Heavy Metals (HMs) Pollution in the Sundarbans Mangrove Estuary of Bangladesh

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Sundarban is reportedly formed from sediments deposited by three main rivers, including the Ganges, the Brahmaputra, and the Meghna, which provide a risk of pollution and metal toxicity. Although a large portion of the Sundarbans has been designated as Sundarbans Reserve Forests (SRF) for conservation and wise use, SRF protection is woefully inadequate because the area surrounding the forest has experienced unprecedented human and industrial encroachment and urbanization over the years. For example, a considerable proportion of the people (about 8,55,000) living in the defined terrain around SRF rely on the forest for a living and use SRF resources on a regular basis. Presently, around 190 separate industries are constructed along a 10km-wide strip bordering the Sundarbans' northeast limit known as the Ecologically Critical Area (ECA). Unfortunately, these enterprises indiscriminately dump untreated industrial waste into the river and transport raw materials and fuels by various heavy water vehicles across SRF waterways. Furthermore, the use of SRF resources by nearby populations, the construction of two coal-fired power plants near the forest, the release of untreated industrial wastes into the riverine aquatic environment, the use of unauthorized river channels by water vehicles, oil spillage accidents into the river during transportation, and so on are the major reasons for deteriorating the quality of wild and eco-life in SRF. Over time, many of these issues have raised concerns for the SRF's sensitive water and habitat (Choudhury et al., 2021).

However, like other mangroves, the Sundarbans operate as a pollution sink and a source of nutrient flow into the marine environment (Islam et al., 2017). The Sundarbans are increasingly endangered by the activities listed above. The mangrove ecosystem is particularly vulnerable to inorganic contaminants such as heavy metals (HMs) (Costa-Böddeker et al., 2017). One of the most harmful contaminants of the mangrove environment, HMs are both non-biodegradable and extremely poisonous. These metals are notoriously hard to eliminate and tend to build up in all sorts of settings. Some of them are important micronutrients for certain types of flora and fauna, and they exist naturally at insufficient concentrations. On the other hand, pollutants such as wastewater, solid waste, particle materials, and so on find their way into mangroves because of their closeness to urban environments and industries. Most studies on the abundances of HMs in Sundarbans mangrove water, soil, and sediment focused on arsenic (As), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), manganese (Mn), nickel (Ni), lead (Pb), and zinc (Zn) (Ali et al., 2022).

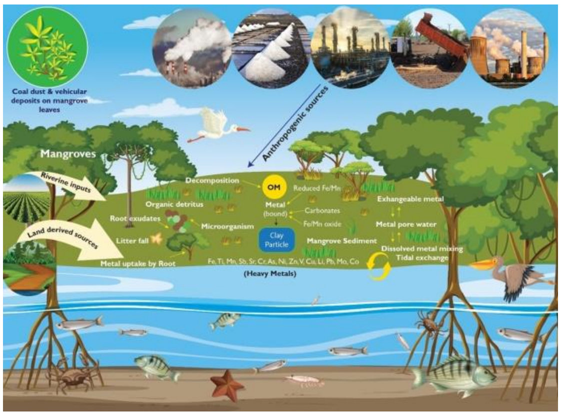

Figure 1: Different Sources of HMs in the Mangrove

Most importantly, HMs are one of the most pervasive contaminants caused by human activity (Choudhury et al., 2021). Anthropogenic activities, including domestic effluent discharge, oil residue from boats, over-siltation, extensive use of motorized boats for transportation and fishing, use of anti-fouling paints or burned oil in motorized boats, and herbicides and pesticides from nearby agricultural fields are contributing to the HMs pollution. Herein, Sundarbans mangrove silt has a greater aluminum concentration due to the presence of basaltic trappean rocks and laterites in the sediment. Because ferries, launches, and motorboats are so important for the transportation and tourist industries of this region. Moreover, they are also a major source of lead (Pb) pollution in the Sundarbans' incoming rivers. Since there aren't many mainland power lines reaching these places; thus, it's possible that lead (Pb) and cadmium (Cd) contamination has arisen through careless usage of rechargeable batteries and improper disposal of used batteries (Chowdhury and Maiti, 2016). Hence, the above discussion also suggests that human actions may possibly be the source of copper and nickel. But natural processes like weathering and erosion may also produce HMs (Bakshi et al., 2018). Mangrove sediments accumulate HMs as oxides and/or oxy-hydroxides from both natural and anthropogenic sources. Bacterial decomposition of HM oxides and/or oxyhydroxides occurs when organic matter is present, releasing the metals into pore water and increasing their bioavailability and release in soluble phases such as organic and sulfide forms of HMs. Albeit, the distribution of HMs in mangrove water, soil, and sediment are dependent on parameters such as pH, salinity, particle size, redox potential, and organic carbon content (Kumar et al., 2019).

As a consequence of fast industrial and agricultural development in Bangladesh and India, land retrieval for aquaculture, agriculture, and urban development, the rapid expansion of human settlements, tourism activity, deforestation, intense fishing, and agricultural, industrial, and aqua-cultural activities, flooding, storm-runoff, atmospheric. In addition, wastes and effluents from home, municipal, and agricultural resources upstream of the Sundarbans' inflowing rivers are causing major ecological change. Due to the aforementioned activities, the Sundarbans ecosystem has become more endangered, despite the fact that it serves as a vital connection between marine and freshwater ecosystems, a pollution sink, and a source of nutrient flow into the marine environment (Islam et al., 2017). Due to the proximity to the urban environment and industry, mangroves receive a wide range of pollutants in the form of wastewater, solid waste, particulate matter, and so on (Kumar et al. 2019). It has been shown that HMs, among other contaminants, constitute a significant risk to the mangrove ecosystem (Costa-Böddeker et al., 2017).

The Sundarbans is the largest continuous stand of mangroves on Earth, and they are also famous for the wide variety of fish, shrimp, and crab that they contain. However, animals living in the Sundarbans have been exposed to HMs contamination to variable degrees as a result of rising industrialization and urbanization upstream of inflowing rivers, increasing anthropogenic and agricultural activities in the Sundarbans (Borrell et al., 2016). Polychaetes, mesozooplankton,

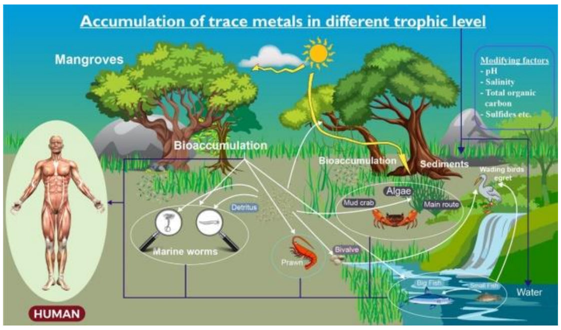

Figure 2: Bioaccumulation of HMs in Different Trophic Levels of the Mangrove Ecosystem

gastropods, copepods, crabs, oysters, shrimp, and fishes from the Sundarbans mangrove have all been tested for HMs (Ali et al., 2022). It was found that the concentrations of HMs varied widely among the various species studied, and several studies also reported the potentiality of bioaccumulation. However, fishes have been shown to have very high levels of arsenic (As) and mercury (Hg) pollution, whereas Mesozooplankton and Copepods have significant levels of copper (Cu), chromium (Cr), iron (Fe), manganese (Mn), nickel (Ni), and zinc (Zn) contamination, according to the obtained data from the previous studies on Sundarbans. The greatest levels of copper (Cu) contamination have been found in oysters, whereas lead (Pb) contamination has been seen in crabs. However, several biotic and abiotic factors influence the accumulation pattern of HMs by fauna, such as species type, feeding behavior (carnivore, omnivore, and herbivore), swimming patterns, metabolic activity, sex, age, size, reproductive cycle, differences in habitat, and living environment (Niane et al., 2015). Most importantly, the bioaccumulation of HMs by mangrove plants and animals poses a concern to the related biota, which includes humans (Kulkarni et al., 2018).

The government and non-government groups in the vicinity of the Sundarbans need to take measures to lessen the pollution caused by HMs. More research is necessary to understand the true extent of metal poisoning in Bangladesh. Taking a core sample of the sediments here would be a great step toward learning more about the long-term effects of metal contamination on this extraordinary ecosystem. HMs may enter the body via the air, water, and food; thus, it's important to undertake model-based human health risk research to determine the extent of the dangers these substances pose. Further studies are needed to identify a suitable biomonitoring agent for trace metals in the Sundarbans. Biomonitoring of HMs in Sundarbans has received surprisingly little attention. Making people aware of the issue of metal pollution in the Sundarbans is another important step. Taking the necessary steps and implementing the appropriate management plans are essential if we are to restore the Sundarbans' forest and prevent further damage to the ecosystem. When the Sundarbans are designated as an ecologically critical area, strict laws are put in place to protect the area's delicate ecosystem. There must be consequences for rule breakers. The department of the environment must consider nine key points to create an effective ECA management rule to protect the ecology, biodiversity, and natural heritage site that is the Sundarbans: no deforestation; no activities that degrade water quality; no activities that harm aquatic life; no waste disposal in the water body of the ECA area; no oysters, corals, etc. Furthermore, an alternate route must be discovered for the surrounding impoverished populations so that they may reduce their reliance on the Sundarbans.

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