan and Indo-Burman Ranges with having little influence of Himalayan tributaries and north Himalayan [13]. Heavy minerals obtained in the study might have the similar source as described by the researchers.

#### 4. Conclusion

The heavy fractions of sands along the Brahmaputra River are primarily the source of the iron titanium and iron oxide minerals magnetite and ilmenite. Most of the heavy minerals are in the 60- to 200-mesh size range. Most of the samples have between 8 and 15 percent heavy minerals. Ilmenite ranges from about 4 to 9 percent and rutile ranges from about 3 to 5 percent. Such percentages are much higher than those of Someshari river sands of Bangladesh. Considering the high heavy mineral concentration in river sands, the possibility of commercial utilization of the heavy minerals in sands along the Brahmaputra River is quite a burning issue at the present time.

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