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Review Paper

Environmental Morphodynamics of Rupnarayan River

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Abstract

The confluence of the Rupnarayan River is located in between the other two river estuaries at a distance of only a few kilometers. The other two river estuaries Damodar and Haldi lie to the north and south respectively of the Rupnarayan which outfall into the Hooghly River. The water of these river estuaries enters and mixes with the water of Rupnarayan River at high tide. Effluents released from Kolaghat thermal power plant and wastewater released from Haldia industrial area mixes with the tidal water of Rupnarayan River which pollutes the river water. Sewage discharges from Haldia, Tamluk and Kolaghat municipalities mixed with the waters of Rupnarayan and became unusable most part of the year. Apart from such pollution, the water of Rupnarayan is now slightly saline for increasing water salinity in the lower reaches of Hooghly River due to sea level rise. Consequent uponthe existence of low salinity in estuarine water, abundant occurrence of giant prawn broods in the confluence has changed the socioeconomic pattern in the localities of three districts surrounding the Rupnarayan River.

Keywords: Bank erosion, Riverbank management, River network, Rupnarayan River, Water quality index, River commons.

Introduction

Rupnarayan River Course: River Rupnarayan, about 80 km in length, is entirely a tidal freshwater river lacking a forest patch along its course[1].The river has its origin from the lower tidal reach below the confluence of Dwarakeswar and Shilabati nearby Bandar at Ghatal of Paschim Medinipur district. At its mid-stretch, Rupnarayan receives huge quantities of water through the discharge by the main flow of Damodar in the form of Mundeswari channel after its bifurcation into two separate channels near Baguhana. Not only the main flow of Damodar i.e., Mundeswari, but Palaspai creek or Old Kansai, a branch of Kangsabati River discharges into Rupnarayan at Gopiganj and increases water load of the flow before outfall of Rupnarayan into Hooghly River at Geonkhali of Purba Medinipur district (Figure-1). The river is not so wide in its upstream particularly at its site of origin i.e., inand around the place of union of Dwarakeswar and Shilabati rivers. Rupnarayan has gradually been widening after receiving discharges from Mundeswari and Old Kansai rivers that form a big river along its downstream stretch.

River Morphodynamics

The Union of Dwarakeswar and Shilabati forms the Rupnarayan River at Bandar near Ghatal town (Figure-2). Rupnarayan is considered as the main river of both Purba Medinipur and Paschim Medinipur districts whereas Dwarakeswar might be considered as the biggest river of Bankura district. Dwarakeswar starts its journey from Purulia district and divides into two halves. This is an important river for Bankura town where river Gandheswari, rising from Saltora meets Dwarakeswar River. Before entering Hooghly district, Dwarakeswar receives water from its tributaries like Adusha, Borai etc. and ultimately unites with Shilabati River near Ghatal to form Rupnarayan River. Like Dwarakeswar, Shilabati River rises in Purulia and flows southeastward before its union with Dwarakeswar River[2].Before the confluence of Dwarakeswar withShilabati, the latter receives water from a number of its tributaries like Jaypanda, Kulbai, Tamal and Parang.

Figure-1: Confluence of Rupnarayan and Hooghly rivers at Geonkhali of Purba Medinipur district (top) and Gadiara of Howrah district (below).

In a stream like Rupnarayan, discharges of sediment and water and their overall balance indicates a stable channel[3,4].When these criteria i.e., overall balance of sediment and water discharge has not been fulfilled, local scour may be created at points and accretion at another. Aggradation or degradation of the river morphodynamics reflect very fast for any gross imbalance between water and sediment discharge. In a meandering tidal river system, high velocity at a particular area causes erosion at outside riverbank as well as accretion in the inside riverbank simultaneously. Naturally, artificial riverbank protection is necessary not only for a tidal meandering river but also for a graded stream[5].

Figure-2: Origin of Rupnarayan River (right) from the union of Dwarakeswar (mid-stream) and Shilabati (left) rivers at Bandar near Ghatal of Paschim Medinipur district.

In such a river system like Rupnarayan, scours of the riverbeds and riverbanks are collectively termed as river scour where riverbank scour needs special attention for protective measures[6-8]. Causes of the damaged riverbanks of Rupnarayan are paid special attention. Riverbanks damaged due to scour or shear failure are identified first with thorough observations and field surveys and then remedial measures are to be applied for each separate distinct cause for the damage of riverbanks[9]. If the river scour causes damage to riverbanks, then revetments, vegetation cover or groins like treatments are to be taken which are necessary to maintain flow with scouring velocity safely away from bank materials. Apart from river scour, when sliding is concerned for riverbank damage, embankment slope is to be reduced or an intermediate berm is to be installed that may enhance the stability of riverbank or compactness of soil for the improvement of shear strength including the fair flow of drainage that reduce seepage pressure[10].

Riverbank Erosion

Rupnarayan is an erosion-prone river in the downstream and faced erosion for years at its right bank near Geonkhali as per the records of 1955, 1965, 1968, 1972, and 1985 by the Calcutta Port Trust[7]. The Calcutta Port Trust selected the Rupnarayan cross section for their study at Natshal, about 2 km upstream of Geonkhali. Geonkhali of Purba Medinipur district stands at the confluence of Rupnarayan and Hooghly rivers surrounded by Gadiara of Howrah district in the north side, and Noorpur of South 24 Parganas from the east side (Figure-3). At Natshal, in the riverbed of Rupnarayan, a submerged tidal shoal continues rising and dividing the entire flow into two distinct separate streams for about 70 years that keep the left bank remain more or less unchanged since fifties of the last century to till date whereas the right bank tends to move outside resulting development of a bend of the river course. Apart from the Calcutta Port Trust, River Research Institute (RRI) of West Bengal had made several hydrographic surveys in the east and west gully in 1977, 1979, and 1985 respectively. Both observational data of Calcutta Port Trust and River Research Institute have been utilized to interpret tidal morphodynamics of Rupnarayan River[7].

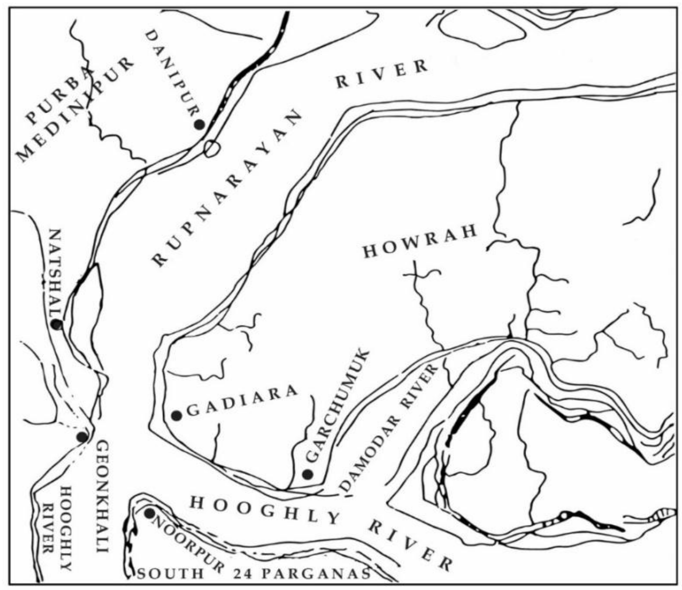

Figure-3: Location map of Rupnarayan – Hooghly River confluence surrounded by Purba Medinipur, Howrah and South 24 Parganas districts.

As per the hydrographic observations of the River Research Institute, the rough bed condition is predominant during the ebb tide[7,8]. The average laminar sublayer thickness higher than the roughness height controls the conditions of no scour formation during the ebb periodat Natshal (Figure-4). But the distribution of radial velocity with the angle of deviation of the main flow from the bank line tends to the riverbank of Rupnarayan near Geonkhali, a vulnerable zone of erosion. River Research Institute observed that the radial velocity is different in direction from surface to bottom in downstream stretches of Rupnarayan River[8,9]. The distribution of radial velocity is positive from surface to mid-depth that leads to the water mass flow towards the bank whereas radial velocity is negative from mid-depth to bottom which attracts water mass away from the bank. Maximum values of radial velocity are near surface and near bottom respectively whereas the value shows zero at mid-depth of the water mass of the river[7-9].

Riverbank Management

River scour disturbs the channel stability of the entire Rupnarayan river system. Along its downstream stretch in Purba Medinipur district, particularly in the left bank, a series of submerged tidal bars are formed that bifurcate the tidal flow pattern of the river as the river is tidal along its entire course. The sediments accumulated in the riverbed require deepening and widening the channel by dredging out of bed materials and the same should be dumped on the riverside of erosion. Only such dredging effort on the riverbed may wash away the accreted bed materials and thus, widen, deepen, and extend the river course and consequently will reduce the intensity of scour by increasing laminar sub-layer for maintaining bed stability. The effect of spiral motion cannot be abolished completely for a tidal river situation but to be checked by applying remedial measures which will accelerate the transportation of accumulated bed materials from the depositional sites to the areas of erosion. Installation of porcupines in rows, a common protective measure for riverbank management may help silt accumulation in the vulnerable zone by the sediment baffling effect.

To achieve such siltation effect in the concave riverside areas, rows of porcupines should be set up keeping their angle of inclination must be higher than the angle of deflection of the river flow. However, the top of the porcupines at mid-depth of the high-water line of the river may help rather better result in arresting sediment particles in the vulnerable zone. Below the low water line, launching the apron may help in protection of the bank where the length of launching apron should cover the anticipated scour depth if it is applied for the riverbank protection of Rupnarayan. Apart from the use of porcupines and launching aprons, block pitching up to low water lines in the concave bank is useful for the protection of riverbanks of Rupnarayan from erosion[4,5].

River Water Characteristics

Generally, total dissolved solid (TDS) is computed from electrical conductivity (EC) as it is a time-consuming method[11]. Total dissolved solids assume to be predominantly ionic species of low enough concentration to yield a linear total dissolved solid - electrical conductivity relationship that is expressed as TDS in mg/L = ke × EC in µS/cm where ke is the constant of proportionality. Total solidis calculated with the sum total of the total suspended solids and total dissolved solids in the process of water[12]. TDS ranges from 90 to 2748mg/l at Geonkhali and from 66 to 1396 mg/l at Kolaghat whereas TSS ranges from 60 to 762mg/l at Geonkhali and 2 to 474mg/l at Kolaghat. Electrical conductivity is much higher in Rupnarayan water for higher TDS values and ranges from 226 to 4250µS/cm at Geonkhali and from 163 to 2220µS/cm at Kolaghat[13].

Water quality indices of Rupnarayan of Kolaghat and Geonkhali have been determined using standard statistical formulas. The determined values of water quality indices show that the water quality of Rupnarayan River is very poor during pre-monsoon and post-monsoon periods (Table-1). Only during monsoon, the water quality of this river is good and suitable for outdoor bathing by local people[14-16].The water of this river is not suitable for drinking due to the presence of faecal coliform bacteria (2000 – 130000 MPN/100ml) in abundance. Faecal coliform bacteria are found in high numbers due to sewage discharge from Tamluk, Kolaghat, and Haldia municipalities mixing with Rupnarayan river water. This same reason increases the level of BOD in river water of Rupnarayan and BOD ranges from 0.5 to 8.2 mg/l though this maximum value of BOD (8.2 mg/l) is occasional. According to the West Bengal Pollution Control Board, the river water is polluted along the stretch from Kolaghat to Benapur as BOD ranges from 3.1 to 5.8 mg/l along this stretch of Rupnarayan[17,18]. As per standard values BOD concentration up to 3mg/l or less is suitable for outdoor bathing. Water pH ranges from 5.97 to 8.38 indicating both acidic and alkaline characteristics of the river water. Fluctuation of pH in the water of Rupnarayan is due to the wastewater discharge by the Tamluk, Kolaghat, and Haldia municipalities and release of industrial effluents from the Haldia petrochemicals and Kolaghat thermal power plant.

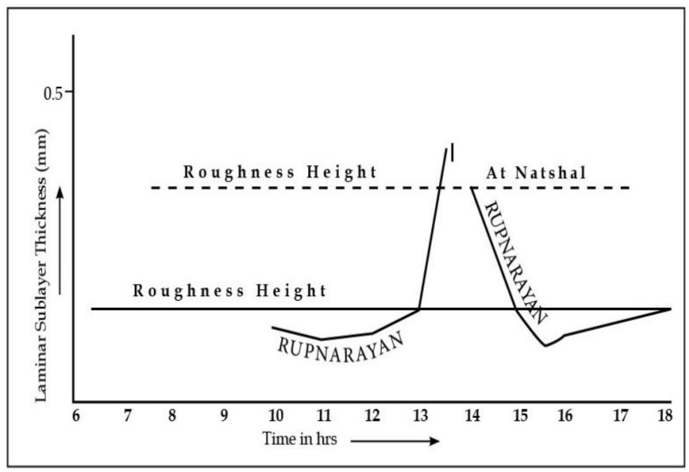

Figure-4: Graphical representation of laminar sublayer thickness against roughness height of Rupnarayan River at Natshal of Purba Medinipur district.

In the lower reaches and confluence of the Rupnarayan River, WQI is poor due to the high concentration of TDS. The reason for this excess TDS is the mixing of industrial effluents with Rupnarayan river water from Kolaghat thermal power plant and Haldia industrial areas and the sewerage water of Tamluk, Kolaghat and Haldia municipalities. Besides, the Damodar River estuary at Garchumuk of Howrah district is a short distance from the Rupnarayan river mouth, so the water mixed with sewage carried by the Damodar River enters the Rupnarayan River. Haldia Industrial Area and Municipality is located at the estuary of Haldi River which is a short distance from Rupnarayan river estuary at its meeting point with Hooghly River. Effluent discharged from Haldia industrial area and municipal sewage flows into the tidal stream and mixes with the water of Rupnarayan River and pollutes the water[19,20]. Due to such higher concentrations of TDS, TSS, and EC the water of Rupnarayan River got polluted. There is a linear relationship between TDS and EC such that higher TDS values will increase EC concentration of the river water.

From the computed water quality index, water quality rating indicates that Rupnarayan river water contains about 25% good water, 54% poor water, and 21% fair water as per standard water quality rating chart during three principal seasons of South Bengal i.e., pre-monsoon, monsoon, and post-monsoon (Table-1). Due to the existence of 54% poor surface water of the river, Rupnarayan river water is not suitable for outdoor bathing.

Changing Water Characteristics for Climate Change

Slow but gradual saline water intrusion and mixing with the river water during high tide as a result of sea-level rise due to climate change continues changing of water quality that affect river ecosystem at the confluence of Rupnarayan and Hugli River where the evening sky of Geonkhali is blazed by the flame emerged from the Haldia Port and that is seen from the bank of Rupnarayan at Gadiara, a well-known tourist spot of Howrah district[21,22]. Anybody could enjoy the overwhelming landscape, scenic beauty and triangle shaped water mass in between at the confluence of river Rupnarayan and Hugli surrounded by Geonkhali of Purba Medinipur, Gadiara of Howrah and Noorpur of South 24 Parganas. A visitor standing on the riverbank at Gadiara enjoyed every moment of enchantment from the top of the terrace of Rupnarayan. But just down to the riverbank at its edge where river water-ripples touch the sandy silt textured flood plain adjacent to the land surface, it tells the tale of truth and toil. Mostly dropout teen aged girls are involved in the netting operations for capturing giant freshwater prawn broods in the evening during ebb time that costs one rupee each or sometimes more. It is like a painting of water colour medium framed with a theme of just existence and survival for these school dropout girls at the spot where the southern breeze hugs the people who pass in idleness at their leisure. And it matters in reality that a girl could earn nearly 200 INR a day by 6 to 8 hours of continuous fishing gear operations by a drag net during ebb tides when water gently recedes.

The occurrence of *Galda chingri meen* i.e., giant prawn (*Macrobrachium rosenbergii*) broods have been enhanced with the increasing salinity at the water of river Hugli and Rupnarayan. The location of the study area is the confluence of Hugli and Rupnarayan rivers, which is surrounded by Gadiara of Howrah District from northwest, Noorpur of South 24 Parganas district from the east and Geonkhali of Purba Medinipur district from southwest. This triangle-shaped geomorphic situation is also important for the abundant occurrence of prawn broods.

The study of water samples reveals that the abundance of prawn broods is enhanced with the increasing salinity in the river waters[23-25]. The water of Rupnarayan-Hooghly confluence at Gadiara, Noorpur and Geonkhali are generally non-saline during monsoon period. The intrusion of mixing-up low saline brackish waters beyond Diamond Harbour along the course of river Hooghly comes upstream andthe waters from the Rupnarayan confluence enters along its upstream only during the period of pre-monsoon season. The waters at the confluence of river Rupnarayan and Hooghly, therefore, get salinised for mixing with saline water entering into the river from the Bay of Bengal due to sea-level rise as a result of the impact of climate change and cause the abundant occurrences of giant prawn broods in this region at pre-monsoon period.

The indented bank of river Rupnarayan at Gadiara is the main spot for abundant occurrences of post larvae i.e., prawn broods of giant freshwater prawn (*Galda chingri*). The tiny post larvae of prawn drift in the river waters, as they are planktonic by nature. The giant freshwater prawn is scientifically known as *Macrobrachium rosenbergii.* The prawn broods occurred mostly in clear water at the pouch-like locales of the erosion site i.e., the inner convex bank of the river.

Table-1: Water Quality Index (WQI) of water samples at different locations of Rupnarayan River.

Sample Locations	Year	Pre-monsoon		Monsoon		Post-monsoon	
		Min	Max	Min.	Max.	Min.	Max
Kolaghat	2013-14	88.28 (Poor)	161.73 (Poor)	40.41 (Good)	65.52 (Poor)	42.33 (Good)	59.21 (Fair)
	2014-15	54.16 (Fair)	92.24 (Poor)	33.84 (Good)	98.78 (Poor)	29.11 (Good)	89.63 (Poor)
Geonkhali	2013-14	110.39 (Poor)	242.59 (Poor)	44.26 (Good)	118.85 (Poor)	51.67 (Fair)	82.98 (Poor)
	2014-15	60.22 (Fair)	289.99 (Poor)	52.48 (Fair)	204.07 (Poor)	44.72 (Good)	90.81 (Poor)

Rating of water quality within parenthesis.

Slight increase in parts per thousands of water salinity of the river waters play a major role in the occurrence of prawn broods in the river. It is interesting to observe that the drifting trend of post larvae of giant prawns is switched on with the increasing salinity of river water during pre-monsoon. Samples are collected from different locations namely Gadiara and Shibpur of Howrah, Noorpur of South 24 Parganas and Geonkhali of Purba Medinipur district to estimate the water salinity in the month of May (pre-monsoon period). After analysis of those water samples the salinity is recorded as follows – at Noorpuraround 1 ppt; Gadiara > 1 ppt; Shibpur < 1 ppt and the salinity at Geonkhaliis about 0.7 ppt (ppt stands for parts per thousand). Prawn broods occur where salinity ranges between 0.25 and 1ppt at Gadiara and Noorpur at the pocket like indented portion of the riverbank with compact silty and stable substratum[26]. So, the geomorphic situation is also an important factor in the giant freshwater prawn brood occurrences[12,25]. Other than the areas of erosion, the lower flood plain covered with tiny grass mat face tidal action is another site where giant prawn broods have occurred at the distal eastern part of Gadiara area.

The collected materials after netting operations are preliminarily sorted out for the prawn seeds mainly for the broods of *Macrobrachium rosenbergii* and thereafter the rest of the materials are left aside on the riverbank or upon the river embankments. A large number of shellfish and finfish are also encountered in this process along with the prawn seeds. This, in turn, is bringing about a tremendous impact in the food web of the river ecosystem, as the collection of giant prawn seeds along with other encounter species is nearly a year-long phenomenon. Numerous finfish and shellfish are suffering a severe loss in population because of random exploitation during sorting out of giant prawn broods. This, in turn, adds to a tremendous threat to the balance of the total ecosystem in and around the confluence of Rupnarayan and Hugli River surrounded by three districts.

Conclusion

Only the water of Rupnarayan River from Kolaghat to Benapur is declared polluted to a large extent by the West Bengal Pollution Control Board as the BOD values range from 3.1 to 5.8 mg/l along this stretch[17,18]. However, the water quality of the river from Kolaghat downstream to Geonkhali in the estuary is of poor quality as per obtained values of water quality index. Further, the river water is also not suitable for outdoor bathing as per the available number of faecal coliform bacteria found in the river water after laboratory analysis. Deterioration of Rupnarayan River water is due to mixing of effluents from Haldia Industrial Area and Kolaghat Thermal Power Plant and sewerage discharge of Kolaghat, Haldia and Tamluk Municipalities. As a consequence, in river water, concentration of TDS, TSS, EC, and BOD are comparatively higher along with the existence of faecal coliform bacteria in numerous numbers in the river water of Rupnarayan[2,27]. Besides, at present, brackish water from Hooghly River flows more upstream along the course of the river due to sea level rise and mixes with the water of Rupnarayan. As a result, the river water at the confluence of Rupnarayan turns into brackish water (about 0.5 to 1 ppt) that helps generate giant prawn broods in huge numbers[22]. The capture of such giant prawn broods has changed the socio-economic status of the local people though Rupnarayan has been famous for the hilsa fish caught atKolaghat for centuries.

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