ENVIRONMENTAL SCIENCES

Khulna University Studies 2(1): 63-70

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

Dilip K. Datta[a*] and V. Subramanian[b]

[a] *Environmental Science Discipline, Khulna University, Khulna 9208, Bangladesh*
[b] *School of Environmental Sciences, Jawaharlal Nehru University, New Delhi 110067, India*

Manuscript received: May 02, 2000; Accepted: July 25, 2000

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 sort ed 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.

Kay 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).

* Corresponding author. Tel.: +88-(041)-721791, 720171-3; Fax: +88-(041)-731244; E-mail: <ku@ku.khulnanet.net>
DOI: https://doi.org/10.53808/KUS.2000.2.1.63-70-ls

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_2O_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 ϕ), the higher the standard deviation (in ϕ) ($r = 0.83$; $n=81$), 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 ϕ).

Rivers (#)	Mean Size	Standard deviation
Ganges –Brahmaputra –Meghna system		
Bhagirathi[1] (6)	1.5 –3.4	0.23 –0.95
Alaknanda[2] (4)	1.3 –2.5	0.45 –1.12
Ganges (Mid.)[3] (19)	1.7 –3.3	0.21 –0.50
^{S}(6)	3.6 –4.2	0.79 –1.10
Ganges[4] ^{S}(24)	4.3 –6.6	0.87 –1.71
Padma (Ganges, Lower)[5]		
(5)	2.5 –4.4	0.12 –1.61
^{S}(4)	6.5 –7.9	1.60 –3.00
Bhagirathi –Hooghly[5]		
(12)	2.5 –5.9	0.37 –1.78
Bhagirathi (Assam)[6]		
(13)	1.3 –3.7	0.51 –1.12
^{S}(13)	3.1 –7.0	1.10 –1.96
Brahmaputra (Bangladesh)[5]		
(9)	2.5 –4.5	0.11 –1.72
^{S}(8)	4.7 –7.1	1.80 –2.10
Meghna[5] (7)	2.6 –4.8	0.32 –2.22
^{S}(7)	4.6 –8.0	1.40 –2.80
Krishna[7] (18)	-0.7 –3.8	0.28 –1.20
^{S}(6)	4.4 –6.6	1.15 –1.55
Cauvery[8] (18)	0.7 –2.1	0.32 –1.07
^{S}(17)	4.7 –8.3	0.73 –2.55
Mahanadi[9]		
^{S}(16)	7.5 –9.1	1.27 –1.79

Values of mean and standard deviation in ϕ (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.
^{S}Suspended sediments; all others are bed sediments.
[1]Panday, 1993; [2]Singh, 1993; [3]Abbas, 1985; [4]Chakrapani *et al*., 1995; [5]This study; [6]Mahanta 1995, [7]Ramesh, 1985; [8]Ramanathan, 1993; [9]Chakrapani and Subramanian, 1994.

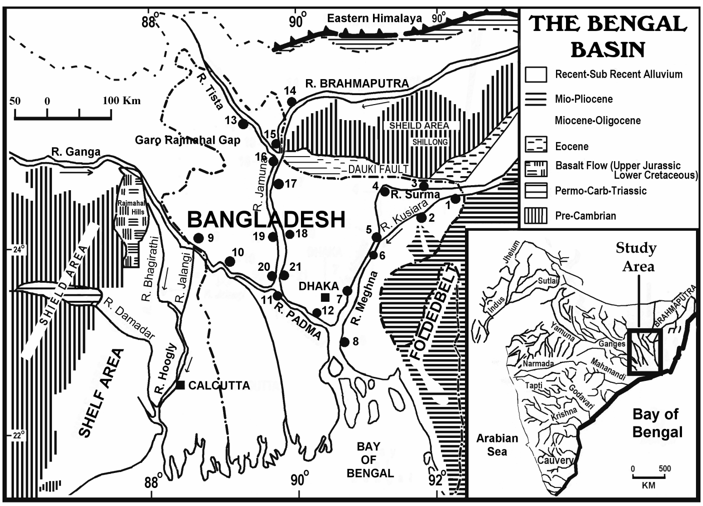

Fig. 1. Location of the Bengal basin, its geology, and the sampling stations.

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 (212µm to 63µm). 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.

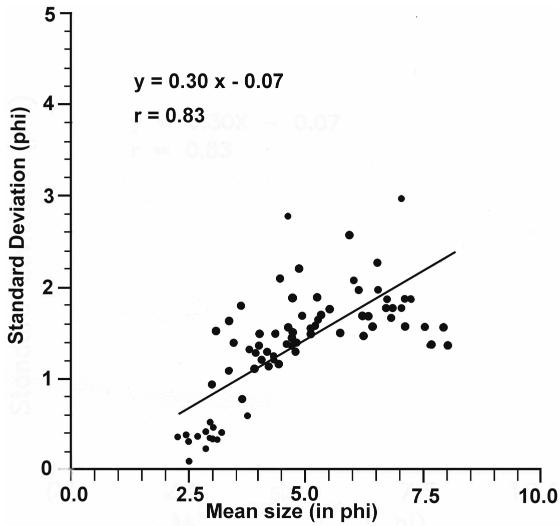

Fig. 2. Plot of mean size (in ϕ) versus standard deviation (in ϕ).

The sediments on the banks and floodplains of the G-B-M system in the Bengal basin are composed dominantly of fine sand and silt (Morgan and McIntire, 1959; FAO, 1977; Alam *et al*., 1990; Umitsu, 1993), and are similar in size to the riverine sediments of the basin. The bank and floodplain sediments can therefore be a major source of river sediments. Meade and Parker (1985) have reported that the major source of sediment supplied to the United States rivers are the sediments occurring in the floodplains. The grain size category is also similar to those observed in the inner Bengal Shelf (Kuehl *et al*., 1989) which ultimately feeds the Bengal Fan *via* the Swatch of No Ground. Moreover, the distribution pattern of the bed sediments overlap most of the distribution spectrum of the suspended sediments (Fig. 4) which suggests that most of the sediments are capable of remobilization, particularly during high flow. This fine size class are fine enough to accumulate higher quantities of metals as well as large enough to resist transport and have longer residence times in the stream channel (Mantei and Foster, 1991).

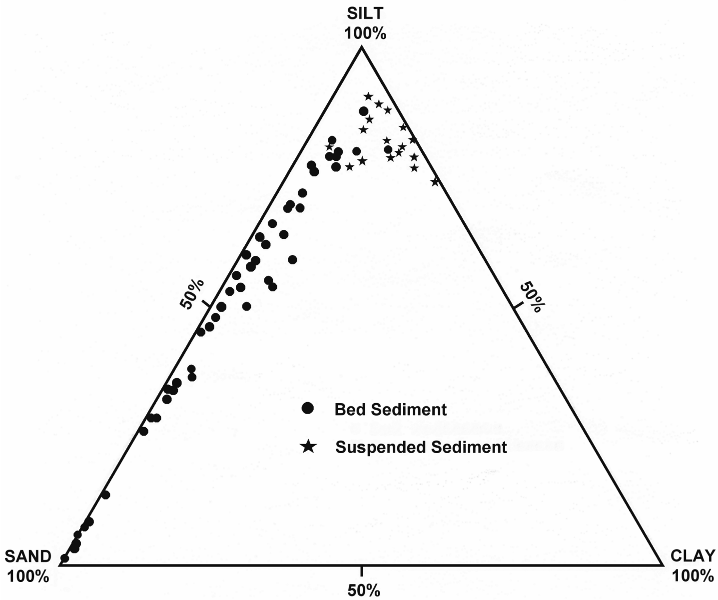

Fig. 3. Ternary diagram showing relative percentage of sand, silt and clay size fraction in the bed and suspended sediments of the Bengal basin.

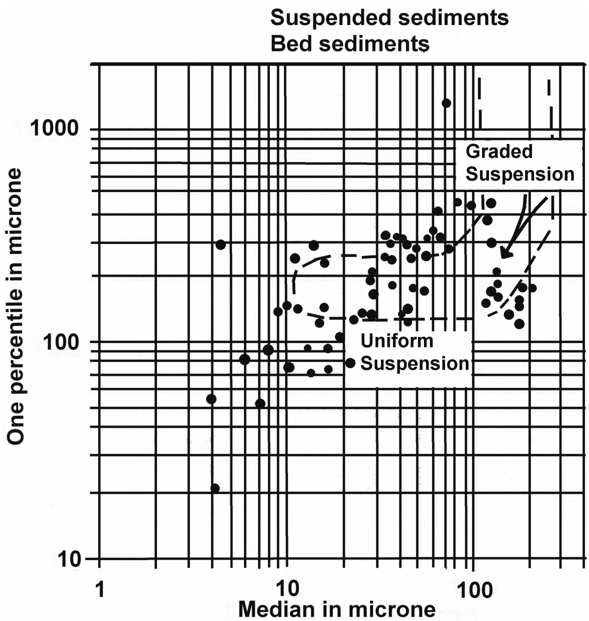

Fig. 4. C-M diagram of the bed and suspended sediments in Bengal basin (adapted from Passega and Byramjee, 1969).

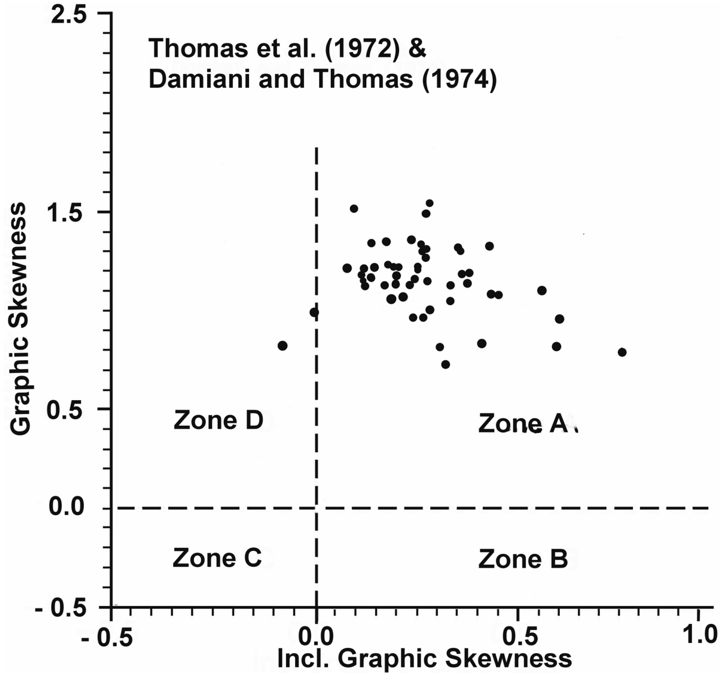

Fig. 5. Zones discriminating energy condition of deposition of bed sediments (adapted from Thomas *et al*., 1972; Damiani and Thomas, 1974).

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.

Reference

Abbas, N., 1985. Geochemistry of the Ganges river basin. Ph.D. Thesis, SES, Jawaharlal Nehru University, New Delhi, 184 pp.

Alam, M.K., Hasan, A.K.M.S, Khan M.R. and Whitney, J.W., 1990. *Geological Map of Bangladesh*. Geological Society of Bangladesh, Dhaka.

Barua, D.K., Kuehl, S.A., Miller, R.L. and Moore, W.S., 1994. Suspended sediment distribution and residual transport in the coastal ocean off the Ganges-Brahmaputra river mouth. *Marine Geology,* 120: 41-61.

Chakrapani, G.J. and Subramanian V., 1994. Grain size distribution and mineralogy of the suspended sediments of Mahanadi river. *Joournal of Geological Society of India,* 44: 541-546.

Chakrapani, G.J., Subramanian V., Gibbs R.J. and Jha, P.K., 1995. Size characteristics and mineralogy of suspended sediments of the Ganges River, India. *Environmental Geology,* 25: 129-239.

Chaudhri, R.S., 1987. Textural behaviour of modern cratonic sediments and its application in deciphering ancient analogues. *Bulletin of Indian Geological Association,* 20(2): 103-119.

Coleman, J.M., 1969. Brahmaputra river: channel processes and sedimentation. *Sedimentary Geology,* 3: 129-239.

Crow, B., 1995. *Sharing the Ganges: the politics and technology of river development*. Sage Pub., New Delhi, 272 pp.

Damiani, V., and Thomas, R.L., 1974. The surfacial sediments of the Big Bay Section of the Bay of Quinte, Lake Ontario. *Canadian Journal of Earth Sciences,* 11: 1562-1576.

Datta, D.K. and Subraminian, V., 1997. Texture and mineralogy of the sediments from the Ganges-Brahmaputra-Meghna river system in the Bengal basin, Bangladesh and their environmental implications. *Environmental Geology*, 30: 181-188.

Datta, D.K., Gupta L.P., and Subramanian, V., 1999. Distribution of C, N and P in the sediments of the Ganges-Brahmaputra-Meghna river system in the Bengal basin. *Organic Geochemistry,* 30: 75-82.

FAO, 1997. *Soil Map of the World, Vol. VII (South Asia)*. Unesco, Paris, 117 pp.

Folk, R.L., 1966. A review of grain size parameters. *Sedimentology,* 6: 73-93.

Folk, R.L., and Ward, W.C., 1957. Brazos river bar: a study of the significance of grain size parameters. *Journal of Sedimentary Petrology*, 22: 125-245.

Friedman, G.M., 1962. On sorting, sorting coefficients and the log-normality of the grain size distribution of sandstones. *Journal of Geology,* 70: 737-753.

Gupta, L.P., and Subramanian, V., 1994. Environmental geochemistry of the river Gomti; A tributary of the Ganges river. *Environmental Geology,* 24: 235-243.

Imam, M.B., and Shaw, H.F., 1985. The diagenesis of Neogene clastic sediments from the Bengal basin, Bangladesh. *Journal of Sedimentary Petrology,* 55: 665-671.

Jahan, C.S., Majumder, T.K., and Roy, M.K., 1990. Sedimentary environmental discrimination using grain size analysis. *Journal of the Geological Society of India,* 35: 529-534.

Kranck K., Milligan, T., Khatun, S., Ahmad, J.U., Hussain, M., Safiullah, S., and Ali, S.I., 1993. Inorganic grain size analysis of some major Bangladesh rivers. In: V. Ittekkot and R.R. Nair (eds.) *Monsoon Biogeochemistry,* SCOPE/UNEP sonderbd. Mitt. Geol. Palaont. Inst., Univ. Hamburg, Heft 76, pp. 11-17.

Kuehl, S.A., Hariu, T.M., and Moore, W.S., 1989. Shelf sedimentation off the Ganges-Brahmaputra river system: evidence for sediment by passing to the Bengal Fan. *Geology,* 17: 1132-1135.

Kumar S., and Singh, I.B., 1987. Sedimentological study of Gomti river sediments, Utter Pradesh, India: example of a river in alluvial plain. *Senckenbergian Marit,* 10: 145-211.

Lindholm, R.C., 1987. *A practical Approach to Sedimentology*. Allen and Unwin, London, 276 pp.

Mahanta, C., 1995. Distribution of nutrients and toxic metals in the Brahmaputra river basin. Ph.D. Thesis, SES, Jawaharlal Nehru University, New Delhi, 174 pp.

Mantei, E.J. and Foster, M.V., 1991. Heavy metals in stream sediments: effects of human activities. *Environmental Geology and Water Sciences,* 18(2): 95-104.

Meade, R.H. and Parker, R.S., 1985. Sediments in rivers of the United States. Nat. Water Summary, 1984, *US. Geological Survey Water Supply Paper*, 2275: 49-60.

Meade, R.H., 1996. River sediments input to major deltas. In: JD Milliman and BU Haq (eds.), *Sea-level Rise and Coastal Subsidence,* Kluwer Academic Pub., pp. 63-85.

Milliman, J.D., Broadus, J.M. and Gable, F., 1989. Environmental and economic implication of rising sea –level and subsiding deltas –the Nile and Bengal example. *Ambio,* 18(6): 340-345.

Milliman, J.D., Rutkowski, C., and Meybeck, M., 1995. *River Discharge to the Sea: A Global River Index* (GLORI). NIOZ, Texel., 125 pp.

Morgan, J.P. and McIntire, W.G., 1959. Quaternary geology of the Bengal basin, East Pakistan and India. *Bulletin of the Geological Society of America*, 70: 319-342.

Nordin, Jr., C.F., Meade, R.H., Curtis, W.F., Bosio, N.J. and Landim, P.M.B., 1980. Size distribution of Amazon river bed sediments. *Nature,* 286: 52-53.

Pandey, S.K., 1993. Hydrochemistry of Bh agirathi (proglacial) stream, Garhwal Himalayas. M.Phil. Dissert., SES, Jawaharlal Nehru University, New Delhi, 75pp.

Passega, R., and Byramjee, R., 1969. Grain size image of clastic deposits. *Sedimentology,* 13: 233-252.

Ramanathan, A.l., 1993. Geochemical studies in the Cauvery river basin. Ph.D. Thesis, SES, Jawaharlal Nehru University, New Delhi. 202p.

Ramesh, R., 1985. Geochemistry of the Krishna river basin. Ph.D. Thesis, SES, Jawaharlal Nehru University, New Delhi. 228p.

Rasid, H., and Paul, B.K., 1987. Flood problems in Bangladesh: Is there an indigenous solution? *Environmental Mangement,* 11: 155-173.

Reimann, K-U., 1993. *Geology of Bangladesh.* Gebruder Borntraeger, Berlin. 150p.

Salomons, W. and Förstner, U., 1984. *Metals in the hydrocycle*. Springer –Verlag, N.Y. pp 349.

Sengupta, S., 1966. Geological and geophysical studies in the western part of the Bengal basin, India. *AAPG Bulletin,* 50: 1001-1017.

Singh, A.K., 1993. Major ion-chemistry of Alaknanda (proglacial)stream, Garhwal Himalayas. M.Phil. Dissert., SES, Jawaharlal Nehru University, New Delhi. 80p.

Singh, I.B., 1972. On the bedding in the natural leve and the point bar deposits of the Gomti river, UP, India. *Sedimentary Geology* 7: 309-317.

Subramanian, V., and Jha, P.K., 1988. Geochemical studies on the Hooghly (Ganges) estuary. In: E.T. Degens, S. Kampe and S. Naidu (eds.) *Transport of carbon and minerals in major rivers, lakes and estuaries*. SCOPE/UNEP, sonderbd., Heft. 55, Hamburg Mitt. Geol. Palaont. Inst., Univ. Hamburg. pp 267-288.

Swift, D.J.P., Schubel, J.R. and Sheldon, R.E., 1972. Size analysis of fine grained suspended sediment –a review. *Journal of Sedimentary Petrology,* 42(10): 122-134.

Thomas, R.L., Kemp, A.l.W., and Lewis, C.F.M., 1972. Distribution, composition and characteristics of the surfacial sediments of Lake Ontario. *Journal of Sedimentary Petrology,* 42: 66-84.

Umitsu, M., 1993. Late Quaternary sedimentary environments and landforms in the Ganges delta. *Sedimentary Geology,* 83: 177-186.

Valdiya, K.S., 1984. *Aspects of tectonics –focus on south –central Asia.* Tata McGraw –Hill, New Delhi. 319 p.