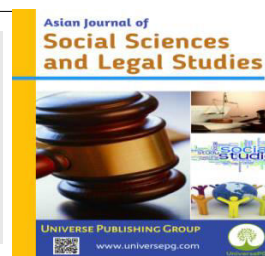




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## Marine Pollution and Sustainable Blue Economy in the Bay of Bengal: Challenges and Opportunities for Bangladesh

Md. Zillur Rahman\* 

Bangladesh University of Professionals, Mirpur, Dhaka, Bangladesh

\*Correspondence: [shomoy119@yahoo.com](mailto:shomoy119@yahoo.com) (Md. Zillur Rahman, MPhil Researcher, Bangladesh University of Professionals, Mirpur, Dhaka, Bangladesh).

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### Abstract

The Bay of Bengal (BoB) is a vital natural resource supporting the blue economy of Bangladesh, embracing fisheries, terminals, shipbuilding /shipbreaking, sea tourism and ecosystem services. Nevertheless, marine pollution is on the rise from land- and sea-based sources in the region. The objective of this paper is to synthesize recent research about the major vectors that deliver pollution to oceans and create deteriorating conditions for marine life including some commercial fishing operators as well as any proven beneficial ocean fertilization including key vectors plastics and microplastics, oil and chemical contaminants, nutrient loadings and heavy metals. It evaluates environmental and socio-economic consequences, governance instruments constraints or opportunities for pollution mitigation pathways to directly address sustainable blue growth. These include case studies of shipbreaking and the toxic legacies thereof in Chattogram, mangrove restoration in the Sundarbans as a nature-based adaptive response, and district-level plastic leakage and circular economy interventions. Finally, the paper provides policy recommendations in respect of land-sea integration governance, financial mechanisms, technology and capacity building, community inclusivity strategies to conserve Bangladesh coastal and marine environment for the benefit of future generations.

**Keywords:** Marine pollution, Blue economy, Pollution control, Bay of Bengal, and Bangladesh.

### 1. Introduction

The Bay of Bengal (BoB) serves as both a key maritime hub and a gateway to vast natural resources, and it is the cornerstone of Bangladesh's coastal and national economies. These offer important ecosystem services that support important industries including aquaculture, fisheries, marine trade, and coastal tourism, all of which are closely related to employment, food security, and overall economic growth. The livelihood of millions of Bangladeshis is dependent on the fishery and aquaculture resources for their nutritional intake, whereas ports and shipping industries facilitate regional as well as international trade (DoF, 2018; Universe PG | [www.universepg.com](http://www.universepg.com)

Jambeck *et al.*, 2015). The Sundarbans' extensive mangrove forests and natural coastal wetlands serve as natural storm barriers that reduce the effects of floods and cyclone damage (Hasan *et al.*, 2024; Mukherjee *et al.*, 2010). They also serve as a major carbon sink in this area, which is under increased strain due to accelerating production emissions linked to global warming (Chowdhury *et al.*, 2024, Sundarbans Biodiversity Conservation Project, 2024).

Nonetheless these ecological resources are in serious jeopardy due to rapidly increasing marine contamination. Plastic wastes and microplastics, oil

spills, heavy metals, chemical contaminants, and nutrient-rich runoff are introduced to water bodies by anthropogenic inputs which are affecting habitats of aquatic organisms and this causes harm to marine biodiversity as well as reduction of fisheries productivity (Hasan *et al.*, 2016; Raha *et al.*, 2021; UNEP, 2021). These challenges intersecting with rapid coastal urbanization, intense industrialization and lax enforcement of environmental regulations (Islam & Rahman, 2020; Paul *et al.*, 2017) imperil Bangladesh's ambition for an inclusive, sustainable blue economy. This paper reviews available scientific literature, field studies and policy reports of past few years to highlight these challenges and recommend strategies for environmental as well as economic sustainability of the Bay of Bengal and Bangladesh.

## 2. Literature Review

The BoB plays an important role in the blue economy of Bangladesh sustaining fisheries, ports and shipping, shipbreaking, tourism and ecosystem services (BOBLME, n.d.; World Bank, 2024).

Nevertheless, the area is confronted with increasing marine pollution from plastics, microplastics, oil and chemical contamination, nutrient loadings and heavy metals (Jambeck *et al.*, 2015; Raha *et al.*, 2021; Hasan *et al.*, 2016). Coastal urbanization, riverine catch of main rivers including large transboundary rivers such as the Ganges-Brahmaputra-Meghna system, act as major sources of pollution. The pollution is exacerbated by industrial activities i.e. shipbreaking yards, where heavy metals and hydrocarbons are released into sediments and the coastal ecosystems (Billah *et al.*, 2025; Shipbreaking Platform, 2024). Eutrophication and algal blooms may be induced by nutrient overloading from agricultural runoff, putting pressure on fish habitats (FAO, 2020). Marine pollution reduces the resilience and capacity for self-repair of mangroves, seagrasses, coral reefs, wetlands, the natural coastal defenses and carbon sinks; which adds costs from the clean-up operations, human health diseases, and decline of activities related to fishing (Hasan *et al.*, 2024; World Bank, 2021). The governance initiatives are undermined by institutional fragmentation; regional programmes such as BOBLME and ProBlue are key to coordination (UNEP, 2021; BOBLME, n.d.). Pollution reduction by taking up circular economic methods is facilitated by

community-led programs and private sector engagement (PLEASE Project; World Bank 2024).

Case studies include shipbreaking pollution in Chattogram, Sundarbans mangrove restoration, which partly improves resilience and carbon storage, and district-level interventions to stop plastic leakage (Billah *et al.*, 2025; Hasan *et al.*, 2024; The State of Plastic Pollution in Bangladesh, 2023). Additional studies into microplastics, bioaccumulation and pollution control are required for policy-making decisions.

### ***Major Pollution Vectors of the Bay of Bengal Plastics and Microplastics***

Plastic pollution is the rapidly growing most visible major marine pollutant that became concern for globally and regionally. Densely populated coastal cities and river catchments are the major sources of land based plastic pollutants for the northern Indian Ocean and the BoB (Jambeck *et al.*, 2015). Institute of Governance and Sustainable Development (IGSD) projects that due to rapid urbanization and challenges in formal waste management infrastructure Bangladesh produces over 800,000 tonnes of plastic yearly with around 200,000 tonnes flowing in to the marine area (IGSD, 2023). River runoff during monsoon seasons, particularly from the Ganges, Brahmaputra and Meghna system drives urban pollution into coastal waters increasing plastic leaking (Lebreton and Andrady, 2019). Studies have shown, presence of microplastics in coastal sediments and catch of fish commercially available at local markets (Raha *et al.*, 2021; Siddique *et al.*, 2023) creating concern about food safety and long term ecological implications.

### **Oil, Chemical and Ship-Related Pollution**

The BoB, hub of maritime trade and offshore industrial activity, including intensified shipping traffic, port operations, and hydrocarbon exploration operations is a source of chronic oil pollution risks. The 2014 oil spill in the Shela River of the Sundarbans proved that how petrochemical pollution was affecting vulnerable habitats (Rahman *et al.*, 2015 gaining a rise during high-profile incidents). The shipbreaking industry in Chattogram the largest tidal beach recycling sites globally responsible for about half of the world's end-of-life ships by tonnage (Shipbreaking Platform, 2024) is another major contributor to chemical and heavy metal

contamination. Research found sediment contamination with lead, cadmium; chromium and hydrocarbons extend several kilometers away from dismantling sites (Billah *et al.*, 2025; Siddique *et al.*, 2012).

### **Nutrient Loading and Sedimentation**

Point sources (primarily wastewater from urban areas) and non-point sources have been the major contributors to increased nitrogen and phosphorus loads into the Bay as a result of agricultural intensification (Paul *et al.*, 2017). These contribute towards eutrophication and harmful algal blooms in the semi-enclosed coastal zones such as Maheshkhali Channel, thereby affecting negatively on shellfish aquaculture and fish spawning grounds (Das *et al.*, 2019). For example, river discharge brings in sedimentation which changes coastal geomorphology by closing inlet mouths and narrowing coastlines smothering benthic habitats essential to the region's fisheries and biodiversity (Allison, 2018).

### **Heavy metals and persistent organic pollutants (POPs)**

The industrial activities inside the coastal districts i.e. Chattogram and Khulna have contaminated fish species in Bangladesh like hilsa (*Tenualosa ilisha*). The degrees of arsenic, mercury, and lead have been greater than maximum permissible restrict values within the fish (Hasan *et al.*, 2016). POPs released by industrial sources have the potential to bioaccumulate along trophic levels, which could have long-term health effects on the ecosystem and human well-being (Rashid, 2014).

### **Ecological and Socioeconomic Impacts Biodiversity and Habitat Degradation**

The environmental effect of marine pollution also extends to the compromising critical habitats such as mangroves, seagrasses, coral patches and coastal wetlands that support fish nurseries and act as natural coastal defenses. The coastal contamination in mangrove forests degrades the carbon sink and protection from oceanic storm surges or human pressure because of wasteland developments, reducing the capacity of ecosystems to sequester and store carbon by increasing emissions (Hasan *et al.*, 2024).

### **Fisheries, Food Security, and Livelihoods**

Small-scale coastal fisheries are important in Bangladesh for employment and nutrition. Pollution

-induced habitat loss, contaminant bioaccumulation and degradation of processing environments decrease the quantity of fish available for harvest, increase post-harvest losses and put consumers at risk of consuming products with potential health risks to human bodies also undermining food security and income (FAO, 2020).

### **Human Health and Coastal Communities**

A multitude of research institutions identified acute and chronic health risks from consuming polluted seafood, swimming at contaminated beaches, and greater occupational hazards especially for ship-breaking laborers. Public health concerns are being heightened by the discovery of microplastics and related compounds, necessitating focused epidemiological research to examine regional health effects and preventative measures (Billah *et al.*, 2025).

### **Economic costs and impediments to Blue Growth**

In addition to the immediate expenses of cleanup, medical care and reduction of tourist, marine pollution also results in indirect costs due to decreased fish populations and sea food quality. This will limit the blue economy dividend's potential. Targeted pollution reductions, on the other hand, can boost innovation in ecosystem services and sustainability while also creating jobs.

## **3. Methodology**

This paper adopts a narrative-analytic review methodology developed by taking scholarly literature (2010-2024), reporting documents from the regional programs, original reports under the Bay of Bengal Large Marine Ecosystem (BOBLME) and World Bank's ProBlue Program as well as Bangladesh national policy documents referring to protection of marine ecosystems and reduction of pollution. The scope focuses on:

- Bangladesh's coastal waters,
- Riverine Inputs from the Ganges-Brahmaputra=Meghna delta and
- Marine-based activities across the BoB.

Data sources included contaminant monitoring studies (Hasan *et al.*, 2016; Hasan *et al.*, 2017), ecological surveys (Raha *et al.*, 2021), socio-economic research (FAO, 2020) and institutional analyses (UNEP, 2021). An additional three in depth case studies to highlight localized pollution effects and responses currently or tentatively in place.

### **Case Studies**

#### **Case Study 1: Chattogram Shipbreaking yards-Toxic Legacies and Transition Options**

The Chattogram tidal beach shipbreaking industry is a highly significant economic sector that is also socially and environmentally sensitive, being the largest ship recycling hub in South Asia. Although it provides a significant portion of Bangladesh's steel needs and jobs, its primarily manual and informal economic processes have made soils and sediments, as well as nearby agricultural lands, chronically contaminated with lead, cadmium, chromium, hydrocarbons, and other persistent toxicants (Billah *et al.*, 2025; Shipbreaking Platform, 2024). After extended contact to dangerous compounds like asbestos and polychlorinated biphenyl (PCB), the toxins persist in the environment, harming marine ecosystems and endangering the health of inhabitants and employees (Billah *et al.*, 2025). Even with court rulings and national environmental regulations in place, enforcement has been patchy and ineffective, which hasn't prevented the environment's unrelenting degradation. By moving operations to onshore dry-dock facilities with improved containment measures, obtaining unsubstantial pre-export hazardous material certifications for incoming vessels, and implementing site remediation techniques like sediment capping and phytoremediation for legacy contamination, the transition strategies aim to formalize the ship-breaking industry (Shipbreaking Platform, 2024). Similarly, official labor protection laws and vocational training are essential for ensuring occupational health. Through regional collaboration and blended finance arrangements, this can help upgrade infrastructure and guarantee complete environmental compliance, which can lower pollution intensity and improve socioeconomic outcomes (Billah *et al.*, 2025).

#### **Case Study 2: Sundarbans Mangrove Restoration- Blue Carbon, Coastal Resilience and Pollution Buffering**

Millions of people are fed by the Sundarbans, the world's biggest contiguous mangrove forest, which also acts as a natural fish nursery, protects against coastal erosion and flooding and absorbs carbon, all of which are crucial for international efforts to slow down climate change. These restoration initiatives, which include community co-management, enrich-

ment planting, and assisted natural regeneration, have clearly improved ecological recovery, increasing biomass and canopy density while providing substantial livelihood opportunities for nearby communities (Hasan *et al.*, 2024a; Sundarbans Biodiversity Conservation Project, 2024). As a natural filter, mangroves aid reset fisheries recoveries and reduce coastal eutrophication by catching sediments and some pollutants before they can reach vulnerable marine areas (Hasan *et al.*, 2024). Unplanned resource exploitation, imbalanced hydrological regimes, and pollution risks are all present in the Sundarbans. Ensuring integrated management, which includes comprehensive coastal zone planning and upstream pollution controls, is also crucial. In order to provide self-sustaining income for restoration and conservation, economic evaluations have emphasized the potential for connecting ecotourism, sustainable fisheries commercialization, and blue carbon financing (World Bank, 2024).

#### **Case Study 3: District-Level Plastics Leakage - Mapping Exposure and Circular Economy Interventions**

There is a substantial spatial variation in plastic pollution in Bangladesh. In most cases, it is the urban centers and major river catchments that contribute to the lion's share of plastic inputs into Bay of Bengal owing to lack of waste management infrastructure. Municipal Services are limited under most of the coastal districts; here relative plastic leakage to marine waters is high in comparison with floatation-based riverine transport (Gugnani *et al.*, 2022; Institute of Governance and Sustainable Development, 2023).

Activities at the district level emphasize improved waste collection logistics, formalization of the informal recycling sector, community-led collection hubs, beach stewardship initiatives connected to tourism, and behavior change programs to curb plastic use and improve disposal practices (PLEASE Project, n.d.). Extended Producer Responsibility (EPR) policies are nested within these frameworks to allow shifting of economic burden on producers who may invest in efficient recycling facilities, improving the efficiency of sorting and recycling.

These integrated measures result in significant reductions of plastic leakage and increase local

engagement, as demonstrated by a pilot project in Bangladesh and more broadly across South Asia (Institute of Governance and Sustainable Development, 2023; World Bank, 2024).

### ***Governance, Policy, and Institutional Responses***

#### **National Policy Frameworks**

The Department of Environment (DoE, 1989) and the Ministry of Environment, Forests, and Climate Change (MoEFCC) are two of the environmental laws and organizations established in Bangladesh that primarily regulate marine pollution. It covers the sectorial concerns of managing coastal zones, ports, and fisheries.

For instance, the effectiveness of pollution control has been hindered by enforcement issues, mandate overlaps between ministries and agencies, and capacity constraints in municipal waste management (UNEP, 2021). Integrated land-sea governance frameworks that can address the interrelated sources of marine pollution, including land-based waste inputs to coastal waterways, are desperately needed.

#### **Regional Cooperation**

Important frameworks for regional cooperation are provided by programs like the Bay of Bengal Large Marine Ecosystem (BOBLME) initiative and multilateral projects like the Food and Agriculture Organization (FAO) and the World Bank's ProBlue projects. By doing this, they establish joint capacity-building, harmonized environmental monitoring, knowledge sharing, and the development of consistent approaches to fisheries management and habitat conservation, all of which are crucial for managing the Bay's transboundary marine pollution and ecosystem issues (BOBLME n.d.; World Bank 2021; FAO 2020).

#### **Private Sector and Civil Society**

For beach cleanups, plastic garbage collection and upcycling and fishery ecolabelling programs, non-governmental organizations, community organizations, private recycling companies, port operators, and sustainable tourist enterprises are involved in pilot projects. In addition to national and multilateral pollution control initiatives, these mechanisms create market incentives and mobilize private sector capital to support green business models, making them an essential component of an inclusive blue economy transformation.

### **Opportunities for the Integration of Pollution Control in Sustainable Blue Economy**

- 1) Upstream waste Management and the Circular Plastics Economy-Only by increasing the quality of waste collection services, source segregation initiatives and adult literacy campaigns and by formalizing informal recyclers and implementing EPRs can the resulting plastic leakage be considerably decreased. Additionally, this will assist small and medium-sized recycling businesses flourish, provide employment, increase the market for recycled plastics, and lessen reliance on the production of virgin plastics (UNEP, 2021; World Bank, 2024).
- 2) Blue Carbon Ecosystem Restoration- Mangroves, seagrass beds, and coastal wetlands serve as crucial carbon sinks, fish spawning grounds, and pollution filters. Fisheries sustainability, biodiversity conservation, carbon financing, and ecotourism will all benefit from this integrated approach, which will also increase coastal populations' resilience for better livelihoods (Hasan *et al.*, 2024).
- 3) Pollution-Aware Fisheries Management- Strategies that aim to protect stocks, enhance the quality of the final product for consumption, and reduce market risks include rights-based fishery access, spatial fisheries planning, seafood safety and pollutant monitoring, enhanced cold chain infrastructure, and certification frameworks (FAO, 2020).
- 4) Safer Shipbreaking, Cleaner Port and Shipping Operations- Environmental and occupational health impacts can be significantly reduced by more thorough enforcement of international marine pollution conventions such as MARPOL, better port waste reception systems, and the phase-out of beaching to onshore, enclosed facilities (Shipbreaking Platform, 2024).
- 5) Advanced Monitoring and Research- Policy advocacy requires long-term, regional monitoring of microplastics and harmful pollutants that contribute to human exposure to the environment. This monitoring helps identify potential responses with ecosystem-level toxicity and inform targeted actions after predictive modeling of contamination. Two nature-based filtration inventions that show

potential as supplements to manmade pollution control systems are mangrove buffer zones and artificial wetlands.

- 6) Financial Instruments for Blue Economy Transitions-Promising tools for leveraging finance for pollution reduction or ecosystem restoration initiatives include blended finance models, green bonds, and Pay-for-Ecosystem-Services (PES). Blue economy initiatives become more accountable and scalable when quantifiable environmental results are combined with financial gains (World Bank, 2021).

### Policy Recommendations for Bangladesh

- Design and enforce an actionable, large-scale Land-Sea Pollution Reduction Strategy.
- Expand Extended Producer Responsibility (EPR) frameworks notably targeting plastic waste, with increased formal sector support.
- Develop large scale blue carbon restoration programs with community livelihoods and market-based financing.
- Strengthen port waste reception facilities and impose strict rules for shipbreaking that are in line with global environmental and worker safety protocols.
- Development of monitoring infrastructure, data sharing and local scientific and technical research capacity at local level
- Mobilize blended finance and innovative investment vehicles for specific pilot projects around testing and scaling-up integrated pollution mitigation solutions.
- Promote community engagement, vocational training, and occupational health safeguards.

### Research Gaps and Future Priorities

Longitudinal data on microplastic concentrations, bioaccumulation in seafood species and socio-economic valuations of pollution impacts are still lacking within Bangladesh's coastal context. Future research priorities include increasing the coverage of monitoring contaminants, focusing epidemiological studies on health impacts related to seafood consumption and prospective evaluations of waste management and restoration measures needed for informed policy making and uptake (UNEP, 2021; FAO, 2020).

### 4. Conclusion

Marine pollution in the Bay of Bengal poses immediate environmental and economic risks to Bangladesh's aspirations for blue economy. Pollution control is a fundamental constituent of sustainable blue growth. In addition to lowering the load, systematic investments in better waste management, circular economy strategies, blue carbon ecosystem restoration and protection, cleaner maritime operations, more resilient fishery management, and improved monitoring for all pollutants can also improve livelihoods and protect biodiversity. In order to achieve these outcomes, improved regional collaboration, cross-sectoral governance frameworks, innovative funding strategies, and community involvement are essential. Bangladesh can safeguard its vital marine resources and create a resilient, inclusive, and pollution-free blue economy if all sectors work together.

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### 6. Conflicts of Interest

I declare that there are no conflicts of interest in relation to this research. The study was conducted independently, and no financial or personal conflicts influenced the integrity of the results.

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