

Coastal and Marine Pollution in Bangladesh: Pathways, Hotspots and Adaptation Strategies

Jatish Chandra Biswas, Md Mozammel Haque, Md Maniruzzaman, Sh Akhtar, and Naveen Kalra

ABSTRACT

Marine and coastal pollution is a global issue for human health and biodiversity. We have investigated pollution sources, flow patterns, hotspots, challenges, and adaptation policies in Bangladesh. Industries, ship breaking yards, sewage, tourism, and transboundary depositions are the main sources of pollutions. The Ganges, Padma, Jamuna, Brahmaputra and Meghna carry wastes to the Bay of Bengal. Pollution hotspots are Dhaka, Gazipur, Narshingdi, Narayanganj, Chittagong, Khulna, Mongla port and Sylhet city. Textile and dyeing industries discharge 12.7–13.5 million m³ waste waters annually and pollute 20% of fresh water. Ship breaking yards dump about 22.5 tons polychlorinated biphenyls in a year. More than 50% of the marine oil pollution comes from urban activities. Plastic wastes at 3000 t day⁻¹ and tourism are also contributing to the coastal pollution. Effluent releasing standards are not maintained, and thus higher concentrations of heavy metals are found with marine fishes. Use of heavy metal tolerant crops (rice: BRRI dhan47, potato: Cardinal, mustard: *Brassica napus*, flower: Marigold, vegetables: Cucumber, fibre: Kenaf, and so on), trap cropping, deep placement of fertilizers, integrated rice-fish-duck culture, etc can be adopted in polluted areas. There are laws for environmental issues, but coordination and financial capabilities does not warrant its effectiveness. Necessary steps are to be taken to improve infrastructure to ensure sanitation and benign discharge of industrial effluents. Systematic study on sources, fate and extent of current effluents dumping in water ways need to be assessed for wellbeing of aquatic life and human health.

Keywords: Industry, ship breaking yards, pollutants, crops, adaptation, policy.

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I. INTRODUCTION

Coastal zone is the area of flood, siltation, cyclone, tidal surge, and salinity in Bangladesh and is the habitat of about 50 million people. It can broadly be divided into eastern, central and western region or as exposed and interior coast. A total of 47201 sq km is coastal area of which 23935 sq km is exposed and 23266 sq km is interior categories [1]. Sea currents, web and tides and upstream fresh water flows play an important role for enriching and/or polluting these areas. There are nearly 230 rivers in Bangladesh that carry billions of tons of sediments into the Bay of Bengal. These sediments not only contain plant nutrients of unknown quantities, but also carry huge amounts of poisonous residues from agricultural chemicals, industrial residues, farm effluents, solid waste, sewage disposal etc. Rapid urbanization, deforestation and unplanned extraction of coastal resources are other avenues of pollutions.

Globally 10,000 million gallons of sewage, 3.25 million metric tons of oil, 10 billion tons of ballast water and millions of tons of solid waste are discharged into the marine environment annually [2]. More than 92% of

untreated wastes reach coastal water [3]. The scenarios are almost similar for developing countries. For example, more than 600,000 tons of N per year is released into the Indian Ocean, while 17 tons of mercury (Hg) and nearly 150 tons of cadmium (Cd) are discharged into the Caspian Sea [2]. In Bangladesh, textile and dyeing industry discharge 12.7–13.5 million m³ waste waters annually and pollute 20% of fresh water [4]. Maximum of raw sewage enter into sea and ocean water from developing countries including Bangladesh and India [2]. Pollutants from India, Nepal and China carry to the Bay of Bengal through Padma, Jamuna and Brahmaputra and deposited its certain part in coastal soils of Bangladesh.

In addition to land based pollutants, ship-breaking yard and oil spill from vessels and off shore platforms are the significant sea based ocean pollutants. In Bangladesh, heavy metal and oil spill pollution mainly take place from ship breaking industries and fishing trawlers [5]. Similar to other offshore power-plants, Chennai power plant of India releases tritium into the Bay of Bengal, which affects neighbouring countries deleteriously [6].

Among the pollutants, the effects of heavy metals, chemicals, persistent organic pollutants (POPs) and radioactive substances are considered as long termed and

deadly [7] because of their genotoxic and carcinogenic effects. Lead (Pb), Hg, Cd, arsenic (As), POPs, polycyclic aromatic hydrocarbons (PAHs) can be accumulated in soil [8] and thus impairing ecosystem and enter into food chain [9]. As a signatory of about 28 environmental treaties, conventions and protocols [10], [11], Bangladesh has to assess pollution impact to conserve biodiversity and to devise effective adaptation strategy against coastal pollution. Therefore, the objectives of this article were: to identify pollution of coastal and marine environment, to evaluate contributions of excess nutrient fluxes from agriculture, livestock and aquaculture, to identify various pathways of entering pollutants to the coastal and marine environments, and to identify adaptation strategies in agriculture and some policy implications for Bangladesh.

II. MATERIALS AND METHODS

Data were mostly collected from Bangladesh Bureau of Statistics [12]-[17], <https://www.thebangladesh.net/major-industries-of-bangladesh.html>. Collected data were analyzed and grouped for interpretations following Microsoft Office Excel 2007 and IDRISI3.2. Sources of pollutions, pathways

of movement and pollution hotspots have been delineated. Sectoral contributions of different pollution sources have been identified along with suggestions of adaptation strategies.

III. RESULTS AND DISCUSSIONS

The findings are discussed under following heads and sub-heads.

A. Sources of Pollution and Pathways

Various sources of pollutants, national and international, are depositing in the coastal zones of Bangladesh and finally to the sea. Most important sources of pollutants are industry including ship breaking yards, sewage and wastes of megacities and transboundary depositions (Fig. 1). The other avenues of coastal pollution are agrochemicals and POPs, deforestation, erosion, rapid urbanization, tourism, inappropriate or no solid waste management, extraction of coastal resources, land use change (e.g., rapid change for shrimp culture) and climate change.

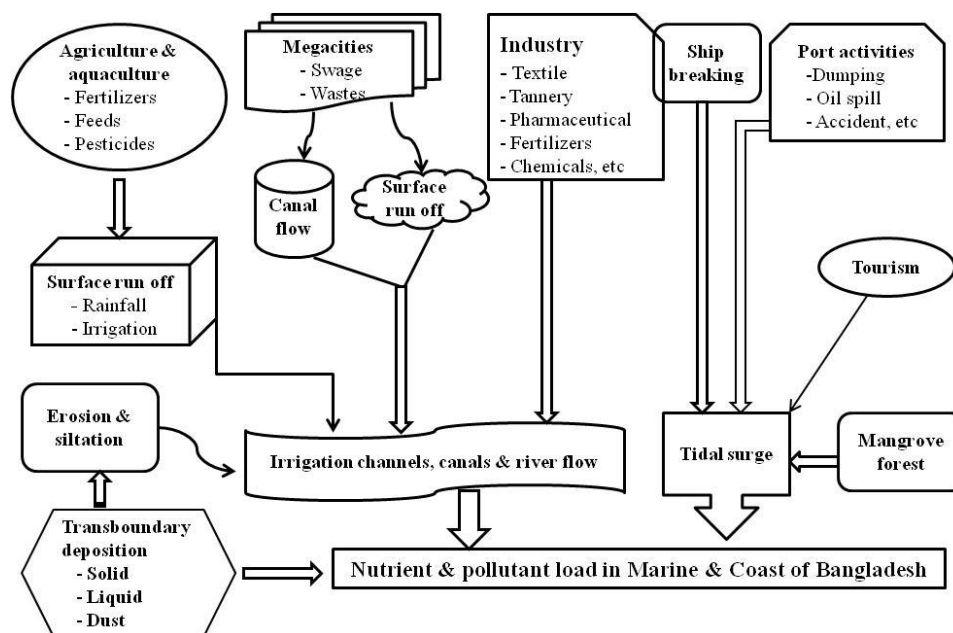


Fig. 1. Flow diagram showing possible movements of nutrients and pollutants towards marine and coastal zones of Bangladesh.

B. Hotspots of Pollution

Either solid, liquid or dust and semisolid pollutants are mixing with soil and water in different amounts and degrees from different sources and making a certain area(s) more polluted than the others depending on locations and distance from the sources and seasons. Major industrial zones are situated in Dhaka, Narayanganj, Gazipur, Chittagong, Khulna, Rajshahi and Bogra district (Fig. 2). Discharges from those industrial areas are mixing with soil and water bodies along with transboundary pollutants and thus making them hotspots of pollution having different degrees of toxicity depending on river flow and rainfall. Generalized pollution hotspots are shown in Table I.

TABLE I: POLLUTION HOTSPOTS IN BANGLADESH

Pollution type	Rivers	Hotspots
Water pollution	Padma, Ganges, Jamuna and Meghna	Nearby areas of river flow
	Buriganga, Shitalakhya, Turag and Balu	Dhaka and Narayanganj
	Karnafuli and Hlada	Chittagong city
	Kirtonkhola	Barisal city
	Surma	Sylhet city
Soil pollution	Moyuri, Rupsa and Bhoirab	Khulna city
	Rupsa and Passur	Mongla Port and Sundarbans
	Industrial polluted area	Chittagong coast Dhaka, Gazipur, Narshingdi and Narayanganj

Source: Adopted from BDP 2100 (2017).

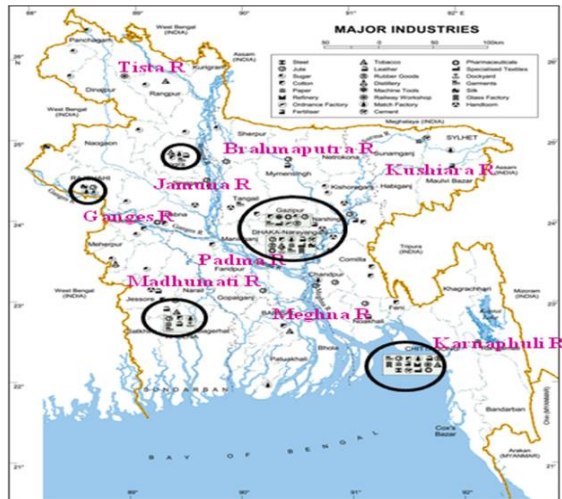


Fig. 2. Major industrial zone (in circles) and main rivers in Bangladesh (Adopted from <https://www.thebangladesh.net/major-industries-of-bangladesh.html>; Access on 18-6-2018).

C. Sectoral Pollutions

1. Crop agriculture

Consumptions of nitrogen (N), phosphorus (P) and potassium (K) fertilizers have increased from 1981 to 2016 [18], but yet farmers usually use imbalanced fertilizers doses for crop production [19]. Not much information is available on excess nutrient fluxes from crop sector in Bangladesh. In some cases, nutrient mining is on-going [20], while Zn and S depositions are taking place because of industrial development [21]. These indicate that plant nutrient over-enrichment is not a very common phenomenon in Bangladesh from crop sector. However, a portion of excess and unutilized fertilizers from agricultural lands might find their way into the Bay of Bengal. Rahman [22] reported that agriculture along with atmospheric deposition, power plants, industry, motor vehicle and distant sources might provide about 40% N to the coastal water. Atmospheric depositions in the Ganges Basin add $107.47\text{--}406.54 \mu\text{mol reactive N m}^{-2} \text{ d}^{-1}$ and $1.31\text{--}7.75 \mu\text{mol P m}^{-2} \text{ d}^{-1}$ [23]. These increased N and P levels in coastal water [24]–[26] are not only because of agricultural activities but also for fossil fuel related emission [27], [28].

2. Aquaculture

Shrimp culture is predominant in coastal areas of Bangladesh and farmers generally utilize variable amounts of nutrients and huge amounts of feeds for its production. These practices are responsible for excess nutrient loading and eutrophication in coastal areas [29]. Das et al [30] found about 109 ppm CaCO_3 , 0.53 ppm $\text{NH}_4^+\text{-N}$, 3.1% organic carbon, 7 ppm PO_4^-P and 5.6 ppm NO_3^-N in shrimp cultured pond surface water that decreased with distance from sources. They also reported higher organic matter and total N contents in sediments of cultured pond than adjacent similar fallow land.

3. Livestock and poultry

In Bangladesh, livestock populations were 181.08 million and in coastal region it was about 40.2 million during 2008 [12]. These imply that livestock excreta might not be an issue of coastal pollution. Most of the cattle and buffalo dungs are used as fuel (Fig. 3) and some portion is used in crop and fish culture. However, broiler and layer enterprises have flourished nearby Dhaka and Gazipur districts and

produced large amounts of wastes which are not properly handled. Some portion of poultry wastes is used in the rice field [31] and raising fish and the rest goes to open water and land sources. Final destination of such pollutants is not known yet; but it can be speculated that with plenty of rainfall in wet season certain portion of livestock pollutants might travel far distances than its sources of origin through Turag River to Buriganga to the Meghna River and finally to the Bay of Bengal.

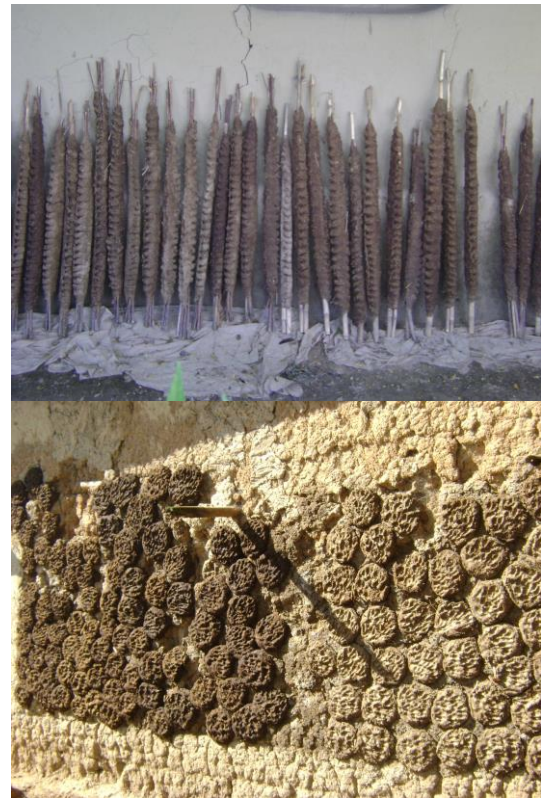


Fig. 3. Drying animal dung to be used as fuel (Photography: Jatish C. Biswas).

4. Use of pesticides

Pesticides are used in Bangladesh since 1957 but its peak use was in 2008 and then declining (Fig. 4). The presence of persistent organic pollutants (POPs) in fish and shrimp species of the Bay of Bengal and estuaries indicated some portion, about one fourth, pesticides reach the coast each year [32]. Since pesticide residues are transported long distances [33], it is believed that agrochemical pollutants from Nepal and India are washed down through shared rivers to the Bay of Bengal and thus influencing coastal and marine environments of Bangladesh.

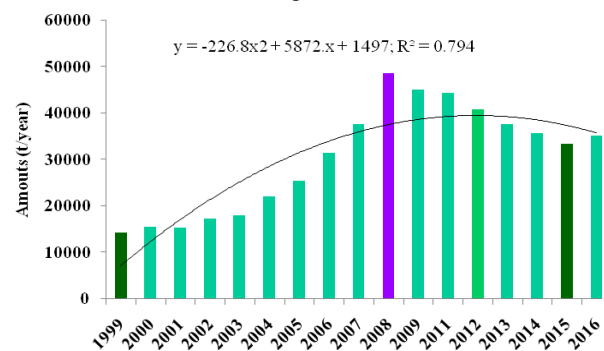


Fig. 4. Pesticide consumption in Bangladesh (BBS, 2017).

D. Industrial Wastes and Pollution

1. Land based pollution

Considering 1988-89 as base year, industrial development was rapid in Bangladesh during 2010 to 2013 (Fig. 5) and so does the dumping of industrial wastes with or without treatments. There are more than 8,542 industrials establishments [13] on the coastal zone of Bangladesh. Concentration of industries is the highest around Dhaka, Narayanganj, Ghorashal and Tongi that pollute Turag and Sitalayakha Rivers, almost pitch black water in dry season [14]. The destination of those polluted waters is the Bay of Bengal through Meghna River (Fig. 2).

The textile industries discharge about 40,000 m³ day⁻¹ waste water and pollution load of these industries is 26,000 kg day⁻¹ [34]. Ship breaking yards at Sitakunda, Chittagong releases 22.5 t yr⁻¹ polychlorinated biphenyls [35]. About 0.15 million t day⁻¹ crude wastes from tannery industries, 35.0 t day⁻¹ China clay from Karnaphuli Paper Mill (KPM), 4.0 t day⁻¹ fibres from Karnaphuli Rayon Mill (KRM) are dumped directly into river and thus enter into coastal and marine water [22]. It is also reported that 3.0 t yr⁻¹ Hg is dumped from KPM and KRM into coastal and marine waters of Bangladesh.

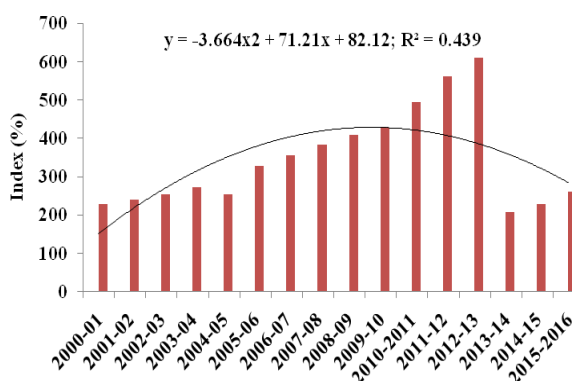


Fig. 5. Industrial growth in Bangladesh during 2000 to 2016 (BBS, 2017).

2. Plastic pollution

About 73,000 t day⁻¹ plastic wastes are moving towards Bay of Bengal from China, India Nepal and Bangladesh [15] through main rivers of Bangladesh. This is one of the biggest issues that not only pollute oceans and manipulate marine lives, but also block drainage systems in many areas. Bangladesh is producing about 3000 t day⁻¹ plastic wastes of which a small portion moves towards the sea. Out of 30 million t day⁻¹ plastic wastes of the world, 8 million tons finds its home in the seas through 10 rivers around the globe. This is really a terrible scenario for the blue world.

3. Sea based pollution

Sea based pollution mainly results from the crude oil transportation systems, such as sea cargo, ships and mechanized vessels, workshops, refinery handling loss, dumping of ballast and bilge waters etc. More than 2,500 t yr⁻¹ operational oil spills arise from the ships and land sources in Bangladesh [36]. Mongla port also contributes in pollution through the vessel discharge waste oil and oil spillage, sewage, and waste. Oil refinery releases about 50000 t yr⁻¹ of which significant portions enter into coastal water. Chittagong port also deals with 150 vessels, 40 oil tankers, 2500 registered vessels and hundreds of

unregistered mechanized river crafts [22] and thus pollutes water ways. Recent offshore hydrocarbon drilling operation in the economic zone of Bangladesh could be a factor of marine pollution, though not much reported.

Industrial wastes contain heavy metals that vary depending on seasons [37]. These heavy metals are accumulated in the body of aquatic lives beyond acceptable limits. For example, the concentrations of As, Cr, Hg, Se, Zn along with K, Ca, Mg, Fe, Ni, Cu, Pb, Sr and Rb in marine fish were much higher than the permissible limit of toxicity [32]. Heavy metals in marine sediment showed the prevalence of Fe>Zn>Ni>Cr>Pb>Cd [38]. Another study revealed higher concentration of heavy metals at 7 locations in and around Sundarban [39], [40], Karnaphuli estuary and its adjacent coastal areas [37]. These clearly indicate that we are polluting coastal zone beyond limit.

4. Domestic and municipal wastes and sewage sludge

Sewage of nearly 40 million people living in 19 Coastal districts directly or indirectly goes to the river water systems and eventually flows into the Bay of Bengal. Assuming 100 g day⁻¹ per person human waste is generated; the total quantities of waste produced in coastal districts would be about 4000 t day⁻¹. Even if 50% goes to coastal water, it will create a big demand for oxygen to decompose it.

5. Salinity intrusion and coastal habitat

Saline area is increasing in Bangladesh mostly because of sea level rise and reduced flow of fresh water from the upstream. In last nine years (2000-2009), salinity areas have increased by 3.5% in Bangladesh; but compared to 1973 the increase is 26.7% [16]. Generally, salinity increases by one part per trillion (ppt) after November towards inland [41] that diminishes depending on rainfall in April-May. Such increase in salinity changes ionic balances in soil and water and thus impair growth of sensitive organisms. The ionic prevalence in saline soils decreased in the order of Na⁺>Ca⁺⁺>Mg⁺⁺>K⁺. But in soils under prolonged brackish water regions, like shrimp cultivated areas, it decreased in the order of Na⁺>Mg⁺⁺>Ca⁺⁺>K⁺. Changes in the ionic prevalence order spoil nutrient uptake patterns by the crops, if grown resulting in poor or no yield. Besides, poor nutrient status and presence of toxic potential acid sulphate in some areas [16] makes this zone difficult to be productive.

6. Soil erosion and siltation

Erosion affects more than 1.1 billion hectares globally and redistributed 75 billion tons soils having variable organic matter and other nutrients. About one billion tons of sediments are carried annually by water of the Ganges-Brahmaputra-Meghna river system and its larger share goes to the Bay of Bengal [42]. The extensive rate of erosion in Hatiya, Sandwip, Bhola and Noakhali for the last few decades must have altered the bottom condition of the habitat [43] that deserves investigation. Deposition on plain lands and erosion of river banks creates slowly moving solid bed reactor for organic carbon processing and such deposition can traps about 10–40% particulate organic matter of the annual load [44]. Thus, erosion of soils and its sedimentation to other areas not only can carry remarkable amounts of nutrients but also other toxic element from upstream areas to pollute Bay of Bengal.

7. Cyclone, tsunami, and storm surges

At least 70 major cyclones have hit the coastal belt of Bangladesh in the last 200 years. The coasts of Noakhali-Chittagong are the most vulnerable receiving 40% of the cyclones during last 35 years, which is in increasing trends [45]. The recent Tsunami episodes in the Asia-Pacific region have added new threats to the coastal region of Bangladesh. Apart from the loss of lives, canals, creeks are filled with sand, debris, saline water, etc. due to cyclone that destroy ecological habitat of coastal Bangladesh depending on intensities of natural calamities.

8. Deforestation

Deforestation is widespread in Bangladesh because of fuel crisis, human settlement, salt production, shrimp farming, etc. For example, the Chokoria Sundarban has totally been cut down [46], [47]. Recently, Rohingya flux has destroyed some forest areas in Teknaf, Chittagong. In hilly areas, land slide takes place almost every year. Such activities intensify coastal and marine pollution, especially through enhanced soil erosion.

9. Coastal tourism

The coastal and marine areas of Bangladesh possess vast potential for tourism. Among the coastal and marine zones, Khulna, Kuakata of Patuakhali district, Patenga beach of Chittagong, Cox's Bazar and St. Martin's island are the major tourist spots. The visitors include both domestic and foreigners and government earns a significant amount of revenues from this sector. However, this tourism also contributes to coastal and marine pollution through solid and liquid wastes (Fig. 6).

E. Adaptation Strategy

Bangladesh through her constitution 1972, amended in 2011 under article 18A, has granted protection and improvement of natural resources, biodiversity, wetlands, forest and wild life for future generations indicating that there are initiatives in terms adaptation and mitigation; the

latter being demands collective efforts of global communities. Coastline stabilization is an enormous and costly task. Moreover, land in coastal Bangladesh is used for various purposes like crop agriculture, aquaculture, forestry, salt production, ship-breaking yards, ports, industries, human settlements, and wetlands. So, adaptation strategies vary depending on importance of enterprise and capacity of the country. There are different mitigation and adaptation strategies that can be adopted by a country depending on its capacity. Considering the problems of coastal and marine water pollution, Bangladesh has adopted certain engineering and non-engineering measures such as strengthening of the coastline at economically and commercially important sites, land reclamation through construction of cross dams and establishment of a coastal green belt along the coastline [48]. Generalized adaptation strategies are shown in Table II.

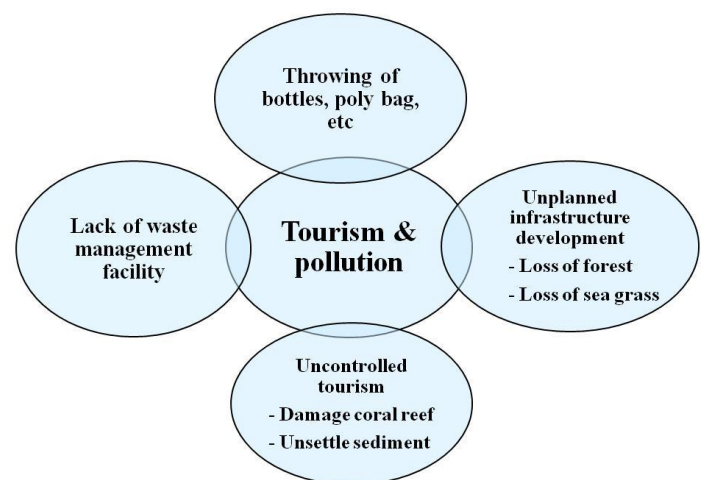


Fig. 6. Tourism and coastal pollution relationship.

TABLE II: GENERALIZED ON-FARM AND STRATEGIC ADAPTATIONS AND POLICY ISSUES FOR COASTAL AND MARINE ECO-SYSTEMS

On-Farm adaptation	Strategic adaptation	Policy and legislative
1. Efficient nutrient & manure management - Soil test based fertilizer dose - Liming in acid soils - Use of manures, saw dust, straw, biochar, rice husk - Use of bio-organic fertilizer - Zn fertilizer reduces Cd uptake	1. Wetland restoration/ creation 2. Land reclamation - Eco-engineering 3. Biodiversity conservation - protected marsh land 4. Establishment of riparian buffers 5. Water and river management - Recycle of industrial wastewater - Constructed wetlands Recycling of industrial, municipal and household wastes	1. Land use planning for industry and agriculture - Trade and price policy - Fiscal policy and budget allocation 2. Law enforcement - Legislation and institutional set ups 3. Monitoring and evaluation 4. International cooperation 5. Ban on single use plastic materials 6. Extended producer responsibility Human, industrial and governance capacity development 9. Ensuring stakeholder participation
2. Phytoremediation of heavy metals - Use of water hyacinth - Trap cropping followed by burning - <i>Solanum nigrum</i> , grasses, etc - Cultivation of resistant crops 3. Ecological production - Recycling of kitchen and agricultural wastes - Floating agriculture 4. Community afforestation 5. Managing soil erosion in hilly areas - Terracing - Contour planting - Fruit gardening		

F. Case Studies for Adaptation

1. Agricultural adaptation

Selection of crop varieties is the prime requirement to be grown in coastal areas. A variety that can withstand water pressure in wet season having some tolerance to salinity and

toxic elements are highly desirable; while for dry season cropping, a variety of high salt and heavy metal toxicity tolerance would be of best choice. From one of our study it was found that grain yield of BRR1 dhan47, BRR1 dhan53 are less affected by soil arsenic levels than other tested

varieties. Similarly, there are other varieties that can be selected for growing in polluted soils as main or trap crops (Table III).

TABLE III: CROP VARIETIES WITH TOLERANCE/RESISTANCE TO HEAVY METAL TOXICITY AND/OR EXCLUSION MECHANISM

Name of crop	Cultivar/variety	Acts against	Reference
Rice	BRR1 dhan47, BRR1 dhan53	As	Iqbal et al. [49]
Sorghum			Jadia and Fulekar [50]
Potato	Cardinal, Diamant, Jam Alu	As	Haque et al. [51]
Mustard	Indian mustard (<i>Brassica Juncea</i>)	Multiple elements (Cd, Cr, Cu, Ni, Pb), Se	Ahmad [52] Koptsik [53]
	<i>Brassica napus</i>	Multiple elements (Cd, Pb)	Kotrba et al. [54] Tang et al. [55]
Flower	Marigold	Cr, Pd, Cu	Ahmad [52]
Vegetables	Cucumber, bitter gourd	Pb, Cd	Zhou et al. [56]
	Sponge gourd	Cd	Lin et al. [57]
Fibre crop	Kenaf (<i>Hibiscus cannabinus</i> L.)		Uddin et al. [58]
	<i>Mesta</i> (<i>Hibiscus sabdariffa</i> L.) <i>Lepchloa fusca</i>	Pb Cr	
Trap crop/ grass	Maize		Ashraf et al. [59] Wuana and Okieimen [60]
	Sesame	Cr, Cu, Pb, Ni, Cd	Gupta and Sinha [61]

Sometimes surface applied fertilizers are lost with tidal flow, which generally occur twice a day during wet season in Bangladesh. Fertilizer deep placement (FDP) is a good technique for such situations. The FDP involves the placement of 1–3 grams of fertilizer super granules at a soil depth of 7–10 cm shortly after rice is transplanted. The benefits could be 20% increase in crop yield, about 40% decrease in N loss and 35% less fertilizer need [62]. Islam et al. [63] also reported that deep placement of NPK briquettes showed no residual effect on soil chemical properties. Use of organic materials, especially kitchen wastes and livestock manures can be easily recycled through biogas production and use of bio-slurry for crop production. Soil test based fertilizer management can minimize buildup of nutrients [64].

An integrated approach of agriculture, livestock and fisheries can improve total production environment in coastal areas. For example, use of crop residues, kitchen waste and livestock manure can be utilized for bio-gas production, the fuel for cooking, and bio-slurry for crop production. Shrimp farming could enhance coastal water and soil quality through efficient use of nutrients in rice-fish integrated culture. Integrated pest management in rice-fish culture is another avenue of reducing pesticide use in agriculture [65]. However, attention should be paid to preserve snail population which are generally used as feed for the shrimps.

Soil-less agriculture or hydroponics is an indigenous practice of sustainable wetland utilization in Gopalganj, Pirojpur and Barisal districts. People utilize locally available straw, water hyacinths and various aquatic plants for making floating islands, locally known as geto, bed or dhap [66], for growing crops, seedlings, and vegetables. A properly

designed hydroponic system needs much less water and nutrients than conventional soil-based agriculture, as the nutrients are recycled. This advantage is important as it can help in reducing the pollution of water bodies from runoff nutrients from agricultural land. In addition, an enormous amount of compost material is produced, which can be used to increase organic content of the soil for land-based agriculture systems.

2. Wetland restoration/creation

The government of Bangladesh recognized the need for protection of the coastal areas and to create and conserve coastal wetlands. So far 5,107 kilometres of embankments to form 123 polders and to protect 1.5 million hectares has been achieved. Coastal afforestation is on-going to protect the coast from cyclones and foreshore erosion. Land reclamation through construction of cross dams is being adopted in Bangladesh. In order to reduce land losses through erosion, the government constructed a few cross dams to facilitate enhanced land accretion. More than 50,000 hectares of new land have been reclaimed [48]. Restoration of wetlands is effective in controlling water pollution through phyto-accumulation.

3. Biodiversity conservation

Tidal salt-water wetlands constitute about 25% of the land area of the country. Bangladesh has taken some protective measures to protect lives and resources with massive coastal afforestation, making shelter houses and freshwater reservoirs. Bangladesh has identified protected areas in the form of national parks, game reserves, wildlife and fish sanctuaries, World Heritage sites, Ramsar sites, marine reserves, and ecologically critical areas [17]. Proper coordination and law enforcement are the prime requirement to conserve biodiversity in Bangladesh.

4. Riparian buffers- establishing treatment to stream

Bangladesh is the lower riparian of three major river systems, the Ganges-Padma, the Brahmaputra-Jamuna and the Meghna (GBM) and constitutes about 7% of the combined catchment area. Over 92% of the annual runoff generated in the GBM catchment areas flows through Bangladesh [10]. The major riparian zone is established in the south-west part, the mangrove forest Sundarban, and natural and artificial mangrove forest in Noakhali, Chittagong and Coxes bazaar areas. Sediment management is still the most challenging task for Bangladesh. International cooperation is highly needed to accomplish such gigantic task.

5. Water and river management

River conservation program have direct linkage with coastal habitat conservation. However, very little efforts have been made at linking river conservation program with coastal conservation activities. A comprehensive approach to river conservation in terms of land use planning, scientific urban management, industrial setting, transportation of chemicals, and discharge of effluents needs to be adopted. In future, without industrial wastewater recycling, there will be unsustainable loads on water environment impacting ecosystems very severely [67].

6. Land pollution minimization

It is necessary to organize ship recycling industry by introducing systems and technology improvements and also by providing training to the workers. Capacity building of

the entrepreneurs of ship recycling industry is needed. Necessary steps are to be taken to improve infrastructure in recycling industry areas to ensure sanitation, waste management, and benign discharge of effluents.

7. Nourishing mangrove forest

The mangroves forest, highly productive ecosystems, provides a buffer between land and shallow sea, preventing erosion of the land and saves life during cyclones or storm surges. It can facilitate sedimentation process and minimize wave stress [68]. Mangrove swamps are also the natural sewage treatment plants. So, its nourishment can help in mitigation of coastal pollution of Bangladesh.

G. Research and Science and Technology Need

Some of the ideas for research are:

- Influence of chemical run-off from inorganic fertilizer and pesticides to water bodies including bio-agents. Physico-chemical properties of coastal water and their biotic influence on eco-system need to be studied.
- Use of satellite based remote sensing technologies.
- Promote, develop, and support initiatives on technology development and use which supports friendly sustainable extraction of natural resources.

IV. CONCLUSIONS

Rapid industrial development and discharge of effluents into rivers and canals without treatments along with domestic and municipal wastes are degrading coastal and marine environments. Many sources and pathways are responsible for coastal and marine pollution. Pollution hotspots are industrial zone based at Dhaka, Narayanganj, Gazipur, Chittagong, Khulna, Rajshahi and Bogra. Big and small rivers carry pollutants to the Bay of Bengal. There are some avenues of agricultural adaptation that need to be adopted. Some legislation should be undertaken to retard degradation. The environmental problems cannot be solved in a short period of time. They need continuous efforts and resources to revert the processes. Control and/or prevention of coastal and marine pollutions are a vast task and costly affair. So, national and international policy and participation is necessary to overcome this problem.

Land-based pollution should be minimized through imposing proper regulations and recycling of waste materials. Sources of harmful chemicals in the Bay of Bengal water need to be identified and proper awareness development on toxic effects of chemicals can alleviate pollution hazards in coastal areas. Systematic study on the sources, fate, and extent of current industrial/agricultural/municipal effluents dumping in the water body and assessment of overall impacts on aquatic life as well as human health deserve special attention. Research on land and water productivity improvement is more than imperative not only to improve total land productivity but also to sustain resource productivity for the future. Research on bioaccumulation of pollutants with estuarine and brackish water fisheries would safeguard human health. Ships and other transports should not be allowed to dispose their pollutants in the coast. In combating surface water pollution, the Government needs to introduce land zoning

for industries, strengthening water quality monitoring, enforcing environment conservation act and rules, and introduce waste reception and treatment facilities in the ports. Most of the pollution studies on the Bay of Bengal are Chittagong coast based, which do not represent the Bay of Bengal as a whole. Detailed study on entire Bangladesh coast can give a clear picture on coastal and marine pollution in Bangladesh and thus proper adaptation strategies mitigation can be delineated.

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CONFLICT OF INTEREST

No conflict of interests among the authors.

AUTHORSHIP CONTRIBUTION STATEMENT

All authors were responsible for data collection and analysis. Drafting was done by Jatish Chandra Biswas and editing was done by Naveen Kalra.

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