POLICY BRIEF

The Asia-Pacific Network for Global Change Research (APN)

Transboundary Microplastics in the Brahmaputra-Jamuna River: Forging Adaptive Governance for Shared Ecosystem Resilience

1. Introduction:

The proliferation of plastic waste, fragmenting into microplastics (MPs) - persistent particles smaller than 5 mm - fundamentally challenges the traditional donor-recipient paradigm of environmental knowledge generation and dissemination across transboundary river systems. In the Brahmaputra-Jamuna basin, a vital artery sustaining millions of lives through Bhutan, India, and Bangladesh, MPs migrate seamlessly across political boundaries, embedding themselves in surface waters, riverbed sediments, and the gastrointestinal tracts of fish that form the dietary backbone of riparian communities. This mobility introduces profound uncertainties: upstream glacial melt in Tibet and minimal inputs in Bhutan's forested highlands give way to urban-industrial surges in Phuentsholing and Guwahati, culminating in downstream flood-driven remobilization in Bangladesh's deltaic plains. The precise magnitude, timing, and ecological fallout of these contaminants remain elusive, compounded by seasonal hydrological shifts - pre-monsoon stagnation concentrating MPs versus post-monsoon flushing that disperses yet reactivates them.

Scientific modeling provides indispensable predictive tools for long-term mitigation, yet its efficacy hinges on integration with lived experiences from fishers, waste collectors, and rural households whose daily practices shape pollution pathways. Stereotypical interventions - such as blanket plastic bans without alternative livelihoods - often yield maladaptive outcomes: informal dumping persists, eroding public trust and inciting localized resistance. In this nexus of societal needs and ecosystem fragility, adaptive governance emerges as a necessity, weaving participatory learning, iterative feedback, and policy flexibility into decision-making fabrics. This brief adopts a diagnostic framework akin to Soft Systems Methodology, scrutinizing MP governance failures: opaque data flows between nations, siloed institutional mandates, and exclusion of indigenous knowledge in hotspot mapping. Despite these fractures, tri-national stakeholder dialogues - spanning workshops in Bangladesh (February 2025), Bhutan (March 2025), and India (October 2025) - revealed a latent willingness for transformative collaboration, provided equitable platforms amplify marginalized voices from remote Harachhu villages to Sirajganj's flood-prone chars. These events, employing policy canvass tools, not only disseminated empirical gradients but catalyzed institutional commitments, exemplified by Bangladesh Agricultural University's immediate campus-wide plastic bottle ban.

2. Problem Context:

India's plastic production, soaring to 19.3 million tonnes annually, intersects with Bangladesh's dense downstream populations and Bhutan's conservation ethos to position the Brahmaputra-Jamuna as a global conduit for microplastic emissions, ferrying millions of particles daily into the Bay of Bengal and ranking South Asia second worldwide in oceanic plastic influx. The river's transboundary trajectory - from Bhutan's high-altitude tributaries (Harachhu, Manas, Toorsa) through India's upstream remoteness (Tuting) and midstream urbanization (Dibrugarh, Guwahati) to Bangladesh's lowland accumulation (Kurigram, Humuria) - mirrors an anthropogenic escalation: near-pristine upstream baselines explode into downstream hotspots where untreated municipal sewage (e.g., high MP conc. in Guwahati), industrial effluents, textile shedding, and agricultural runoff converge.

Pre-monsoon low flows act as natural concentrators, elevating MP densities in stagnant pools and depositional zones, while monsoon deluges - exceeding 2,000 mm in catchment areas - scour sediments, remobilizing weathered fragments and amplifying downstream loads twice in urban-adjacent sites. MPs, adsorbing heavy metals and pesticides, transcend mere physical presence to become vectors of compounded toxicity. In fish, a cultural and nutritional cornerstone, MPs trigger hemato-biochemical cascades - anemia, elevated liver enzymes (in exposed catfish) - and histological lesions from gill hyperplasia to intestinal villi erosion, with demersal and carnivorous species bearing disproportionate burdens due to benthic foraging, as validated in 60-day PET/LDPE exposures yielding growth retardation.

Dietary pathways compound vulnerabilities: focus groups revealed 84.6% of consumers eviscerate fish, yet 15.4% do so incompletely, and 23-43% intentionally retain guts or gills in traditional preparations, yielding lifetime exposures of five hundred thousand to million particles per person in high-risk zones like Sirajganj. Awareness deficits are stark - remote Tuting respondents recognize general river degradation but remain oblivious to MPs - perpetuating a cycle where scientific warnings fail to alter behavior. Existing policies, fixated on macro-plastics and municipal solid waste, neglect micro-scale governance, fostering inter-jurisdictional blame-shifting: Bhutan cites downstream imports, India points to Tibetan atmospheric deposition, and Bangladesh laments upstream legacies. This fragmentation breeds citizen disillusionment, evident in sporadic protests over fish safety and calls for transparent transboundary monitoring, as echoed in workshop deliberations.

3. Analysis and linking to APN-Funded Project Findings:

Under APN's CRRP, this multi-institutional endeavor mobilized Bangladesh Agricultural University (lead), Assam Agricultural University (India), Royal University of Bhutan, and the University of North Carolina Wilmington to dissect MP dynamics across thirteen stratified stations. Dual-season campaigns - pre-monsoon capturing dry-season concentration and post-monsoon (September 2024) assessing flood-driven dispersion - deployed standardized protocols: plankton nets for water MPs (items/km²), Ekman grabs for sediments (items/kg), and meticulous GIT dissections from 63 ecologically diverse fish species, alongside benthic invertebrates (mussels/snails).

Analytical rigor encompassed stereomicroscopy for morphotypes (fibres 67% in water, fragments 87% in sediments; black/blue dominant at 41–62%), Fourier Transform Infrared Spectroscopy confirming polymers (PVC, PA, CPVC prevalent, tracing to textiles, pipes, coatings), and Scanning Electron Microscopy revealing surface weathering - cracks and pits signaling nanoplastics formation. Two-way ANOVA illuminated significant season-station interactions ($p<0.001$), with pre-monsoon peaks reflecting low dilution and post-monsoon variability driven by site-specific hydrology; supplementary Old Brahmaputra analysis showed winter urban peaks (6-folds to rural).

Gradient analysis crystallized anthropogenic linkages: Harachhu's near-zero baseline contrasts Toorsa's urban spike, Guwahati's metropolitan apex, and Humuria's cumulative overload; sediments spanned sixty-fold. Fish bioaccumulation followed trophic and habitat gradients—demersal omnivores accumulating two-to-three times pelagic planktivores, with benthic invertebrates (mussels ~10 MPs/individual) mirroring water loads. Laboratory exposures validated causality: dose-dependent hematological shifts, organ pathology, and reproductive impairments in Asian stinging/walking catfish. Complementing hard data, 150+ FGDs/KIIs across socio-economic strata exposed behavioral fault lines: small-fish consumers (affordable, nutrient-dense) ingest whole specimens, while processed products

(30.8% market share) mask MP loads; human EDI reached 0.50 particles/kg BW daily (2–3x downstream).

Tri-national policy workshops - Bangladesh (BAU, Feb 2025: waste management/transboundary gaps, plastic ban enacted); Bhutan (RUB, Mar 2025: source tracing, health monitoring); India (AAU, Oct 2025: industrial EPR, cleanup) - employed 'Policy Canvass' tools to diagnose systemic gaps: inadequate transboundary data protocols, weak enforcement of effluent standards, and absent public education on fish preparation. Yet, convergence emerged on shared priorities—hotspot mapping, 5R internalization, and regional accountability—signaling fertile ground for adaptive co-management, with outputs including four peer-reviewed papers, ten theses, and trained around sixty young scientists.

4. Ways Forward:

Institutionalize Transboundary Synergy: Establish a Brahmaputra-Jamuna Microplastics Observatory under APN auspices, convening annual summits for real-time data harmonization, joint risk modeling, and synchronized regulations. Upstream nations (Bhutan/India) prioritize prevention - phasing out microbeads and single-use plastics via border-trade accords - while downstream Bangladesh scales remediation technologies like floating barriers and sediment dredging in depositional chars, leveraging workshop-proven pilots.

Embed Source-Control Mechanisms: Mandate Extended Producer Responsibility (EPR) across the plastics value chain, compelling manufacturers to internalize end-of-life costs and innovate low-shed textiles. Retrofit high-emission clusters - Phuentsholing's ferroalloy units, Guwahati's refineries - with advanced effluent treatment plants (ETPs) targeting fibre interception, potentially curbing 60–70% of industrial MP inputs based on Old Brahmaputra benchmarks and AAU advocacy.

Reengineer Waste Ecosystems: Roll out incentive-driven infrastructure - reverse vending networks in Bhutan's thromdes, municipal 5R hubs in Assam's urban councils, and community-led sorting in Bangladesh's upazilas. Leverage digital tools - citizen-science apps integrated with satellite imagery - to crowdsource hotspot intelligence, empowering local governance units to preempt dumping in riparian zones, as prioritized in BAU canvasses.

Fortify Food-Chain Safeguards: Institutionalize evidence-based fish consumption advisories: excise GITs and gills rigorously, especially for small/indigenous species. Launch multilingual awareness cascades through schools, markets, and faith-based networks, bridging the knowledge chasm from Tuting's tribal hamlets to Sirajganj's fishing cooperatives. Fund interdisciplinary consortia (RUB-BFDA-AAU-BAU) to decode polymer-specific toxicities and cooking-induced leaching, informing safe-preparation standards and mitigating 2–3 fold downstream EDI disparities.

Cultivate Adaptive Capacity: Pilot Soft Systems-inspired participatory modeling in select sub-basins—co-designing scenarios with fishers, waste workers, and regulators—to stress-test policies under climate-hydrology variability. Develop basin-wide MP indices beyond Pollution Load Index (PLI<10 signals containment, yet toxicity demands nuanced thresholds), feeding into national adaptation plans and SDG 14 and SDG 12 alignment.

Catalyze Enforcement and Innovation: Replicate BAU's campus plastic ban across educational and governmental estates; impose escalating penalties for non-compliance while rewarding circular-economy pioneers - biodegradable packaging startups, upcycled textile ventures. International financing mechanisms (APN, GEF) can underwrite technology transfer, ensuring equitable burden-sharing and significant basin-wide reductions by 2030.

By transcending fragmented mandates and anchoring decisions in participatory diagnostics, the Brahmaputra-Jamuna basin can evolve from a pollution corridor into a resilience exemplar—where scientific precision, local wisdom, and political will converge to secure a microplastic-free legacy for generations.

Study Team: Prof. Dr. Harunur Rashid & Prof. Dr. Kizar Ahmed Sumon (BAU, Bangladesh), Dr. Rajdeep Dutta & Dr. Utpal Kumar Das (AAU, India), Ms. Yogeeta Dahal (RUB, Bhutan) & Ms. Ugyen Tshomo (NEC, Bhutan), Md. Mahmudunnabi Mithu (BAU, Bangladesh), Dr. Md Shah Alam (UNCW, USA), "Transboundary microplastics contaminations in fish and aquatic food chain along Brahmaputra river" Project funded by APN (https://doi.org/10.30852/p.18799)

Contact: Prof. Dr. Harunur Rashid, Department of Fisheries Management, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh, rashid@bau.edu.bd

Acknowledgements: APN for catalytic funding; project partners, fishers, waste managers, and policymakers whose insights illuminated pathways from data to decisive action.