ENERGY CONDITION OF DEPOSITION AND SOURCE OF SEDIMENTS IN
THE BENGAL BASIN FROM GRAIN SIZE ANALYSIS

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Abstract: The annual sediment discharge of the Ganges-Brahmaputra-Meghna (G-B-M) river system—estimated in the Bengal basin—is one of the highest globally, and more than 60% of this sediment load is delivered in the delta itself. The sediments typically consist of fine to very fine sand, silt and clay. The sediments are poorly sorted and positively skewed suggesting dominance of the finer grained portion relative to the mean size. The distribution is mostly leptokurtic. A relatively high-energy hydraulic environment affects their deposition which takes place mostly under a graded (for bed sediments) and uniform suspension (for suspended sediments) condition. The riverbank and flood plain sediments show close similarity in size with the riverine sediments of the Bengal drainage basin, and could be a major source of river sediments. Sediments transported by the Himalayan rivers are relatively fine grained compared with that of the sediments transported by the Peninsular rivers to the Bay of Bengal.

Key words: Grain size analysis; Energy condition of deposition; Bengal basin; Bangladesh

Introduction

The sediment discharge of the Ganges-Brahmaputra-Meghna (G-B-M) river system - the highest sediment dispersal system of the world (Kuehl et al., 1989) - has been estimated to be about 1050 million tons annually in the Bengal basin (Milliman et al., 1995); about 600 million tons of which are deposited in the Bengal delta itself (Meade, 1996). Thus the Bengal basin serves as a potential reservoir for the enormous sediment load carried down by the G-B-M system because of its low elevation (between 5 and 6 meters above sea level; Milliman et al., 1989), frequent flooding (Rasid and Paul, 1987) and Holocene sea level changes (Umitsu, 1993).

The particle size analysis is one of the most powerful tools available for the interpretation of any population of sedimentary particles, and is a prerequisite to understand their roles in a set of sedimentary processes (Swift et al., 1972). Moreover, the quanta of transported toxic substances such as, heavy metals, radionuclides, nutrients etc. are controlled to a large extent by the grain size of the riverine sediments (Salomons and Forstner, 1984; Datta et al., 1999).
The Bengal basin represents one of the geologically youngest and tectonically most active denudation regime of the world (Morgan and McIntire, 1959; Valdiya, 1984; Umitsu, 1993; Reimann, 1993). It is situated at the confluence of the Ganges-Brahmaputra-Meghna (G-B-M) river system. The basin accounts for about 12.7% of the total drainage basin of the G-B-M system covering political boundaries of both Bangladesh and India. The geology and structural setting of the Bengal basin can be seen elsewhere (Morgan and McIntire, 1959; Sengupta, 1966; Imam and Show, 1985; Reimann, 1993). Discrete reports on the statistical parameters of grain size distribution of riverine sediments of the Bengal basin can be seen in Morgan and McIntire (1959), Coleman (1969), Chaudhri (1987), Subramanian and Jha (1988), Jahan et al., (1990), Alam et al., (1990), Kranck et al., (1993), Barua (1994), Chakrapani et al., (1995) and Datta and Subramanian (1997). However, no study has yet been made that has considered the grain size distribution of the total Bengal basin with respect to other major river sediments of the subcontinent. Moreover, because of the mere catastrophic volume of the sediments annually delivered to the basin, the sediments deserve an integrated grain size study. We report here our results on the grain size distribution of the riverine sediments of the Bengal basin and we applied the statistical parameters as a tool for discriminating depositional processes.

Methodology

Bed and suspended sediments were collected during 1991-94 at different stations throughout the basin in different seasons (Fig. 1). The bed sediments were collected from the top few centimeters of the river channel, and the suspended sediments were decanted out of 10 liter water samples collected at a depth of 50-100 cm from the water surface approximately at the middle of the channel. The grain size distribution were determined by sieve shaker (Fritsch Analysette 03.502) and Laser Particle Sizer (fritsch Analysette 22) after treating the samples with 25% H$_2$O$_2$. The statistical parameters of bed sediments were derived by graphic method (Folk and Ward, 1957) and that of the suspended sediments were derived by the method of moment (Lindholm, 1987).

Results and Discussion

The range of mean grain size and standard deviation of the riverine sediments from the Bengal basin along with that of other major rivers in the South Asia are presented in Table 1. Like most of the alluvial rivers the sediments tend to be finer towards the lower reaches of the G-B-M system. This phenomenon, however, has not been observed to be significant in the Amazon (Nordin Jr., 1980). Fig. 2 shows that the higher the mean size (in $\phi$), the higher the standard deviation (in $\phi$) ($r = 0.83; n=81$), which suggests that, fine grained sediments are poorly sorted (Folk, 1966). More than 96% of the bed sediments and more than 85% of the suspended sediments are positively skewed which indicates the dominance of fine-grained sediments relative to the mean size. More than 74% of the bed sediments show a leptokurtic distribution which is a general criteria for most river bed sediments (Friedman, 1962). Such distribution characteristic of sediments has also been observed in tributaries of Ganges (Singh, 1972; Kumar and Singh 1978; Gupta and Subramanian, 1994).
Table 1. Range of mean grain size and standard deviation of riverine sediments in South Asia (in \( \phi \)).

| Rivers (#)                  | Mean Size | Standard deviation |
|-----------------------------|-----------|--------------------|
| Ganges – Brahmaputra – Meghna system |           |                    |
| Bhagirathi\(^4\) (6)        | 1.5 – 3.4 | 0.23 – 0.95        |
| Alaknanda\(^3\) (4)         | 1.3 – 2.5 | 0.45 – 1.12        |
| Ganges (Mid.)\(^3\) (19)   | 1.7 – 3.3 | 0.21 – 0.50        |
| Ganges\(^5\) (6)            | 3.6 – 4.2 | 0.79 – 1.10        |
| Padma (Ganges, Lower)\(^5\) (5) | 4.3 – 6.6 | 0.87 – 1.71        |
| Bhagirathi – Hooghly\(^5\)  (12) | 2.5 – 5.9 | 0.12 – 1.61        |
| Bhagirathi (Assam)\(^6\)   (13) | 1.3 – 3.7 | 0.51 – 1.12        |
| Brahmaputra (Bangladesh)\(^5\) (9) | 3.1 – 7.0 | 1.10 – 1.96        |
| Meghna\(^5\) (8)            | 4.7 – 7.1 | 1.80 – 2.10        |
| Krishna\(^7\) (18)          | 4.6 – 8.0 | 1.40 – 2.80        |
| Cauvery\(^8\) (18)          | 4.4 – 6.6 | 1.15 – 1.55        |
| Mahanadi\(^9\) (16)         | 4.7 – 8.3 | 0.73 – 2.55        |

Values of mean and standard deviation in \( \phi \) (phi). Phi is the negative logarithm of the base 2 of the particle size in millimeters, which means an inverse relation between particle size and the phi values.

# Total number of stations at which multiple sampling was done.

\(^5\)Suspended sediments; all others are bed sediments.

1Panday, 1993; 2Singh, 1993; 3Abbas, 1985; 4Chakrapani et al., 1995; 5This study; 6Mahanta 1995, 7Ramesh, 1985; 8Ramanathan, 1993; 9Chakrapani and Subramanian, 1994.

Fig. 1. Location of the Bengal basin, its geology, and the sampling stations.
The relative abundance of sand, silt and clay size fraction in the bed and suspended sediments are shown in Fig. 3. Sand size fraction dominates in 52% of the total bed sediments. The sand population ranges from 10.8 to 99.9% and represents fine to very fine sand-size class (212 µm to 63 µm). The remaining samples are dominated by silt size fraction. Clay size fraction varies from 0.0 to 9%. Temporal variations in the sediment grain size are not conspicuous. However, the Bhagirathi-Hooghly show more fine grained sediments compared with that of other major channels in the Bengal basin.

Fig. 4 (adapted from Passega and Byramjee, 1969) suggests that graded suspension (for bed sediments) and uniform suspension (for suspended sediments) are the major hydraulic conditions affecting the depositing sediments. The plot of skewness versus kurtosis of bed sediments (Fig. 5) (after Thomas et al., 1972 and Damiani and Thomas, 1974) show clustering of the samples in zone A, which suggest a relatively high energy condition of deposition.
Fig. 3. Ternary diagram showing relative percentage of sand, silt and clay size fraction in the bed and suspended sediments of the Bengal basin.

Fig. 4. C-M diagram of the bed and suspended sediments in Bengal basin (adapted from Passega and Byramjee, 1969).
The Himalayan rivers transport more fine grained sediments as compared with that of the Peninsular rivers (Table 1). Negatively skewed grain size pattern is more significant at the upper reaches of the Ganges (Singh, 1993; Panday, 1993) and the Brahmaputra (Mahanta, 1995) as well as in the rivers of the Peninsular India (Ramesh, 1985; Ramanathan, 1993; Chakrapani and Subramanian, 1994).

Since the sediments are mainly derived from a floodplain which is important globally for concentration of population (more than 400 million) and intensive agricultural activities (Crow, 1995), they might carry anthropogenic contaminants capable of polluting the natural aquatic system. Thus this sediment mass offers a good opportunity for studying their various geochemical components. Moreover, the mere amount of the sediment flux through the basin to the Bay of Bengal is significant enough to influence a tropical marine system such as the Bay of Bengal.

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