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# Impacts of industrialization and infrastructure developments on the flora, fauna and ecosystems of the Sundarbans and surrounding areas

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## Abstract

The impacts of rapid industrialization in the periphery of the Sundarbans on the flora and fauna (tiger, deer, crocodile, dolphin, fishes, etc.) and ecosystem of the Sundarbans, surrounding areas and on the other components like river banks erosion, livelihoods of the people, etc. of the Sundarbans and surroundings areas were studied to develop a guideline for future conservation and restoration. The study area is 20 km inside and outside (Periphery) of the Sundarbans under Mongla and Rampal *upazilas* of Bagerhat district, Bangladesh. Fortnight sampling was carried out and air, water, soil and biological samples were studied in the field and laboratory. The recorded data indicate that the present condition of Sundarbans and its surrounding area has reflected a sign of threatened environment. The Sundarbans has lost both floral and faunal diversity by the years. Tigers are disappeared, fishes lost their habitat, trees are affected with unknown diseases, other faunal diversity are also disappeared, erosion is concentrated along the Pashur River, people are being helpless and migrated their occupation. The industries have also brought the curse for natural environment of this area by discharging waste, gases, hot water recklessly into river and surrounding water bodies. As a result the world largest mangrove forest- Sundarbans may can lose its recognition as world heritage site.

***Keywords:*** *Impacts, Industrialization, Flora-fauna, Ecosystems, Sundarbans*



## 1. Introduction

The Sundarbans is a fragile ecosystem and the largest single tract mangrove forest in the world that has been declared Ramsar Site and Natural World Heritage, which is situated in the South-West area (21R 312-22R 382N and 89R 002-89R 552 E) of Bangladesh. It is intersected by a network of tidal canals, creeks and rivers. It is covered an area of 6,000 km$^2$ of which 3,956 km$^2$ mangrove forest lands and more than 1,800 km$^2$ water bodies (Hussain and Acharya, 1994; and IUCN, 2001). This tidal forest is very rich with natural resources, especially floral and faunal diversity like 66 species of plants, more than 200 fish species, 42 mammals, 234 birds, 51 reptiles, 8 amphibians, a lot of invertebrates, etc. (Chowdhury, 2003). More than 500 thousand peoples are directly and indirectly dependent on the Sundarbans for their livelihoods as well as socioeconomic

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purposes. Around 200 thousand people go to the Sundarbans regularly to collect the resources for their livelihoods; less than 200 thousand collect the resources seasonally and around 100 thousand people are doing business of the collected resources and they never go to the Sundarbans directly for resources extraction. Roughly 22% people's livelihoods are involved with the collection of wood resources; 5% are involved with the non-timber forest product; 69% are involved with the aquatic resources and 4% are involved with other purposes. 38% wood resource related people spend 71-75% income for their food; 33% NTFP related people spend 76-80% income for food and 50% aquatic resource related people spend 61-65% income for food which indicate that the most of the Sundarbans dependent are poor (Uddin *et al*., 2013). 84-89% the Sundarbans dependent spend 5% income for their health; 40-68% spend 5-10% for repairing and construction of houses, and 55- 75% spend 5-7% for different social purposes like sons/daughters marriages, attending relatives marriages, religious functions, others festivals, etc. So it is clear that the Sundarbans is the prime source of livelihoods for a good number of people (Chowdhury, 2003 and 2012; and Uddin *et al*., 2013). The findings of the different studies (Alongi, 2002; Biswas *et al*., 2007; CEGIS, 2013; and Chowdhury, 2003, 2009, 2011, 2012 and 2017; Chowdhury and Akber, 2015; FAO, 2007; Giri *et al*. 2007; Hossain, 2014; Hussain and Acharya, 1994; IUCN, 2001; Jahan *et al*., 2000; Mannan, 2010; Mannan *et al*., 2012; Rahman *et al*., 2014; Rahman *et al*., 2013; and Sarkar, 2012) indicate that the floral and faunal composition of the Sundarbans are being changed due to some environmental threats like macro and micro climatic changes, increasing of salinity in soil and water, natural calamity, land erosion, siltation of the river beds, decreasing of the fresh water flows from the upstream, oil spills, industrialization, etc. The number of population of some high saline tolerant plants like, *Ceriops decandra, Excoecaria agallocha,* etc. are increasing in the low saline areas due to increasing of salinity day by day. On the other hand the number of population of low saline tolerant plants likes *Heritiera fomes, Xylocarpus granatum,* etc. are decreasing. Similarly populations of some faunal diversity are being decreased (Mannan, 2010; and Mannan *et al*., 2012).

In last few years, different types of industries like coal based power plant; cement, and LPG gas factories and large infrastructures like silo are being established within 10 to 15 km periphery of the Sundarbans. According to the opinion of the local people, rapid industrialization is being happened in the Mongla and Rampal *upazilas*, which are within 10 to 15 km periphery of the Sundarbans since the inception and construction of coal based power plants in Rampal *upazila*. The raw materials and other products of those industries are being transported by different types of ships, cargoes and navigational vessels in and around the Sundurbans through the Pashur river and its connected rivers. Activities like loading-unloading, noisy ambience, lighting, speedy movements, discharging of burn and ballast water from those vessels and industries may have some direct and indirect impacts on the habit, habitat, food chain, diversity, population, etc. of the flora and fauna and ecosystems of the Sundarbans and the surroundings areas. Many workers did the research on the different issues (environmental impacts, flora and fauna, water and soil quality, food chain, oil spills, salinity intrusion, etc.) on the Sundarbans and surrounding areas. But no such quantitative data are available on the impact on the Sundarbans and surrounding areas fauna (tiger, deer, crocodile, dolphin, fishes, etc.), flora, river banks erosion, livelihoods of the people, etc. due to rapid industrialization and infrastructure developments in the periphery (within 10 to 15 km distance from the Sundarbans) of the Sundarbans.

Under these circumstances, it has become imperative to institute an investigation on the impacts on the Sundarbans and surrounding areas fauna (tiger, deer, crocodile, dolphin, fishes, etc.), flora, river banks erosion, livelihoods of the people, etc. due to rapid industrialization and infrastructure developments in the periphery of the Sundarbans for future conservation of the Sundarbans and surrounding areas ecosystems; especially the tiger and other fauna and their habitats.

## 2. Materials and methods

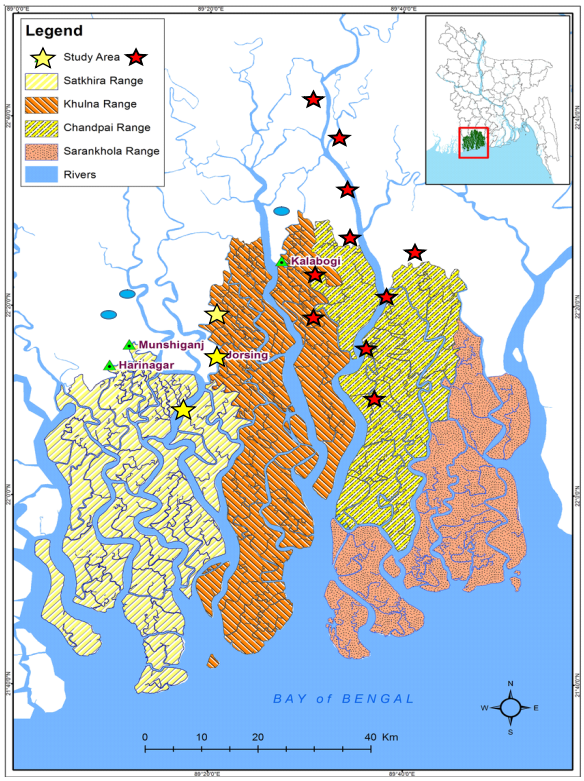
The study area is 20 km inside and outside (Periphery) of the Sundarbans (Karomjal area) under Mongla and Rampal *upazilas* of Bagerhat district, Bangladesh. The research was done in 10 permanent stations of each study area (Rampal, Mongla and the Sundarbans). Research was also done in 3 different locations of nonindustrial areas of the Sundarbans - Gharilal (22º 11´ 54.80´´ N 89º 20´ 04.52´´ E), Jorshing (22º 14´ 38.97´´ N 89º 21´ 34.70´´ E) and Kalagachia (22º 12´ 22.78´´ N 89º 14´ 37.58´´ E) of the western part of Sundarbans. Fortnight sampling was carried out from July 2015 to June 2020 and air, water, soil and biological samples were studied in the field and laboratory. Secondary data were collected from published documents and different government offices. All data were analyzed and potential environmental impacts were identified and calculated by using standard tools and methodologies (Hoshmand, 1998).

The samples of the rivers and the Sundarbans were collected by using a country boat. Water samples were collected from 10-25 cm depth by using a scale (Trivedy, 1993) for physico-chemical analysis. Physico-chemical parameters were measured *in situ* and *ex situ* conditions by following Welch (1948), APHA (1989), Mishra *et al*. (1992) and Gautam (1990). Air Pollution was measured by using High volume sampler (Envirotech APM-415). Noise pollution was measured using Sound Level Meter (Lutorn, SL-4010). Shovels and large ladders were used for collecting the soil samples according to Trivedy (1993). Soil quality were determined in the laboratory by following Jackson (1973) and Page *et al*. (1982). Planktons and benthos were studied by following Welch (1948), Transeau (1951), Edmondson (1966), Tonapi (1980), APHA (1989) and SWAMP (1007). The populations of aquatic and terrestrial plants in field were measured by following quadrat method (Ambasht, 1974). Standard observations and monitoring methods (Jayaraman *et al*., 1998) (Foot / Pug marks per quadrat area / a standard area curve) were followed for different faunal study. Latitude and longitude were measured by using a hand GPS meter (model GARMIN GPSMAP® 78s). Statistical analysis among the different parameters were done by following Hoshmand (1998**)**. The investigation tools also were site observations and spot analyses; Key Informants Interview (KII); Focus Group Discussions (FGD) with community people of that area.

**Impact assessment (IA):** Most of the development projects produce impacts on or changes in the state of natural environment. Of which some are positive and some are negative. Similarly, some positive and negative impacts were identified in this study by following the DOE (1997) guidelines for industries, ADB (2003) environmental assessment guidelines and FPCO (1992) guidelines. These issues and impacts were evaluated in terms of distribution, quantity, quality, seasonality, ecological and socioeconomic importance. The sources of information for the scoping process were: (1) Field visits and environmental survey; (2) Collected data from different sources, departments, institutes, *upazila*s, Ups, etc. (3) Meeting with chairmen, members, local people, govt. officials, teachers, social workers, different stakeholders, etc.

**Impact assessment matrix:** The impact assessment matrix was done in consultation with multi-disciplinary team members. When an impact could not be quantified, qualitative judgment was used based on professional experience. The scoring were done within a 21-point score scale ranging from –1 to –10 for negative impacts and +1 to +10 for positive impacts while "0" was used for no impact (neutral impact) (Pastakia and Jensen, 1998).

**Showing sampling stations-industrial sites (red star) and nonindustrial sites (yellow star)**



## 3. Results and discussion

### *3.1. Physico-chemical condition of water and soil*

Physico-chemical and biological conditions of water of the study areas (Rampal, Mongla and the Sundarbans mangrove forest) have been presented in Table 1 and physico-chemical conditions of the soil have been presented in Table 2.

**Table 1: Physico-chemical and biological conditions in the water bodies of the study areas (Rampal, Mongla and The Sundarbans)**

| Parameter | Unit | Present Study | | | | Previous Study (Before 2010) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | SD | Min | Max | Mean | SD | Min | Max |
| Air temperature | °C | 28.2 | 1.9 | 20.7 | 35.3 | 27.9 | 1.6 | 20.3 | 34.5 |
| Water temperature | °C | 28.4 | 1.5 | 21.2 | 34.6 | 26.5 | 0.9 | 20.6 | 29.1 |
| Transparency | cm | 11 | 1.5 | 08 | 16 | 25 | 4 | 23 | 32 |
| Total suspended solid | mg/l | 491 | 137 | 257 | 678 | 9.5 | 1.8 | 8.9 | 15.8 |
| pH | | 7.7 | 0.8 | 7.4 | 8.4 | 8.1 | 0.4 | 7.8 | 8.8 |
| Dissolved oxygen | mg/l | 5.6 | 0.3 | 3.8 | 6.9 | 6.4 | 0.6 | 4.9 | 7.2 |
| Total dissolved solid | g/l | 19 | 1.5 | 13.7 | 24 | 12.5 | 1.6 | 10.8 | 15.2 |
| Salinity | ppt | 12.9 | 3.7 | 12.1 | 22.6 | 12.2 | 1.5 | 11.6 | 17.5 |
| Total hardness | mg/l | 1662 | 143 | 1583 | 2029 | 952 | 37 | 815 | 1028 |
| Biological oxygen demand ($BOD_5$) | mg/l | 3.9 | 0.7 | 2.8 | 5.5 | 2.1 | 0.5 | 1.6 | 2.8 |
| Chemical oxygen demand | mg/l | 365 | 29 | 281 | 584 | 133 | 28 | 75 | 192 |
| Carbon dioxide ($CO_2$ alk.) | mg/l | 21 | 8 | 17 | 35 | - | - | - | - |
| Carbonate ($CO_3$ alk.) | mg/l | - | - | - | - | 32 | 7 | 26 | 43 |
| Bicarbonate ($HCO-_3$) | mg/l | 142 | 22 | 112 | 165 | 123 | 18 | 97 | 132 |
| Nitrate as nitrogen ($NO_3$-N) | mg/l | 3.72 | 0.56 | 2.89 | 4.33 | 2.26 | 0.43 | 2.07 | 3.11 |
| Inorganic phosphate ($PO_3$) | mg/l | 1.90 | 0.07 | 1.76 | 2.03 | 1.72 | 0.07 | 1.53 | 1.84 |
| Silicate | mg/l | 5.63 | 0.54 | 4.87 | 6.95 | 5.73 | 0.68 | 4.94 | 6.77 |
| Calcium | mg/l | 774 | 66 | 725 | 880 | 576 | 49 | 481 | 690 |
| Magnesium | mg/l | 494 | 57 | 479 | 597 | 317 | 34 | 235 | 448 |
| Productivity | mg/l | 2.1 | 0.3 | 1.6 | 3.0 | 7.9 | 0.7 | 7.1 | 11.4 |
| Oil content | mg/l | 45 | 7 | 29 | 68 | 8.1 | 0.5 | 4.2 | 10.8 |
| Phytoplankton (Abundance) | units/l | 153 | 35 | 137 | 199 | 369 | 58 | 275 | 462 |
| Phytoplankton (No. of Species) | no./l | 21 | 6 | 14 | 30 | 38 | 5 | 29 | 51 |
| Zooplankton (Abundance) | units/l | 69 | 8 | 63 | 85 | 92 | 13 | 80 | 126 |
| Zooplankton (No. of Species) | no./l | 16 | 3 | 12 | 20 | 25 | 4 | 22 | 29 |
| Benthos (Abundance) | no./kg | 19 | 4 | 15 | 24 | 37 | 6 | 30 | 48 |
| Benthos (No. of species) | no./kg | 14 | 5 | 10 | 20 | 26 | 4 | 23 | 32 |

**Note:** – = Not detected.

**Table 2: Chemical conditions of soil of the study areas (Rampal, Mongla and the Sundarbans)**

| Parameter | Unit | Present Study | | | | Previous Study (Before 2010) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | SD | Min | Max | Mean | SD | Min | Max |
| pH | | 7.6 | 0.2 | 7.5 | 7.9 | 8.2 | 0.2 | 7.9 | 8.5 |
| Salinity | ppt | 13.4 | 0.8 | 12.5 | 14.3 | 12.1 | 0.3 | 11.4 | 13.9 |
| Total Nitrogen | % | 0.26 | 0.019 | 0.20 | 0.28 | 0.16 | 0.005 | 0.12 | 0.19 |
| Phosphorus | $\mu$g/g soil | 171 | 42 | 95 | 268 | 21 | 1.8 | 14 | 25 |
| Sulfur | $\mu$g/g soil | 114 | 11 | 93 | 129 | 72 | 5 | 61 | 98 |
| Calcium | meq/100g soil | 14.3 | 1.2 | 13.4 | 15.5 | 15.8 | 0.4 | 14.6 | 16.5 |
| Magnesium | meq/100g soil | 10.1 | 0.3 | 9.7 | 10.8 | 11.6 | 1.5 | 10.7 | 12.9 |
| Potassium | meq/100g soil | 1.55 | 0.11 | 1.36 | 1.71 | 1.64 | 0.38 | 1.49 | 2.02 |
| Oil content | mg/kg of 2 inch surface soil | 10.7 | 0.9 | 7.5 | 15.6 | 4.8 | 0.4 | 3.4 | 7.6 |

The recorded data indicate that, high total suspended solids (491 ± 137 mg/l), total hardness value (1662 ± 143 mg/l) and content of oil (45 ± 7 mg/l) along with higher chemical oxygen demand (COD) value (365±29 mg/l) were present during the period of study in the Pashur rivers and its connected canals (in and around the Sundarbans) which are being contaminated continuously by the different effluents of the different industries. On the other hand, low transparency (11 ± 1.5 cm) and productivity (2.1 ± 0.3 mg/l) values, poor abundance of phytoplankton (153 ± 35 units/l), zooplankton (69 ± 8 units/l) and benthos (19 ± 4 no./kg), and poor number of species of phytoplankton (21 ± 6 no./l), zooplankton (16 ± 3 no./l) and benthos (14 ± 5 no./kg) were recorded in the effluent contaminated areas of the Sundarbans (The Pashur river and its connected canals sites). Whereas, the previous recoded data (before rapid industrialization and before 2010) of the same study area and the uncontaminated areas of the Sundarbans (Western part of SRF) indicate that the values of total suspended solids (9.5 ± 1.8 mg/l), chemical oxygen demand (133 ± 28 mg/l), total hardness (952 ± 37 mg/l) and oil content (8.1 ± 0.5 mg/l) were lower than those of contaminated areas of SRF (The Pashur rivers and its connected canals sites). Similarly the values of transparency (25 ± 4 cm) and productivity (7.9 ± 0.7 mg/l), and abundance of phytoplankton (369 ± 58 units/l), zooplankton (92 ± 13 units/l) and benthos (37 ± 6 no./kg), and number of species of phytoplankton (38 ± 5 no./l), zooplankton (25 ± 4 no./l) and benthos (26 ± 4 no./kg) of the uncontaminated areas and before rapid industrialization (before 2010) were much higher than those of the contaminated areas of SRF (the Pashur river and its connected canals). Physico-chemical conditions (Table 2) of soil (2-6 inches surface soil) of intertidal zones of the Pashur river and its connected canals sites (The Sundarbans) are being contaminated day by day due to different types effluents of different industries; this contamination is being increased gradually by these industries related shipping activities. High values of total suspended solids, chemical oxygen demand, total hardness and oil content; poor values of productivity and transparency; poor abundance and species diversity of phytoplankton, zooplankton and benthos of water, physico-chemical conditions of soil and air quality (Table 1, 2 & 3) indicate that the study areas of the Sundarbans reserve forest (The river Pashur and its connected canals sites) ecosystems are being changed by the rapid industrialization on the periphery of the Sundarbans. This finding has been supported by the studies of Chowdhury (2009 and 2011), Hossain and Chowdhury (2008), Rahaman *et al.* (2013) and Rahman *et al.* (2006, 2013 and 2014). They had recorded good transparency (27 ± 5 cm), productivity (17 ± 0.8 mg/l), phytoplankton (407 ± 53 units/l) and zooplankton (59 ± 14 units/l) abundance but low values of total suspended solids (9.2 ± 1.4 mg/l), chemical oxygen demands (63 ± 5 mg/l), total hardness (946 ± 53 mg/l) and oil (7.26 ± 0.4 mg/l in water, 3.0 ± 0.2 mg/kg of 2 inch surface soil) in their studies in the Sundarbans.

Chowdhury and Zaman (2001 and 2002) and Bhuiyan (1983) recorded in their studies that different industrial effluents contamination in the water body were responsible for increasing of total suspended solids, COD and total hardness values of water and for decreasing of transparency, productivity and abundance of phytoplankton and zooplankton of water. The recorded data of the industrial effluents contaminated areas of

the Sundarbans have been supported by the observations of Chowdhury and Zaman (2001 and 2002) and Bhuiyan (1983).

More than 10 mg / l of oil in aquatic habitat can be lethal for the aquatic lives (APHA, 1989). Higher content of oil was observed in the water and soil of intertidal zones of the industrial sites of the Sundarbans (Tables 1 and 2). The recorded SPM, NOx and SOx values (Table 3) indicate that due to industrialization these values are being increasing in and around the Sundarbans Therefore, the air, water and soil of the study areas of the Sundarbans (The Pashur river and its connected canals sites) are being polluted and affected by the industrial wastes.

### *3.2. Phytoplankton, zooplankton and benthos*

Diversity and abundance of phytoplankton, zooplankton and benthos of the industrial contaminated (The Pashur river and its connected canals sites SRF) and uncontaminated areas of the Sundarbans (Western part of the SRF), and previous study (before 2010 data) of the Sundarbans indicate that diversity and abundance of phytoplankton, zooplankton and benthos are being decreased in and around the Sundarbans (Industrial sites). Besides, the presence of *Euglena* sp. and *Phacus* sp. (pollution indicator) in study areas also indicates pollution of the aquatic habitat of Sundarbans by industrial effluents and industry related shipping activities (discharge burn oil, wastes, ballast water, etc.). Islam (1973), Chowdhury (2003), Hossain and Chowdhury (2008) reported 44 phytoplankton species with good abundance in different season from the aquatic ecosystems of the Sundarbans before rapid industrialization (before 2010) beside the Sundarbans. So, it can be concluded that the different types of species and abundance of the phytoplankton (primary producer) are being affected by the industrial effluents in aquatic ecosystems of the study sides of Sundarbans. This result has been supported by the findings of Chowdhury and Zaman (2001) as they observed phytoplankton (primary producer) species diversity and abundance always being decreased by the industrial pollution in the aquatic ecosystems. Presence of Protozoa (Zooplankton-pollution indicator) in study areas of the Sundarbans also indicates the pollution of water (Chowdhury and Zaman, 2002). Islam (1974) and Chowdhury (2003 and 2011) recorded good number of zooplankton species in the aquatic ecosystems of the Sundarbans in different seasons. So, it is clear that the zooplankton (primary consumer of water) diversity and abundance of the Sundarbans are being decreased by the industrial and shipping pollutants. Chowdhury and Zaman (2002) also recorded that most of the zooplankton species couldn't survive in the aquatic ecosystem except protozoa when oil content of water became more than 10 mg / l. Chowdhury (2002 and 2011) recorded 34 benthos species in the Sundarbans during his studies and most of the recorded benthos abundance was in good condition. The recorded benthos status of the present study indicates that benthos population and diversity are being affected by the pollutants in the industrial sites of the Sundarbans. Phytoplankton, zooplankton and benthos abundance of the industrial contaminated areas of the Sundarbans showed statistically significant negative correlation with TSS (> -0.872), COD (> -0.790), total hardness (> -0.822) and oil content (> -0.785) values.

**Table 3: Air quality of the study areas (Rampal, Mongla and the Sundarbans)**

| Study Location | SPM (mg/m³) | | $NO_x$ (µg/m³) | | $SO_x$ (µg/m³) | |
|---|---|---|---|---|---|---|
| | Study Period | Before 2010 | Study Period | Before 2010 | Study Period | Before 2010 |
| Sundarbans area (Industrial sites) | 237- 486 | 115 - 180 | 24 – 35 | 12 - 19 | 21-38 | 9 – 14 |
| Mongla area | 276 – 515 | 158 - 259 | 74 -149 | 56 - 101 | 56 – 88 | 40 - 58 |
| Rampal area | 241 – 397 | 132 - 218 | 62 – 98 | 53 - 72 | 43 -74 | 34 - 50 |
| Sundarbans area (Unindustrial sites) | 84 – 116 | 79 - 114 | 11 – 16 | 10 - 14 | 8 – 12 | 7-11 |
| EQS- Bangladesh | 400 | | 80 | | 80 | |

### *3.3. Flora and fauna*

The recorded floral and faunal conditions of the industrial contaminated areas and uncontaminated areas have been presented in Table 4.

During the period of study it was observed that some flora and fauna were affected by industrial pollution in many different ways (Table 4). Some of the seedlings of mangrove plants and 'saline water lily' of the intertidal zones were affected by changed physico-chemical conditions of water and soil and they were being decomposed (Table 4). Pneumatophores and some of the seeds of the Sundri plant were found black coloured; more than 70% embryos of the seeds were decomposed, thus their germination would be prohibited. Whereas, almost 100% embryos of the Sundri seeds were found in good condition in the uncontaminated areas (west SRF- without industry). In the Sundarbans, three species of macro red algae (*Catenella* sp.) which remain attached with plant root and pneumatophores, and two species of a brown macro algae (*Colpomenia* sp.) which grow in small creeks as benthic form (Islam, 1973; and Chowdhury, 2003). But these algal flora were found in poor abundance in the industrial sites of Sundarbans compare to without industrial areas (Table 4).

During study period 14 to 20 species of fishes were recorded in the industrial effluents contaminated areas, but 27 to 33 fish species were recorded in the unpolluted areas (Table 4). During breeding season, only 1700-2400 (units / l) eggs and hatchlings of commercially valuable fishes like Parshe (*Liza* spp.), Khorsula (*Mugli* spp.), Bagda shrimp (*Penaeus monodon),* etc. were found in the industrial areas of the Sundarbans; whereas 6300 to 8700 units / l of eggs and hatchlings of those fishes were recorded in the nonindustrial areas (West SRF). In previous study (before 2010) 6800 to 9600 units / l of eggs and hatchlings of these fishes were recorded

**Table 4: Floral and Faunal status of the study areas and other areas of the Sundarbans**

| Name of the flora and Fauna | Units | Present Study | Non industrial areas | Previous study Before 2010 | Comments |
|---|---|---|---|---|---|
| Seedling of Plants on intertidal zones | no. / $m^2$ | 2-3 Observed poor number of the seedlings | 10-14 | 12-19 | |
| Saline water lily on intertidal zones | no. / $m^2$ | 3-5 Plant bodies were being decomposed | 9-15 | 14-24 | Plant bodies were being decomposed due to change of soil & water quality |
| Fruits / Seeds of Sundri Plants | no. / $m^2$ | 6-10 >70% seeds embryos were black | 12-19 | 10-19 | Black embryos generally be decomposed as a result seed are not germinated |
| Pneumatophores (Breathing roots) of plants | no. / $m^2$ | >20% Pneumatophores growth are been affected. | >95% Pneumatophores are ok. | All pneumatophores are ok. | Physiological activities of the plants may be affected by the pollution |
| *Catenella* sp. (3sps.)- a red algae attached with plant roots | no. / $m^2$ | 35% lower than nonindustrial site | Present in good conditions | Present in good conditions | Worked as primary producer; Source of food and nutrient of the many aquatic animals |
| *Colpomenia* sp. (2sps.)- a brown macro algae grows in small creeks as benthic form | no. / $m^2$ | Only 4-9% covered area. | Present in good conditions | Present in good conditions | Worked as primary producer; Source of food and nutrient of the many aquatic animals |
| Eggs & hatchlings of different fishes i.e. Parshe, Khursula, Bagda, Harina etc. | units / l | 1700 to 2400 (During breeding season) | 6300 to 8700 | 6800 to 9600 | Source of natural and cultivated fish production in the South-west coastal areas of Bangladesh |
| Mudskippers – a common intertidal zone fish | no. / $m^2$ | 0-2 | 2-4 | 3-7 | Indicator of mangrove ecosystem and used as food by the birds, fishing cat, otter, snake and other animals. |
| Mud Crabs (Kakra) (4sps.) – a common intertidal zone Crustacea | no. / $m^2$ | 0-1 | 2-4 | 3-6 | Indicator of mangrove ecosystem and used as food by the birds, crocodiles and other animals. |
| Snails (Shamuk) (10 sps.) – a common intertidal zone Mollusk | no. / $m^2$ | 3-7 | 9-15 | 10-16 | Indicator of mangrove ecosystem and used as food by the fishes, birds, crocodiles and other animals. |

**Table 4 (Cont.)**

| Name of the flora and Fauna | Units | Present Study | Non industrial areas | Previous study Before 2010 | Comments |
|---|---|---|---|---|---|
| Fishes –common fishes of the rivers, canals, creeks etc. | No. of species | 14-20 species | 27-33 species | 31 - 43 species | Major aquatic resource of the Sundarbans |
| Frogs (2 sps.) – intertidal zone of the Pashur river & canals | Study period | Few frogs were observed in the study period | Many Frogs were observed in the intertidal zones | Unlimited Frogs were observed in the study area | Common Amphibian of the Sundarbans |
| Snakes (7 sps.) | Study period | 11-15 snakes of 4 species were observed | 23-28 Snakes of 7 species were observed | 26-33 Snakes of 7 species were observed | Vey Common Reptile of the Sundarbans |
| Monitor Lizards (3 sps.) – intertidal zone of the Pashur river & canals | Study period | 9 monitor lizards were observed in the study period | 23 Monitor Lizards of 3 different species were observed | 21- 27 Monitor lizards of 3 different species were observed in the study area | Common reptiles of the Sundarbans |
| Crocodile – common animal of the Pashur river and connected canals | Per day / study period | Only 3 crocodiles were observed in the study period | 4-5 crocodiles were observed in a day | 5-6 crocodiles were observed in a day | Threatened species and Indicator of the mangrove ecosystem |
| Intertidal Bird (Masked finfoot) - intertidal zone of the Pashur river & canals are habitat | Study period | Only 2 Masked finfoot bird was observed in the study period | Only 5 Masked finfoot was observed | 29 Masked finfoot birds were observed in the study area | Worldwide Threatened species and only the mangrove bird |
| Common Birds (Heron, Kingfisher etc. - common animal of the Pashur river and connected canals | Study period | Only 27 birds of 5 different species were observed in the study period | 162 birds of 33 different species were observed | More than 300 birds of 46 different species were observed | Common animals of the mangrove ecosystem |
| Ban Morog (Birds) - common beside the Pashur river and connected canals | Study period | 2 Ban Morog were observed in the study period | 16 Ban Morog were observed | Ban Morog was available | Common bird of the mangrove ecosystem |
| Migratory Birds – intertidal zone of the Pashur river & canals are habitats | Study period | No Migratory bird was observed in the study period | Few migratory birds were observed | Many Migratory birds were observed in the study area | The Sundarbans is the habitat of the Migratory birds |
| Fishing cat - intertidal zone of the Pashur river & canals are habitats Otter – intertidal zone of the Pashur river & canals are the habitats | Study period | Only 3 foot marks of fishing cats were observed in the study period | 19 Foot marks of fishing cats were observed | Many foot marks of fishing cat were observed in the study area | Common animal of the Sundarbans |
| Dolphins - common animal of the Pashur river and connected canals | Study period | 2 foot marks of Otter were observed in the study period | 12 Foot / Pug Marks of Otter were observed | Unlimited Foot Marks of Otter were observed | Threatened animal in the main land but a common animal of the Sundarbans |
| Deer – beside the Pashur river & connected canals | no. / hour | 7-9 times movements of dolphin were observed / hour | 15-17 times movements were observed / hour | 19-22 times movements were observed / hour in the study area | Threatened species and indicator of the mangrove ecosystem |
| Wild Boar – beside the Pashur river & connected canals | Study period | Poor no. of deer was observed | Available deer was observed | Unlimited deer were observed in the study area | Common Animal of the Sundarbans |
| Tiger – beside the Pashur river & connected canals | Study period | 11- 16 no. Wild Boars was observed in the study period | 24- 30 no. Wild Boars were observed in the study period | Unlimited Wild Boars were observed | A Common Animal of the Sundarbans |
| Tiger - beside the Pashur river & connected canals | Study period | 3-4 tigers pug marks were observed in the study period | 11 - 15 tigers pug marks were observed in the study period | 9 - 12 tigers pug marks were observed in the study area | Threatened and indicator species of the Sundarbans |

in the Sundarbans (Chowdhury, 2011). Present study indicates that the industrial effluents posed profound threat for the eggs and hatchlings of different fishes. During the period of study it was found that mudskippers, mud crabs, and snails diversity and population are being decreased on the intertidal zones of industrial areas of the Sundarbans compare to nonindustrial areas and previous study data. In this study the diversity and abundance of frogs, snakes, monitor lizards, otter and fishing cat were found very poor in the industrial sites

of the Sundarbans areas, whereas these faunal species were in normal conditions in the nonindustrial areas of the Sundarbans (Table 4) as well in previous study. In the industrial sites of the Sundarbans, birds population and diversity were observed in poor conditions compare to nonindustrial sites of the Sundarbans and previous study data (before 2010). In the period of study poor number of dolphin, crocodile, Masked finfoot (worldwide vulnerable mangrove bird), wild boar and deer were recorded in the industrial sites of the Sundarbans areas (The Pashur river and its connected canals, creeks, etc. and their intertidal zones and *char Islands*). Whereas their number of population were comparatively higher in previous study (before 2010) and in nonindustrial sites of the Sundarbans areas (Table 4). Chowdhury (2003, 2011) and IUCN (2001) recorded dolphins, crocodile, Maskedfinfoot, migratory birds, wild boar, deer, etc. in and around the river Pashur and its connected canals and creeks. Royel Bengal Tiger – a threatened and indicator species of the world largest mangrove forest but during the period of study only 3 tigers pug marks were observed in the industrial sites of the Sundarbans areas (The Pashur river and its connected canals, creeks, etc. and their intertidal zones and *char Islands*). Whereas 12 tigers pug marks were recorded in the same study areas in the study of before 2010 and 15 tigers pugmarks were recorded in the nonindustrial sites of Sundarbans areas (Table 4). Status of the tigers indicates that the study area has been loosed habitat quality of the tigers may be continuous changing of air, water and soil quality by the rapid industrialization as well as increasing of industry related shipping activities in and around the Sundarbans.

### *3.4. River systems and Erosion*

The Passur and all its distributaries are tidal channels and is the main river to control drainage systems of the total study and industrialization area. The average elevation of the sites is about 2 m above the mean sea level. The study area slopes gently towards Southwest. Small tributaries and canals that finally join the river Passur and drain the industrialization area. The river Passur flows in Southern direction. The name of connected rivers or tidal channels of the Passur river are Maidara, Mongla, Chunkuri, Ghasiakhali, Bishna, Kumarkhali, Gona, Dagura and Ichhamati rivers and their connected small creeks / channels, and Biddarbahon Channel, Burirdanga khal, Chak Gona khal, Daudkhali khal, etc. and their small creeks. These rivers / channels / creeks / khals and their all small creeks are situated as like as net in the study areas (growing industrialization areas). All these channels are acting as creeks through which tidal water enters into the study site during high tide and drains out during the ebb tide. The Passur river is the main navigational channel for transportation of the construction materials, imported raw materials, coal, oil, etc. of the different industries. The width of this river varied from 700 to 850 m at different locations; depth varied 6.5 to 8.00 m; catchment area more than 400 sq. km; minimum discharge (6000 $m^3/s$) month is February and minimum depth in dry season 6 to 6.50 m at Mongla; maximum discharge (22500 $m^3/s$) month is August and maximum depth in wet season 8 m at Mongla. The rainfall of the study areas initially stores in the ditches, agricultural lands, shrimp farms and other low lying areas. Aftermath, multiple creeks in the project area receive the rainfall runoff and finally discharge into the Passur River. Maximum surface runoff from this flat or nearly flat land is found during monsoon. This runoff flows to the nearby connected rivers / canals / creeks of the Passur river. The tides of the Passur river are important for navigation as determines the possibility of crossing the shallow outer bar at the entrance. The approximate range of the tide observed at Mongla station is between 1.2 m to 3.5 m and the tidal amplitude is around 3.25m (Observation of Mongla Port Authority). The tide is semi-diurnal in nature.

Two tides (e.g., flood and ebb) are regularly observed in the Passur river, which enters into the study sites through numerous connected creeks. Earlier, maximum study areas were inundated because of tidal flooding. Tidal water intruded into the land during high tide, flooded twice in a day and discharged with the creeks during low tide when the river water is in lower stage. The average height off lood tides rise during spring tide and decline during neap tide. Eventually, those areas have been raised due to regular sedimentation with tidal flooding. Semi-diurnal tide (two flood tides in 24 h) occurs in the Passur River, which enters inland area through numerous connected creeks. Within the study area, lands that are not protected by coastal polders are inundated by tidal floods twice in a day. Tidal water intrudes into these lands during flood tide, and flows back to Passur during ebb tide with the numerous tidal creeks. The study sites were dominated by seasonal shrimp cultivation and agricultural practices. These areas were protected by the earthen made local levees, which is the common practice to

prevent tidal inundation of the study area at present. Most of the lands of the study areas (also growing industrialization areas) are occupied by shrimp farms where river water intrusion through tidal creeks is regulated by indigenous earthen made local levees and wooden water control structures. These fragile wooden structures allow river water to enter during flood tide according to the demand of the shrimp farms.

Now, the name and presence of the connected rivers or tidal channels of the Passur river (Maidara, Mongla, Chunkuri, Ghasiakhali, Bishna, Kumarkhali, Gona, Dagura and Ichhamati rivers and their connected small creeks / channels, Biddarbahon Channel, Burirdanga khal, Chak Gona khal, Daudkhali khal, etc.) and their small creeks are going to be disappeared due to growing industrialization in the study areas. It has been observed that when an industry buy the land for settling industry, they fill up the entire land space for industrial infrastructures and they also fill up all the small canals and wetlands inside their boundary. It has been also observed that natural tidal flow areas are going to be decreased day by day with the growing industrialization in the study areas. The satellite maps of the 1978 and 1998 indicate the presence of Pashur river connected all channels; but the satellite map of 2017 indicates the declined scenario of the connected rivers or tidal channels of the Passur river and their small creeks in the study areas. As a result siltation rate is increasing gradually (Siltation data) on the beds of Pashur river and its connected rivers and channels due to continuous decreasing of natural tidal flow areas of the Pashur river.

Analysis of time-series hydrographic level surveys of BIWTA shows a gradual decline of navigability especially in the reach of Harbaria to Mongla Port. The siltation data of different locations shows gradually decreasing the depth of the Pashur river (beside the Mongla port) and its all connected channels. According to BIWTA data, the Pashur river water depth is above 9 m at Akram point, 8.1 m at Harbaria canal, 7m at Sagir canal, 5.6 m at Chila bazar, 4 m at Coast guard jetty, 6.1 m Mongla port jetty and 4 m at Mongla port berthing Jetty.

On the other hand, the pressure of tidal flows are increasing on the both sides riverbank of the Pashur due to the decreasing of depth of river and declining the natural tidal flow areas. As a result, riverbank erosion is increasing on the both sides of the Pashur river. During the last five years, from proposed Rampal Coal based power plant site to Koromjol (Western riverbank of the Pashur, 22 °26.318' N & 89° 35.281'E) and Joymonirghol (Eastern riverbank of the Pashur, 22°21.227' N and 89°38.163' E) areas 130 to 360 m width riverbank erosion were been happened in different locations. Main Baniashanta bazar, old Koromjol Forest offics, old Baniashanta brothel houses, Baniashanta bazar to Dhangmari forest office connected road, etc. became the part of the Pashur river due to massive erosion. River bank erosion also responsible for the increasing of siltation on the river beds and decreasing the depth of the Pashur river in different locations. The rate of siltation, riverbank erosion and current of tidal flow are statistically significant positive correlation ($r => 0.851$) with each other. It was recorded that the number and activities (anchoring, landing, staying, movement, etc.) of the cargo vessels are being increased with the growing industrialization for different industrial purposes. "The anchoring and movement of the cargo vessels are also enhancing the riverbank erosions" complained by the people of the Baniashanta and Dhangmari areas.

Navigation facilities is essential for coal transportation (raw material of Rampal Coal Power plant) from Akram point to plant site. Mongla Port Authority provides aids to navigation within its port limit only. Besides, BIWTA provides aids to navigation in inland water transportation routes. The channel from Mongla Port Fairway Buoy (MPFWB) to Mongla Port Jetty is properly marked by necessary aids for day time navigation only. Channel from Port Jetty to project site (power plant) is marked by both day time and night navigational facilities e.g. lightened buoy and beacons by BIWTA. Mongla port is located at 14 km south from the proposed Rampal Power plant site. The plant has been envisaged with the aim of using Mongla Port facilities (not berthing / jetty facilities) for primary fuel-coal transportation from source countries to the project coal terminal with the capacity of handling 6.5 million tons in a year. According to the navigational information of Mongla Port Authority, at present, Mongla Port handles 1.6 million tons of cargo yearly. The average turn around time (in day) for a bulk cargo is 5.5 and 2.5 for a container cargo. They are handling 250 vessels in every years. At present, Mongla port operates five general cargo / container berths, seven river mooring berths, and fourteen anchorage berths. In addition, there are seven specialized private berths.

**Table 5: Rate of River Bed Siltation**

| Location | 2013 (cm) | 2014 (cm) | 2015 (cm) | 2016 (cm) | 2017 (cm) |
|---|---|---|---|---|---|
| Harbaria | 7-9 | 10-15 | 17-20 | 19-21 | 20-22 |
| Koromjol | 15-19 | 18-24 | 25-30 | 26-37 | 30-39 |
| Coast Guard Jetty | 4-6 | 6-7 | 7-8 | 7-9 | 8-10 |
| Mongla Port Jetty | 11-15 | 14-19 | 19-24 | 26-29 | 29-33 |
| Mongla Port Berthing Jetty | 13-18 | 16-22 | 24-30 | 25-33 | 27-36 |

**Table 6: River Bank Erosion had been studied in the following locations**

| Latitude | Longitude |
|---|---|
| 22.370561 N | 89.632661 E |
| 22°21'227' N | 89°38'163' E |
| 22°20'901' N | 89°38'188' E |
| 22°26'542' N | 89°36'071' E |
| 22°28'135' N | 89°35'038' E |
| 22°27'989' N | 89°35'042' E |
| 22°27'539' N | 89°35'057' E |
| 22°27'530' N | 89°35'048' E |
| 22°27'529' N | 89°35'046' E |
| 22 °26.235' N | 89 °35.495' E |
| 22 °26.285' N | 89° 35.309' E |
| 22 °26.318' N | 89° 35.281' E |
| 22 °26.235' N | 89° 35.495' E |
| 22 °26.232' N | 89° 35.495' E |
| 22 °26.233' N | 89° 35.418' E |
| 22 °26.233' N | 89° 35.498' E |
| 22 °26.838' N | 89° 35.065' E |
| 22 °26.980' N | 89° 35.053' E |
| 22 °27.069' N | 89° 35.037' E |

"Maintenance of draught is the main challenge for Mongla port" Authority said. Presently, maximum allowable draught at jetty is 6.5 m. Vessels having 6.0 m to 6.5 m draught can take berth at port jetty. So, regular dredging of the above mentioned Pashur channel is necessary for importing necessary coal for the proposed Rampal power plant. According to the guidelines of the Department of Environment of Bangladesh is indicating that without detailed EIA dredging is not possible as the channel is the habitat of the endangered dolphin and it is situated inside the fragile ecosystem of the Sundarbans. Degradation of the natural environmental conditions due to continuous dredging can't be mitigated in any way. Its impacts would be an irreversible mitigation (IM).

Based on the data of the present investigation and conditions of the study areas like physico-chemical conditions of air, water and soil, floral and faunal status it can be concluded that the intertidal zones and the

**Loss of house due to riverbank erosion**

**Loss of house due to riverbank erosion**

**Industrialization beside Baniasanta bazar (at N 22°28'135" & E 89°35'038")**

**Established Silo beside the Sundarbans**

**Industrialization near Joymonirghol**

**Shipping activities**

**Erosion inside the Sundarbans**

**Deer inside the Sundarbans**

**Working in the field**

**Working inside the Sundarbans**

forest floor besides the river Pashur and its connected canals, creeks of the Sundarbans are being contaminated by the different type of pollutants of the different industries and industry related shipping activities. According to Islam (1982) and Islam (1997), Karim (1988), Hussain and Acharya (1994), Nazrul-Islam (1995), Jahan *et al*. (2000), IUCN (2001), Chowdhury (2003) and Hossain (2014) this areas were free from different type of pollutions. Floral and faunal status indicate that population and diversity of some primary producers, consumers, aquatic animals and plants, and their habitats have already been affected by the pollutants of rapid industrializations besides the Sundarbans. It is a natural habit of crocodile to prepare their hatchling house besides the rivers, canals and creeks during the month of April-May (IUCN, 2001). But due to pollution of water and soil besides the river, canals and creeks crocodiles may not be able to prepare their hatchling house in these areas to lay and hatch their eggs. As a result, crocodile may migrate from their own habitats and face territory conflict and ultimately crocodile's population would be affected. Similarly due to loss of habitat may tigers migrate from the affected parts of the Sundarbans and face territory conflict and may lose their natural breeding capacity. Ultimately, the population of tiger would be decreased and it may become a critically endangered species.

Regeneration of the Sundri trees; population, habit and habitats of mudskippers, mud crabs, snails, monitor lizards, intertidal zone birds (world endangered bird 'Masked finfoot'), common birds, fishing cat, otter, dolphins, crocodile, deer, wild boar and tigers are being affected due to continuous increasing of industrial pollution.

So industrial pollution is a matter to be concerned and long term monitoring and research are necessary to find out the detail information on the long term impact of industrial pollution and self recovery capacity of ecosystem of the Sundarbans. Similarly the rules and regulations of international conventions like Ramsar, UNESCO Natural Heritage Site, Convention of Biological Diversity (DoE 2010), etc. and guideline of MoEF (2010) must be implemented properly and a national and international commitment is necessary to stop all kinds of activities which may create this type of the problem for the fragile ecosystem of the Sundarbans.

Sattar (2010a) described on the emission level of different toxic gases and heavy metals of coal fired power plant. Human health hazards and possible impact on the Sundarbans due to coal-fired power plant have also been discussed by Sattar (2010b). Chowdhury (2017) mentioned the wind flow is indicating that the total study area, i.e., Rampal, Mongla and the Sundarbans will be affected by the toxic gases and ashes of the coal based power plant in different seasons; especially the Sundarbans will be affected during pick tourism period in the month of December to February. It is a matter to be concerned when the Sundarbans reserve forest is already facing threats from natural calamity, deforestation, rise in salinity and extinction of many species mainly due to human carelessness, ignorance and lack of implementation of laws, poaching and illegal wildlife trade (Mannan 2010; Chowdhury 2011; and Hossain 2014). Study of Chowdhury and Akber (2015) on the impacts of oil spill on the Sundarbans indicates that sink of coal, oil and industrial raw materials loaded ship created some problems for the biodiversity and ecological conditions of the Sundarbans. Kingston (2002) addressed the Long-term environmental impact of oil spills.

Environmental Impact Assessment (EIA) of physical, biological, social and economic environment of the Sundarbans and the surrounding areas indicate that the impacts of industrialization are negative and irreversible (-39) which can't be mitigated in any way. It is indicating that climate, topography, land use

pattern, air and water quality, floral and faunal diversity, aquatic ecosystems and capture fisheries of the Sundarbans and the surrounding areas will be affected permanently due to continuous industrialization on the periphery of the Sundarbans and proposed coal fired power plant. Increasing of river erosion, noise pollution and health hazards, loss of culture fisheries, health hazards, and destruction of agriculture will be happened due to unplanned industrialization. These problems may be reversible after long mitigation process except agriculture. But all reversible mitigations are negative (total no. is -58). Mitigation of agricultural loss will be very difficult and many people will become land less. Urbanization, development of markets / bazaars, transportation and industrialization will be developed which may be sustainable but mitigation must be ensured. The total no. of sustainable mitigation is only +13 which indicates that the study area (Periphery of the Sundarbans) is not suitable for industrialization and urbanization (Table 7). Only electrification in the rural area and very few job, and localized business facilities will be increased by establishing the industries and coal fired power plant. The benefits / facilities of industrialization on the periphery and proposed coal fired power plant of Rampal is poor (S +24) than that of negative impacts.

So environmentally, physically, socially and economically the periphery areas of the Sundarbans are not suitable to establish different type industries including coal based power plant. On the basis of IECs and EIA, industrialization on the periphery of the Sundarbans will be act as "to add insult to injure" on the Sundarbans areas and its fragile ecosystems, flora and faunal diversity. A long term research and intensive monitoring must be done to find out the detail information on the long term impact of industrialization on the biodiversity

**Table 7: Environmental Impact Assessment Matrix for industrialization on the periphery of the Sundarbans**

| IECs | Present Amount/Frequency | Industrial Impact | Impact Type | Impact Rating |
|---|---|---|---|---|
| **A. Physical Environment** | | | | |
| Climate: | Mean temperature varies from 28.2 ±1.9˚C / 28.4 ±1.5˚C | Will be increased. | IR | -3 |
| Temp | Annual mean 268 mm. | May slightly decrease. | IR | -1 |
| Rainfall | Highly disturbed in and around the Sundarbans areas. | May be highly disturbed in all areas. | IR | -5 |
| Topography | | | | |
| Land Use | Agricultural land use dominated with rural set up. | Changed into industrial and unplanned urban land use. | IR | -5 |
| Flooding / water logging Hazard | Low in some parts of Rampal. | Flood hazard will be increased due to earthen filling for new construction. | RM | -3 |
| River Erosion | Common in the Sundarbans, Mongla and Rampal. | Increase river erosion for movement of raw materials loaded cargoes. | RM | -6 |
| Water Pollution | Low | Will be increased due to discharge of effluents, leaching of coal, oil spills and dumping of waste. | RM | -5 |
| Air Pollution | Very poor | Air pollution will be increased by increasing SPM, oxides, hydrides and nitrides gases of carbon, sulfur and nitrogen. | IR | -2 |
| Noise Pollution | Low | Moderate | RM | -3 |

**Table 7 (Cont.)**

| IECs | Present Amount/Frequency | Industrial Impact | Impact Type | Impact Rating |
|---|---|---|---|---|
| **B. Biological Environment** | | | | |
| Habitat | About 80% habitats for flora and fauna in the Sundarbans. | Reduced habitats of flora and fauna. | IR | -5 |
| Flora | Among the existing species some are decreasing due to different hazards. | May endanger and extinct of some natural floral species in the Sundarbans, Mongla and Rampal areas. | IR | -6 |
| Wildlife | 56 species (5 endangered) of the project area. | More wildlife will be endangered and extinct in and around the Sundarbans. | IR | -7 |
| | Capture Fisheries Meet the 40-45% of fish demand. | Reduced production for increasing pollution in the rivers of Sundarbans and other natural water bodies. | IR | -5 |
| | Culture Fisheries Meet the 55-60% of fish demand. | Reduced production for loss of eggs and fish fries. | RM | -4 |
| Agriculture | Covered by 60% land area. | Reduced area. | RM | -5 |
| **C. Social Environment** | | | | |
| Human Settlement | 30-40% area covered by settlement. | Decrease human settlement due to land acquisition. | RM | -4 |
| Population of land less | Poor no. | Population of land less will be increased. | RM | -4 |
| Status of husband less Women | Poor no. | No. of husband less women will be increased. | RM | -3 |
| Electricity Facility | Absent in some villages. | Electricity facility will be available in all villages. | S | +8 |
| Health hazards | Poor in the study areas except salinity. | Health hazards will be increased by increasing air and water pollution. | RM | -4 |
| Human Diseases | Prevalence of diarrhea, skin diseases, worm infection and anemia. | Lung and pharyngeal diseases, air and water borne diseases will be increased. | RM | -3 |
| Parasitic Diseases | Dengue, malaria and other parasitic diseases are uncommon. | May increase the parasitic diseases. | RM | -1 |
| **D. Economic Environment** | | | | |
| Urbanization | Rural area. | Semi urbanization will be developed. | SM | +4 |

**Table 7 (Cont.)**

| IECs | Present Amount/Frequency | Industrial Impact | Impact Type | Impact Rating |
|---|---|---|---|---|
| Industrialization | More than 300 industries | Increase industrialization and pollution will be increased. | SM | +4 |
| Employment: | Average 10 %. | May slightly increase. | S | +3 |
| Government sector | Average 10 %. | May moderately increase. | S | +6 |
| Industrial sector Business | Average 50 % people involved in business. | Business opportunity will increase. | S | +7 |
| Market and Bazars | Mainly Rampal Bazar; Mongla Port Market and Foylahat. | Increased numbers of markets/ bazars without sanitation condition. | SM | +5 |
| Tourism | Medium. | Tourism will be decreased inside the Sundarbans due to loss of ecosystem and biodiversity of the Sundarbans. | RM | -4 |
| Shipping | Medium | Will increase | RM | -5 |

**Note:** S - Sustainable, SM - Sustainable with Mitigation, RM - Reversible with Mitigation, IR - Irreversible.

and ecological conditions of the Sundarbans before introducing the new industries and coal based power plant around the Sundarbans. Otherwise the fragile ecosystem of the Sundarbans including its buffer zone would be threatened by the pollutants of the industrialization.

## 4. Conclusion

- The study concluded that the present condition of Sundarbans and its surrounding area has reflected a sign of threatened environment.
- The Sundarbans is a magnificent and unique ecosystem and largest remaining mangrove forest in the world, which are under threat from development.
- The Sundarbans is the sole protector of cyclone and storms, generator of livelihood for local people, wild attraction for tourist and a source of national economy.
- It has lost both floral and faunal diversity by the years. Tigers are disappeared, fishes lost their habitat, trees are affected with unknown diseases, other faunal diversity are also disappeared, erosion is concentrated along the Pashur River, people are being helpless and migrated their occupation
- Bangladesh is a developing country and it needs energy. Industrial development in this area has made revolutionary changes by increasing country's net production and also creating more job opportunity.
- Local people are being enchanted by the job opportunity offered from industrialization but it is not work well (According to the opinions of the local people). Only a few people are being benefitted by offering a low ranked job from different industries.
- These industries have also brought the curse for natural environment of this area by discharging waste, gases, hot water recklessly into river and surrounding water bodies.
- The existing industries are solely responsible for depletion of fish and other natural resources, increasing sedimentation in river as they continuously discharge the industrial waste, effluent, dry ash, etc. reported by local people.

- The "Silo" is a recent major example of industrial deterioration to environment.
- Moreover, the government is moving ahead with the 1320 MW coal fired power plant at the mouth of the Sundarbans in Rampal of Bagerhat, along the Poshur River.
- If coal based power plant operate, damage to Sundarbans is obvious. People who will work in plant will be at greater health risk, would cause a significant damage to aquatic life in rivers and canals network in the Sundarbans mentioned by the local communities (local govt. representatives, govt. officials, local political leaders, journalists, fisherman, farmers, businessman, foresters, civil societies, journalists, workers of the industries, religious leaders, general people, etc.) .
- The forest may can lose its recognition as world heritage site.
- So morale, 'development' and 'environment' cannot place side by side, development is needed for any country but not by cost for environment.

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## References

ADB. (2003). *Environmental assessment guidelines.* Asian Development Bank. 175pp.

Alongi, D.M. (2002). Present state and future of the world's mangrove forests. *Environmental Conservation,* 29(3), 331-49.

Ambasht, R.S. (1974). *Plant Ecology,* Students' Friends and Co., Varanasi, India. 261 pp.

APHA. (1989). *Standard methods for the examination of water and waste water*, American Public Health Association, Washington. 1125 pp.

Bhuiyan, A.M. (1983). Fresh water and brackish water pollution in Bangladesh. *F.I.B.*, 1(3): 1-32.

Biswas, S.R., Choudhury, J.K., Nishat, A. and Rahman, M. M. (2007). Do invasive Plants threaten the Sundarbans Mangrove forest of Bangladesh? *Forest Ecology and Management,* 245(1-3), 1-9.

CEGIS. (2013). *Final report on environmental impact assessment of 2x (500-660) mw coal based thermal power plant to be constructed at the location of khulna*. Center for Environmental and Geographic Information Services, Ministry of Water Resources, Bangladesh. 500pp.

Chowdhury, A. H. and Zaman, M. (2001). Physico-chemical characteristics and phytoplankton abundance of a water body polluted by oil-grease. *Bangladesh J. Life. Sci.,* 13(1&2), 197-203.

Chowdhury, A.H. (2003). Glimpses of flora and fauna of the Sundarbans. *Proceedings of the National Seminar on The Sundarbans, the Largest Mangrove Forest on the Earth: A World Heritage Site*, (25-26 June 2003), Khulna University, Bangladesh.

Chowdhury, A.H. (2009). Impact of climate change on the rivers of Sundarbans. *Proceedings of the Conference on Climate change and Bangladesh Development Strategy: Domestic Policy and International Cooperation*, (2 January 2009), Organized by BAPA, Dhaka, Bangladesh.

Chowdhury, A.H. (2011). Environmental threats on the plant resources of the Sundarbans-the World Heritage Site of Bangladesh (ICAER / O / 103). *Proceedings of International Conference on Advances in Ecological Research,* (19-21 December, 2011) M Ganga Singh University, Bikaner 334 001 India.

Chowdhury, A.H. and Akber, M.A. (2015). Study of Impacts of oil spill on the Sundarbans mangrove forest of Bangladesh. *J. Asiat. Soci. Bangladesh Sci.*, 41(1), 75-94.

Chowdhury, A.H. and Zaman, M. (2002). Impact of power plants effluent on the zooplankton. In: *Proc. Conf. Industry & Environment*, 28-30, Dec. 1999 in Karad, India (Ed. R. K Trivedy). 201-207.

Chowdhury, Abdullah Harun (2012). The Sundarbans–a ramsar site and the prime source of livelihood (ICAER / O / 103). *Proceedings of Regional Seminar on Wetlands, Recreation and Ecotourism* (21-23 March 2012), Khajuraho, (MP) India.

DoE. (1997). *EIA guidelines for industries by department of environment*, Ministry of Environment and Forest, Government of the People's Republic of Bangladesh.

DoE. (2010). *Fourth National report to the convention on biological diversity biodiversity*, Deparment of environment, Ministry of environment and forests, Government of the people's republic of Bangladesh.

Edmondson, W.T. (Ed.). (1966). *Fresh water Biology*, John Wiley and Sons. INS. P 1-1248.

FAO. (2007). *The World's Mangroves 1980-2005*, Rome: FAO.

FPCO. (1992). *Guidelines for Environmental Impact Assessment (EIA)*, Flood plan coordination organization, Ministry of Water Resources, Government of the people's republic of Bangladesh.

Gautam, A. (1990). *Ecology and Pollution of Mountain Water*. Ashish Publ. House, New Delhi, India. 209.

Giri, C., Pengra, B. , Zhu, Z., Singh, A. and Tieszen, L.L. (2007). Monitoring mangrove forest dynamics of the Sundarbans in Bangladesh and India using multi-temporal satellite data from 1973 to 2000. *Estuarine, Coastal and Shelf Science,* 73(1-2), 91–100.

Hoshmand, A.R. (1998). *Statistical methods for environmental and agricultural sciences,* CRR Press LLC, New York, USA. 439.

Hossain, G.M. (2014). *Ecosystem health status assessment of the Sundarbans mangrove forest in Bangladesh*, Ph. D. thesis (unpubl.) Dept. of Botany, Jahangirnagar University, Savar, Dhaka.

Hossain, M.Z. and Chowdhury, A.H. (2008). Phytoplankton abundance in relation to physico-chemical conditions of the Sundarbans estuary. *J. Asiat. Soci. Bangladesh Sci.,* 34(2), 103-112.

Hussain, Z and G. Acharya. (1994). *Mangrove of the Sundarbans, Volume 2: Bangladesh*. IUCN, Bangkok, Thailand. 180.

Islam, A.K.M.N. (1973). The algal flora of Sundarbans Mangrove forest. *Bangladesh J. Bot*. 2(2): 11-36.

Islam, A.K.M.N. (1974). Study on the zooplankton of Sundarbans, Bangladesh. *Bangladesh J. Zool*., 2(2), 112-125.

Islam, A.K.M.N. (1982). Physiochemical properties of soils of Sundarbans Mangrove Forest. *Proceedings of the Second National conference on forests*, Dhaka, 50-52.

Islam, G.M.J. (1997). *Reports on the Malacofauna of the Sundarbans*. M.Sc. Thesis (unpubl.). Dept. of Zoology, University of Rajshahi, Bangladesh.

IUCN. (2001). *The Bangladesh Sundarbans: A Photoreal Sojourn*. IUCN Bangladesh country office Dhaka, Bangladesh. 186.

Jackson, M.L. (1973). *Soil Chemical Analysis*, Prentice-Hall of India (Pvt.) Ltd, New Delhi, India.

Jahan, M.S., Islam, G.M.J. and Rahman, M.R. (2000). Molluscan biodiversity of Sundarbans, Bangladesh. *Proceeding of the National Seminar on Coastal Environment and Energy Resources in Bangladesh*, Organized by Environmental Sci. Discipline, Khulna University, Bangladesh 8-9 Dec. 1998.

Jayaraman, K., Easa, P.S. and Jayson, E.A. (1998). *Evaluation of methods for estimating the abundance of herbivores in the forests of Kerala.* Kerala Forest Research Institute, Peechi, Thrissur, India. 47.

Karim, A. (1998). *Enironmental factors and the distribution of mangroves in Sundarbans with special reference to Heritera fomes.* Buch-Ham. Ph.D. Thesis (unpubl.) University of Calcutta.

Kingston, P.F. (2002). Long-Term Environmental Impact of Oil Spills. *Spill Science and Technology Bulletin,* 7(02), 53–61.

Lewis, R.R. (1983). Impact of Oil Spills on Mangrove Forests. In *Biology and Ecology of Mangrovves,* (Ed. H. J. Teas. and W. Junk). 171-83. The Hague.

Mannan, M.A. (2010). *Impact of environmental hazards on the plant diversity of the Sundarbans Satkhira range*. Ph.D. Thesis (unpubl.), Dept. Bot., Jahangirnagar University, Dhaka, Bangladesh. 157.

Mannan, M.A., Rahman M.M. and Chowdhury, A.H. (2012). Plant population of Satkhira range of the Sundarban in relation to its physico-chemical conditions of soil. *Jahan. Univ. J. Biol. Sci.* 1(2), 17-24.

Ministry of Environment and Forests. (2010). *Technical EIA Guidance Manual for Thermal Power Plants*. IL&FS Ecosmart Ltd., Government of India. 269.

Mishra, S.N., Swarup, R. and Jauhari, V.P. (1992). *Encyclopaedia of ecology, environment and pollution control. Environmental Air and Water Analysis*, 17. Ashish Publ. House, New Delhi, India.

Nazrul-Islam, A.K.M. (1995). Ecological conditions and species diversity in Sundarban mangrove forest community, Bangladesh M.A. Khan and I.A. Unger(eds.). Biology of salt tolerant plants 294-305 Book Grafers. 6BE International Drive Chelsea, Michigan. USA.

Page, A.L., Miller, R.H. and Keeney, D.R. (1982). *Methods of Soil Analysis (Part-2)*, American Society of Agronomy, Madison, Wisconsin, USA.

Pastakia, C.M.R. and Jensen, A. (1998). The rapid impact assessment matrix (RIAM) for EIA. *Environ Impact Asses Rev (Elsevier)*, 18, 461- 482.

Rahaman, S.M.B., Sarder, L., Rahaman, M.S., Ghosh, A.K., Biswas, S.K., Siraj, S.M.S., Huq, K.A., Hasanuzzaman, A.F.M. and Islam, S.S. (2013). Nutrient dynamics in the Sundarbans mangrove estuarine system of Bangladesh under different weather and tidal cycles. *Ecological Processes,* 2(29), 1-13.

Rahman, F., Rahman, M.T., Rahman, M.S. and Ahmad, J.U. (2014). Organic Production of Koromjol, Passur River System of the Sundarbans, Bangladesh. *Asian J. of Water, Env. and Pollution,* 11(1), 95-103.

Rahman, M.M., Rahman, M.T., Rahaman, M.S., Rahman, F., Ahmad, J.U., Shakera B. and Halim, M.A. (2013). Water quality of the world's largest mangrove forest. *Canadian Chem. Transactions,* 1(2), 141- 156.

Rahman, M.S., Ara, H. and Islam, M.M. (2006). Determination of the total hydrocarbon (Oil) concentrations in the shipping channel inside the Sundarbans Mangrove forest of Bangladesh. *KU Stud.* (Special issue), 73-77.

Sarkar, P.K. (2012) (14 March). Fighting for the survival of the Sundarbans. *The Daily Star*, Bangladesh.

Sattar, M.A. (2010a). Impact of coal-fired power plant on air pollution, climate changes and environmental degradation. *Bangladesh J. Environ. Sci.,* 19, 1-12.

Sattar, M.A. (2010b). Saving Sundarban for millions of years as world heritage. *Bangladesh J. Environ. Sci.,* 19, 13-24.

SWAMP (2007). *Standard Operating Procedures for Collecting Benthic Macroinvertebrate Samples and Associated Physical and Chemical Data for Ambient Bioassessments in California*, Surface Water Ambient Monitoring Program. California Department of Fish and Game. 1-45.

Tonapi, G.T. (1980). *Fresh Water Animals of India*. Oxford and IBH Pub. Co. India. 342.

Transeau, E.N. (1951). *Zygnemaceae,* Ohio State Uni. Press. Colu. USA. 1-327.

Trivedy, R.K. (1993). *River Pollution in India*. Ashish Publ. House, New Delhi, India. 294.

Uddin, M.S., de R. van Steveninck, E., Stuip, M. and Shah, M.A.R. (2013). Economic Valuation of Provisioning and Cultural Services of a Protected Mangrove Ecosystem: A Case Study on Sundarbans Reserve Forest, Bangladesh. *Ecosystem Services,* 5, 88–93.

Welch, P.S. (1948). *Limnological Methods*, McGraw Hill Book Company, New. York. 381.

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