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ARTICLE

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MICROPLASTIC POLLUTION IN GANGA: PRESENT STATUS AND FUTURE NEED

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Potential hazardous consequences of microplastic pollution have led to recent surge in research activities on microplastics occurrence in aquatic ecosystems and they are being found ubiquitously both in marine and riverine habitats. The problem is especially exacerbated in developing countries like India where major river systems like Ganga are facing heavy threat of microplastics pollution due to lack of proper solid waste disposal, wastewater treatment system and various anthropogenic activities along the riverbank. The Ganga River is documented with moderate to heavy microplastic contamination both in water and sediment and estimated to carry a large amount of plastic debris to ocean system. However, monitoring microplastics contamination in the Ganga River has just begun and future effort is required to assess toxic effect to native fauna.

Introduction

Plastics are penetrating all commercial sectors worldwide, ushering in the plastic age[1]. These durable, flexible, lightweight, and relatively inert synthetic polymers emerged in the early 20th century. But the usage of plastic has tremendously increased many folds over the last three decades owing to faster lifestyles and changing consumption patterns. It was reported that plastic use has expanded many folds in the last few decades[1]. But these magic materials are extremely durable and do not degrade naturally. Hence after use, the generated plastic waste is piling up thus affecting the world's habitat including the isolated and complex ecosystem. According to a report by WWF[2] nearly 75% of the total plastic produced becomes waste and about 87% of mismanaged solid wastes from uncontrolled landfills are dripped into the natural environment contributing to plastic pollution[2]. It was reported that out of 2.5 billion tons of solid waste generated globally, coastal countries generate nearly 275 million tons of plastic and simultaneously oceans receive 4.8-12.7 million tons[3]. The Great Pacific Garbage Patch of plastic of nearly 600 km^2 of the North Pacific Ocean is one such habitat known as the world's largest plastic dumping site[4]. Despite extreme durability under natural conditions these discarded plastics transform into small particles due to several environmental processes viz. physical disintegration, photodegradation, oxidative degradation, etc. giving birth to the new type of contaminants christened as Microplastics (size < 5 mm). They are also introduced into the environment through direct anthropogenic activity (primary microplastics). For example, primary microplastics are generated commercially for use in facial cleansers and cosmetics, air blasting technology, etc. while secondary microplastics are derived from broader plastic debris due to natural processes[5, 6].

The secondary microplastics are available in nature in a variety of morphological forms such as fragments,

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fibers, pellets, films, beads, foams, etc. irrespective of the environments (marine and inland open waters). Their tiny size, shape and natural abundance make them easily accessible to aquatic life. These microplastics are easily transported to the oceans by natural waterways and pollute marine ecosystems. Abandoned fishing boats, plastic bags, food containers and water bottles thereby polluting aquatic ecosystems[7, 8]. Studies have opined that lower aquatic organisms (planktonic life) prefer floating and less dense microplastics whereas, dense microplastics are favored by benthic invertebrates (amphipods, polychaete worms, mollusks and echinoderms)[9,10]. Concurrently, fiber and fragments (600-1000 μm) are mostly detected in field animals[9].

Microplastics Contamination Status in Ganga

In general, microplastics was considered to be major pollution concern in the marine ecosystems. Until recently they have also been found abundantly in the riverine systems worldwide. Beside direct dumping of plastics waste in ocean, flow of plastic waste through river channel is now being considered as the biggest contributor to the marine plastic pollution. An empirical global model estimated that ocean receives about 1.15 to 2.41 million ton of plastics through river and globally, 67 % of the marine plastic pollution is contributed by the twenty Asian river out of which the river Ganga river catchment is ranked second by an annual discharge of 0.12 million ton of plastics after the Chinese Yangtze river which contribute around 0.33 million tons of plastics[11]. According to studies, plastics or microplastics mostly enter the river Ganga through industrial wastewater, municipal sewage, surface runoff, religious offerings, etc.[8]. The dense population the cities and industrial hubs along bank of the river Ganga cause large chunk of pollutants which are discharged directly into the river. Moreover, recent literatures confirmed that beach tourism, inshore recreation, fishing activities and religious wastes are the major sources for beach plastic debris[12]. Effluent from wastewater treatment plants (WWTPs) are the vital point source of microplastic pollution[13]. Choked sewers and non-functioning pumping stations in urban and periurban areas are directly releasing the raw sewage containing plastic litter from land-based sources and inland runoffs which enters the sea mouth through rivers[14]. Thus, untreated municipal and industrial discharges have increased the pollution load in Ganga upto 75%[15]. It was also reported that river plastic input is highly seasonal with > 74.5% occurs between May and October. Similarly, in Ganga, it was reported that the Indian and East Asian summer monsoon (June-September) with its peak in August brings about 44,500 ton per month of plastics in comparison to lean season (December to March) with < 150 ton per month[15]. Surface water of the river is reported to contain about 1.30-2.42 items/m^3 [15] with major contribution by fragments followed by films and fibre, whereas the level was 99.27–409.86 items/kg in sediment as reported by ICAR-Central Inland Fisheries Research Institute (ICAR-CIFRI)[8]. Study showed that the mighty Ganga water is heavily polluted with microplastics at Varanasi, Haridwar and Kanpur where industrial and human settlement are more prominent[15]. At Haridwar, Kanpur and Varanasi, the average microplastics concentration in the flowing water was found to be huge at 1296, 2162 and 2414 items/m^3 [15]. The study by ICAR-CIFRI at seven sites along the river Ganga viz. Buxar, Patna, Bhagalpur, Nabadwip, Barrackpore and Frazergunj reveal that Ganga river sediments abundantly contained microplastics with various morphological diversity with mass range 11.48 to 63.79 mg/kg and numerical abundance of 99.27- 409.86 items/kg[8]. However, these values are found to be lower as compared to some other rivers of world like (2600-71400 mg/kg), Beijiang River of China (178 to 544 items/kg), Thames River (185-660 items/kg), etc. Depending on hydrodynamic condition and source loading, some sites of Ganga are found to contain more amount of sedimental microplastics. According to ICAR-CIFRI's study the most abundant polymer types in the sediments are polyethylene, polypropylene and polyethylene terephthalate and the major morphotypes being film and fibers. These morphochemical types are found to be most widely distributed microplastics globally. A separate study by IISER, Kolkata also found that the mass abundance microplastics in Ballia, Patna, Bhagalpur, Farraka and Diamond harbour ranged from 10 to 45 mg/kg of sediment (Singh et al., 2021). However, the numerical abundance was found to be lower (17 to 36 items/kg) as compared to the study by ICAR-CIFRI. This might be due the fact that a high mesh size (300 μm) was used by IISER-Kolkata study while extracting microplastics as compared to ICAR-CIFRI (63 μm). Nevertheless, both the studies signify that the Ganga sediments are polluted with microplastics to an extent which need immediate action. The IISER study also estimated the microplastics content in the flowing water at these five sites which ranged from 380 to 684 items/1000 m^3 (numerical abundance) and 143 to 340 mg/1000 m^3 (mass abundance). It was observed that a high abundance of flowing microplastics at Patna (684 items/1000 m^3). A separate study also revealed that Patna site is highly polluted by microplastics and numerical concentration of 92213 items/Kg was found when sediment is passed through a filter size of 0.45 μm[16]. The details of the microplastics load in sediment and water of river Ganga is presented in Table 1.

Effect of Microplastics on Ganga Aqualife

Microplastics are reported to cause hazard to aquatic animal ultimately affecting aquatic biodiversity. Due to small size, they are being ingested by fishes and other aquatic animal. Fishes are reported to accidentally engulfed plastic particles along with their preferred food items. Microplastics fragments, fibres, beads etc. are found to harm fish health either by blocking the food consumption or by leaching toxic molecules like flame retardant, plasticizers, etc. These leached molecules are reported to be well known endocrine disrupting chemicals effecting the normal growth as well as the reproductive behaviour of the fishes. A recent study at wastewater fed aquaculture system at East Kolkata Wetland found that various types of plastics particles in the gut of fishes[13]. Till now there is nil report on the effect of microplastics on the Ganga aquatic, however, a recent report identified Gangetic dolphin (*Platanista gangetica*) and gharial (*Gavialis gangeticus*) at risk overall from plastic litter in the Ganga River Basin. There are numerous reports on plastic ingestion by dolphin taxa including marine species[17] and river dolphins[18]. European Cetacean Society at 31st Annual Conference in Middelfart (Denmark) had considered plastic litter as one of the major threats for marine mammals including dolphins[19]. Till now there is no report on harmful effect of plastic litter on Gangetic dolphin. However, due to frequent reporting of plastic litter ingestion on other dolphin taxa, Ganges River dolphin is considered to be at high risk of ingesting items like plastics bag and food packaging[20]. Ingestion of plastics by dolphin may result in death due to gastric blockage, starvation, perforation or rupture of the gastro-intestinal tract, peritonitis and septicaemia[17,19]. However, due to high intelligence level of Gangatic dolphin CMS, UN has scored interaction risk as “Moderate” for both ingestion and entanglement. However, the impact score for ingestion and entanglement risk for dolphin was reported as “Potentially lethal” and

Table 1 Average Concentration of MPs in the Water and Sediment of River Ganga at Different Locations

Location	GPS location	Size fraction	Sediment		Water		References
			items/kg	mg/kg	items/1000 m^3	mg/1000 m^3	
Haridwar	29.9535167 -29.926168 °N 78.1699730 -78.129333 °E	5 mm- 300 µm	-	-	1296	-	Toxic Link, 2021[15]
Kanpur	26.368803 -29.926168 °N 80.496345- 78.129333 °E	5 mm- 300 µm	-	-	2162	-	Toxic Link, 2021[15]
Varanasi	25.3047508- 25.2838190 °N 83.0090871- 83.0093925 °E	5 mm- 300 µm	-	-	2414	-	Toxic Link, 2021[15]
Buxar	25.5764337 ° N, 83.9711082 °E	5 mm- 63 µm	352.18	63	-	-	Sarkar et al., 2019[8]
Ballia	25.72503° N; 84.19291° E	5 mm- 300 µm	36	44	380	170	Singh et al., 2021[21]
Patna	25.6219472 ° N, 85.1702555 °E	5 mm- 63 µm	80.38	39.52	-	-	Sarkar et al., 2019[8]
	25.61363° N, 85.20276° E	5 mm- 300 µm	23	45	684	327	Singh et al., 2021[21]
	25.6530056 -25.6174194 ° N 85.0905583 -85.1931277 ° E	>0.45 µm	92213	57.2	-	-	Singh et al., 2022[21]
Bhagalpur	25.2636222 ° N, 86.9966555 °E	5 mm- 63 µm	130.92	35.38	-	-	Sarkar et al., 2019[8]
	25.26893° N; 87.02603° E	5 mm- 300 µm	17	10	443	143	Singh et al., 2022[16]
Farraka	24.81535° N; 87.91886° E	5 mm- 300 µm	22	41	424	225	Singh et al., 2021[21]
Nabadwip	23.3969306 ° N, 88.3746583 °E	5 mm- 63 µm	44.64	11.48	-	-	Sarkar et al., 2019[8]
Barrackpore	22.7703861 ° N, 88.3383166 °E	5 mm- 63 µm	115.22	45	-	-	Sarkar et al., 2019[8]
Godakhali	22.3964556 ° N, 88.1384583	5 mm- 63 µm	76.43	24.55	-	-	Sarkar et al., 2019[8]
Diamond harbour	22.17579° N; 88.19661°E	5 mm- 300 µm	29	35	402	340	Singh et al., 2021[21]
Frezergunj	21.5765111 ° N, 88.2421694°E	5 mm- 63 µm	327.47	43.16	-	-	Sarkar et al., 2019[8]

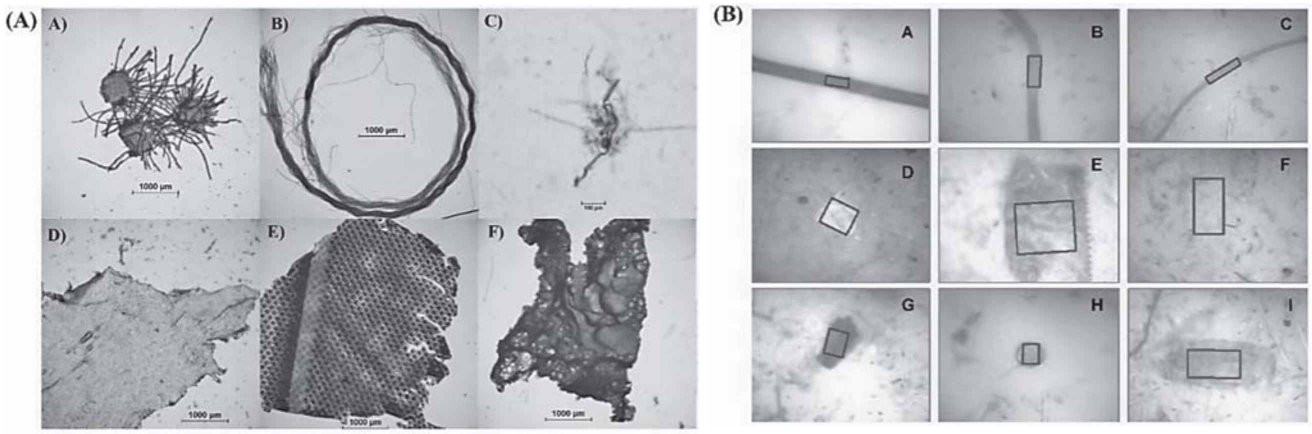

Fig. 1 Optical microscopic images of microplastics extracted from (A) sediments (Buxar, Patna, Bhagalpur, Nabadwip, Barrackpore and Frazergunj) and (B) water (Haridwar, Kanpur and Varanasi) of river Ganga[8, 15].

"Lethal", respectively. However, due to very limited reference on the ingestion of plastic litter by crocodile species, the score for interaction impact risk for gharial was reported to be "Low" and "Unlikely". But since there are extensive evidence on the mortality by entanglement the interaction score for same was given "High" and risk score as "Lethal". The Ganga River CMS listed species risk scores forplastic litter is presented as Table 2.

Future Need

So far, the Government of India has initiated a number of programs to curb the pollution of the Ganga River, including the National Mission to Clean up the Ganga River in 2009, 2011 and the Namami Ganga Mission in

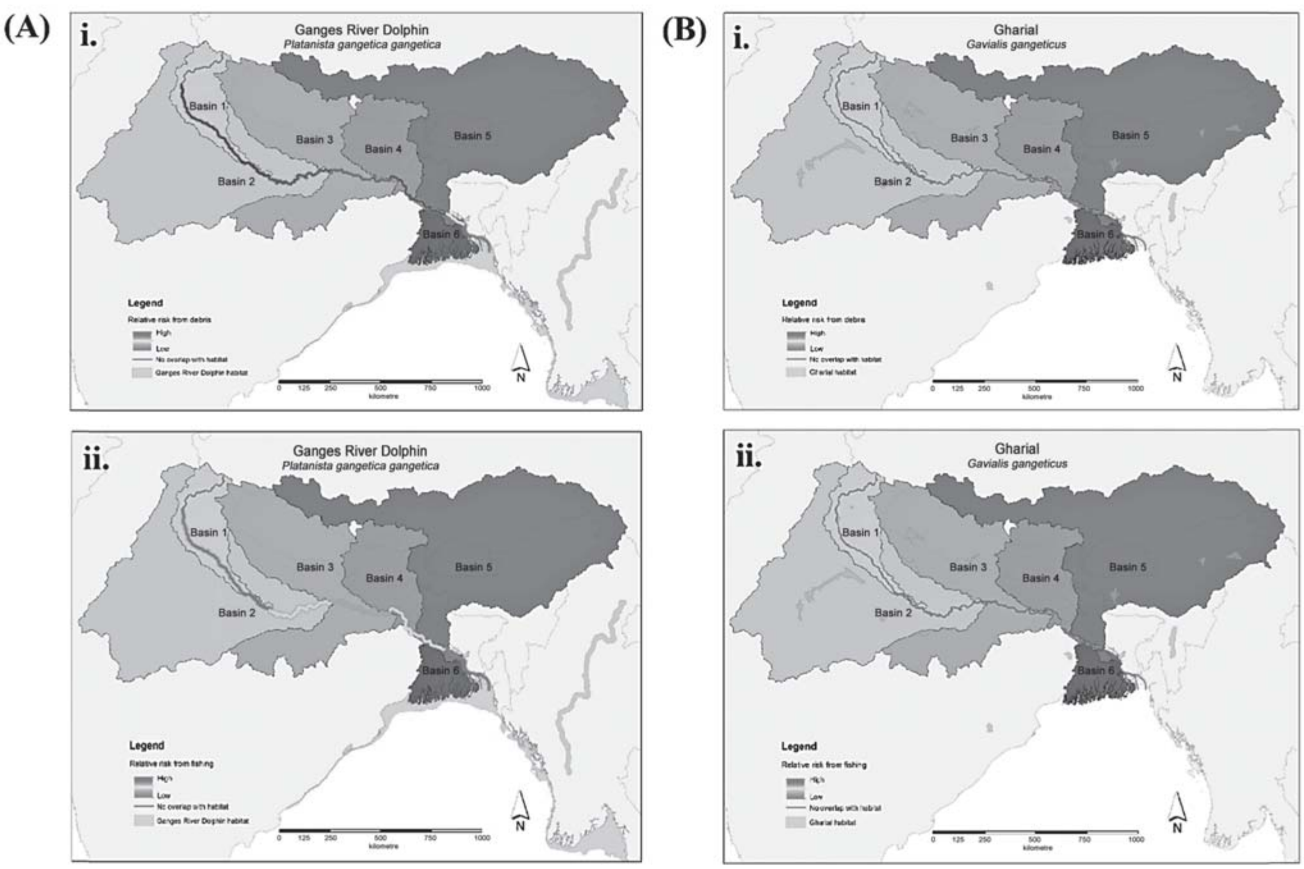

Fig. 2 Relative risk from litter ingestion (i) and fishing debris (ii) for Ganga River CMS species dolphin (*Platanista gangetica gangetica*) (A) and gharial (*Gavialis gangeticus*) (B)[20]

2014. However, these national level initiatives do not include the strategies for the mitigation of microplastic pollution. Hence there is a need to change the regulatory framework to include the microplastics pollution besides other pollutants. Although its presence has been detected in Ganga river but there is irgent need depth studies to understand the transfer mechanism of microplastics in aquatic system and its potency in causing human health risk[22]. Firstly, land based plastic pollution sources need to be checked and plastic management system need to be improved. Improvement of the industrial effluents and sewage discharge system at every entry point/nallahs to the river and adjacent waters system in required. Strengthening and implementation of Extended Producer Responsibility (EPR) in Plastic Waste Management Rules is the need of the hour since river Ganga receives a lot of plastic debris through sewage effluents, industrial wash, and pilgrimage offerings. Plastic manufacturing companies should be responsible for implementation of EPR that will augment the strategic management of plastics wastes. Regulatory measures are to be implemented to restrict the use of single use plastic since they are the key pollutant[23]. Declaration of no plastic zone in river is one another powerful strategy to control plastic pollution. Simultaneously, public awareness campaign on reducing their lifestyle habits, ready to eat consumption pattern etc. that will immensely reduce the consumption and use of single use plastics.

Table 2 Ganga River CMS Listed Species Risk Scores for Plastic Titter

Species	Interaction	Impact	Risk Score
Ingestion			
Ganges River Dolphin	3 (Moderate)	3 (Potentially lethal)	9 Medium risk
Entanglement			
Ganges River Dolphin	3 (Moderate)	4 (Lethal)	12 High risk
Gharial	4 (High)	4 (Lethal)	16 High risk

Conclusion

Due to numerous benefits, plastic has become dominant feature in the day to day human life. Its production and consumption have increased tremendously worldwide including India. But lack of plastic waste disposal and recycling techniques has led to a condition that most the aquatic and terrestrial ecosystem has become polluted with microplastics which has been reported to have potential harmful effect to aquatic life and human health. The river Ganga was estimated to carry a huge amount of plastic litter to the ocean. Real time sampling and detection of microplastics in the river Ganga has started very recently and few reports are present. Hence, more research is required on realising the potential harmful effect of the microplastics on the vast aquatic and terrestrial life at Ganga catchment. ❐

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