

## ASSESSING MUNICIPAL SOLID PLASTIC WASTE MANAGEMENT IN PATENGA, CHATTOGRAM: A MATERIAL FLOW ANALYSIS FOR SUSTAINABLE URBAN DEVELOPMENT

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### ABSTRACT

*In developing countries, economic prosperity and population growth have made municipal solid plastic waste (MSPW) management critical for addressing environmental and health challenges and achieving Sustainable Development Goals (SDGs). This study focuses on Patenga, located 14 kilometers south of Chattogram, Bangladesh, a region known for its scenic beauty along the Bay of Bengal. A field survey was conducted using WaCT Tools to evaluate waste generation and recycling practices across various settings, including households, markets, hotels, restaurants, offices, and streets. Survey results and Material Flow Analysis (MFA) indicate that the area produces approximately 1,138.2 tons of solid waste and 98.34 tons of plastic waste monthly, with a collection efficiency of 57.83%. Notably, about 25% of plastic waste is recycled through formal and informal sectors. However, approximately 455.91 tons of solid waste, including around 74.25 tons of plastic, are mismanaged and discarded in open environments. To mitigate these issues, a comprehensive waste management EPR strategy is proposed centered on reducing, reusing, and recycling (3Rs). This strategy aims to support city officials and policymakers in developing sustainable urban development plans while enhancing recycling initiatives across governmental and non-governmental organizations, ultimately fostering environmental sustainability and protecting public health.*

**Keywords:** Solid plastic waste management, WaCT Tools, STAN, SDGs, Material flow analysis

### INTRODUCTION

Solid plastic waste management (SPWM) is increasingly recognized as a significant global challenge, worsened by ongoing trends of rapid urbanization and population growth over an extended period (Alamgir & Ahsan, 2007). The surge in plastic production since World War II, which escalated from 2 million tons in 1950 to 390.7 million tons by 2021, has led to significant environmental pollution and health risks (Zhang et al., 2024). Plastics are favored for their strength, lightweight nature, affordability, durability, and corrosion resistance; however, their widespread use contributes to a growing volume of solid waste that threatens both the environment and public health (Gilani et al., 2023). In Bangladesh, the challenges of SPWM reflect those faced by many developing countries. By 2025, per capita waste generation in Bangladesh is projected to reach 0.75 kg per day, totaling around 21.07 million tons annually (Abdullah & Abedin, 2024). The improper disposal of plastic waste poses direct and indirect risks to the Bay of Bengal's marine ecosystem and human health.

During the fiscal year of 2019-2020, the estimated annual plastic consumption of Bangladesh was approximately 1.71 million metric tons, with the packaging industry being the largest consumer. Each person uses about 10.13 kilograms of plastic products annually, resulting in approximately 7.9 kilograms of waste per person (Siddique et al., 2022). This consumption has increased notably from 3 kg in 2005 to 9 kg in 2020, further intensified by the COVID-19 pandemic's rise in single-use plastics like masks and personal protective equipment (PPE) (Abdullah & Abedin, 2024). Currently, Bangladesh recycles about 28% of its plastic waste through informal sectors; however, a significant amount remains uncollected and ends up in landfills or the environment (Saju et al., 2024).

Traditional disposal methods such as landfilling and incineration not only lead to inefficient resource use but also create secondary pollution problems (Drangert & Kjerstadius, 2023). Mismanaged landfills contaminate the environment and pose health risks (Mor & Ravindra, 2023). The growing awareness of plastic pollution has made SPWM a vital area for research aimed at enhancing environmental sustainability and public health (Kumi-Larbi Jnr et al., 2022). Sustainable SPWM is essential for fostering a circular economy based on principles like reuse, reduction, recycling, and recovery of materials—principles that have gained traction globally (Gilani et al., 2023).

To implement sustainable practices effectively, understanding material stocks and flows is crucial (Villalba, 2020). Material flow analysis (MFA) is an important tool for assessing how materials move through systems by evaluating inputs and outputs (Stanisavljevic & Brunner, 2014). MFA can reveal material composition changes over time and highlight opportunities for improved resource efficiency (Villalba, 2020). It typically utilizes Sankey Diagrams to illustrate waste flows in municipal solid plastic waste management systems, identifying sources and outcomes related to plastic pollution while supporting Sustainable Development Goals (SDGs) such as sustainable cities (SDG 11), responsible consumption (SDG 12), marine protection (SDG 14), and clean energy (SDG 7) (Gilani et al., 2023).

Despite its importance, research on sustainable SPWM using MFA is limited in Bangladesh, particularly regarding solid plastic waste in Chattogram City's Patenga ward. This study aims to address this gap by analyzing the generation and collection of municipal solid plastic waste in Patenga while visualizing its flow through MFA techniques. The anticipated findings will provide valuable insights for policymakers and stakeholders working towards effective strategies for sustainable waste management that mitigate health hazards associated with plastic pollution while promoting environmental sustainability.

## METHODOLOGY

### Study Area

The 41 No. Patenga Ward (Figure 1) in Chattogram has a deep harbor, which significantly boosts its commerce, business, and industrial activities, and serves a population of 67156 (BBS, 2023). The Chattogram experiences an annual mean temperature that varies from 22 to 32 °C in summer and 20–26 °C in the winter, with an average annual rainfall of 2,889.7 mm (Naim & Kafy, 2021). The selected ward faces significant challenges in waste management, particularly due to inadequate waste collection infrastructure. This has resulted in visible plastic litter accumulating on streets and clogging drainage systems, which exacerbates waterlogging during heavy rainfall and increases the risk of plastic pollution entering the nearby Karnaphuli River (Ahmed, 2024). These pressing issues highlight the urgent need for targeted interventions in Patenga Ward to improve solid waste management practices and protect both the environment and public health.

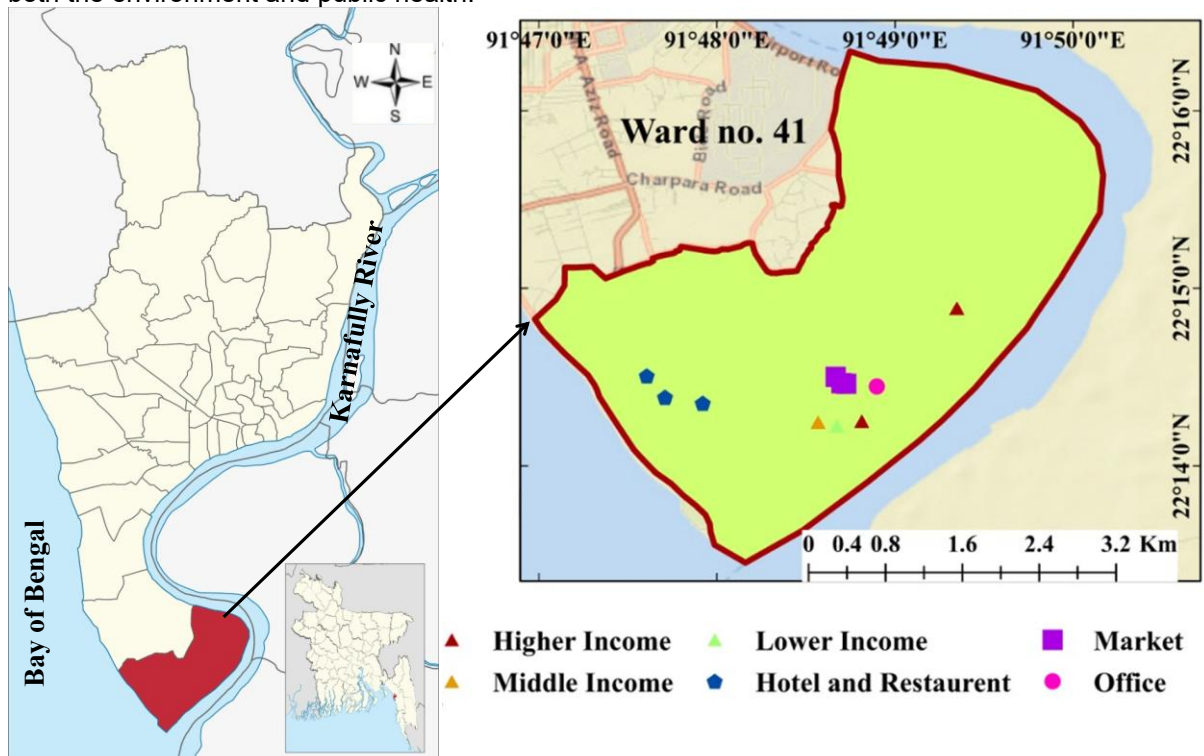


Figure 1 Study area map along with sampling points

## Data Collection Process

The study conducted over three months, from November 2023 to January 2024, collected data from both primary and secondary sources to analyze solid plastic waste generation and recycling. Primary data were collected through on-site investigations, observations, and interviews with key plastic waste management chain stakeholders. Secondary data were sourced from the Chattogram City Corporation (CCC), various non-governmental organizations (NGOs), and local recycling industries. The research focused on 90 households across three income groups: high, middle, and low. Solid waste samples were collected over seven days, excluding the initial day to avoid mixing from previous waste, resulting in a total of 630 samples (90 households × 7 days).

The study relied on the Dhaka North City Corporation (DNCC) master plan, which estimates that household solid waste comprises 61% of total solid waste. The remaining 39% is attributed to various sectors: markets (10%), hotels and restaurants (9%), offices (3%), and streets (17%) (DNCC, 2019). Consequently, additional solid waste samples were collected from three markets, three hotels and restaurants, three offices, and three streets, totaling 84 samples (12 facilities × 7 days) for non-household waste. After the collection phase, Municipal Solid Waste (MSW) was categorized into plastic waste and organic & other waste. Plastic waste was further classified according to the guidelines of the Central Pollution Control Board (CPCB). Where plastics are visually categorized into types such as Polyethylene Terephthalate (PET), High-Density Polyethylene (HDPE), Polyvinyl Chloride (PVC), and others. To gain insights into recycling practices for plastics in the studied area, visits were conducted with recyclers who purchase, process and sell scrap products.

## Materials Flow Analysis

Materials Flow Analysis (MFA) is a systematic method for assessing the movement and accumulation of materials within a defined system, characterized by specific spatial and temporal boundaries (Stanisavljevic & Brunner, 2014). This analysis meticulously tracks how materials enter, exit, and circulate within the system, with measurements typically expressed in tons per month (t/mon). This study focuses on the flows of solid and plastic waste related to waste collection, transportation, treatment, and final disposal—either through landfilling or open dumping—specifically within the spatial confines of Patenga Ward. The temporal period of the collection spans from November 2023 to January 2024. The assessment was conducted using the STAN tool, which facilitates a detailed evaluation of material flows in this context.

## RESULTS AND DISCUSSIONS

### Solid Waste and Plastic Waste Generation

The Chattogram City Corporation (CCC) generates solid waste daily at varying per capita rates: 367.63 grams for high-income groups, 358.19 grams for middle-income groups, and 241.16 grams for low-income groups. Notably, high-income individuals produce an average of 34.5 grams of plastic waste per capita per day, which is approximately 1.9 times more than the plastic waste generated by low-income individuals. The total waste (1138.2 tons/month) generated in the 41 No Ward was comparably lower than the total waste (4020 tons/month) generated by the 39 No. South Haliashahar because of the lower population (3.81 times) and more open tourist spots in the Patenga Ward (Hossain et al., 2024). This disparity in solid waste generation, particularly regarding plastic waste, is largely attributed to the higher consumption patterns of wealthier groups, who often neglect to use reusable shopping bags during purchases, thereby exacerbating their waste output.

Furthermore, the sources of plastic waste have distinct contributions: markets account for 9.74%, hotels, and restaurants for 7.35%, offices for 8.9%, and streets for 7.54% of the total plastic waste generated in the city.

Table 1 Estimated waste proportion from different sources

Waste Type	Household (HH)			Market	Hotel & Restaurant (RH)	Office	Street
	High Income	Middle Income	Low Income				
Total waste (gm/cap/day)	367.63	358.19	241.16	N/M	N/M	N/M	N/M
No. of population	290	207	220	N/M	154	180	N/M

Organic & Other Wastes (%)	90.51	90.24	92.56	90.26	92.65	91.1	92.46
Plastics (gm/cap/day)	34.5	35.39	17.93	N/M	N/M	N/M	N/M
Plastics (%)	9.49	9.76	7.44	9.74	7.35	8.9	7.54

Note: N/M indicates not measured

Overall, the study area generated a total of 37.94 tons of waste daily, which included 23.14 tons of household waste, 6.45 tons of street and construction waste, 3.8 tons of market waste, 3.41 tons of waste from hotels and restaurants, and 1.14 tons of office waste.

Household is the most significant contributor to the waste stream of this ward. Figure 2 outlines the percentage of plastic waste types and recycling rate from household sources.

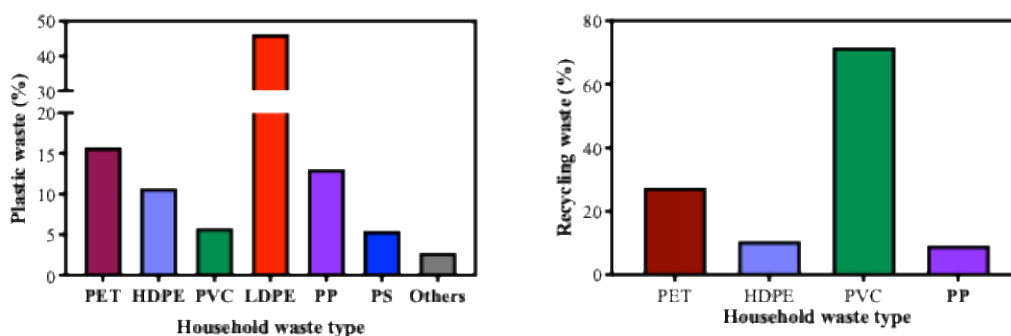


Figure 2 Household plastic waste generation and recycling rate

LDPE was found to be the most prevalent type in households (46.30%). In household waste, single-use plastic shopping bags are the primary source of LDPE (Figure 3).



Figure 3 People carry single-use plastic (SUP) for shopping from the market.

Currently, in Households, PVC is recycled with an impressive 71.79% of its total, indicating a robust recycling infrastructure. In contrast, PET is recycled at 27.56% of this material is recycled, primarily sourced from households. Other plastics such as HDPE and PP have lower recycling rates at 10.70% and 9.29%, respectively, reflecting challenges in collection and processing, as these materials are commonly found in containers, pipes, and stationery items. Polystyrene (PS), used in disposable cutlery and foam packaging, is notably absent from recycling streams due to its low density and bulkiness, making it economically unfeasible to collect and process.

Table 3 overviews the plastic waste compositions sourced from different outlets. LDPE predominates in households (51.53%), and streets (61.66%), while PET is the dominant plastic in markets (41.73%), offices (73.59%), and hotels and restaurants (82.79%). In household waste, the major contributor to LDPE is single-use plastic bags utilized for shopping, while in market waste, packaging waste is the primary source of LDPE. Hotels and restaurants predominantly contribute PET bottles used for water and cold drinks.

Table 3 Plastic waste composition (%) in different waste sources from November 2023 to January 2024

Facility Types	PET (%)	HDPE (%)	PVC (%)	LDPE (%)	PP (%)	PS (%)	Others (%)
HH	18.85	12.99	3.23	51.53	8.02	4.18	1.2
Market	41.73	3.34	6.92	38.68	4.85	3.05	1.43
HR	82.79	0.31	0.17	3.53	7.25	5.48	0.47
Office	73.59	2.93	0.73	5.87	11.25	4.9	0.73
Street	18.45	1.38	1.19	61.66	7.71	8.66	0.95

### Materials Flow Analysis

#### Municipal Solid Wastes Flow

Figure 4 illustrates the flow and management of solid waste within the study area, where approximately 1138.2 tons of solid waste is generated monthly. Flows 1 to 5 represent waste generation from various sources, including households, markets, hotels, offices, and streets. Flow 7 shows the movement of the generated solid waste to the landfill site (LFS), with 658.2 tons per month collected through municipal collection points. An important aspect highlighted in the figure is the recycling process (Flows 6 and 10), which accounts for roughly 24.09 tons per month. Despite these recycling efforts, Flow 8 indicates that a significant portion—approximately 455.91 tons of waste—is mismanaged each month. This mismanagement leads to improper disposal, resulting in environmental pollution and waterlogging issues, particularly during heavy rainfall events.

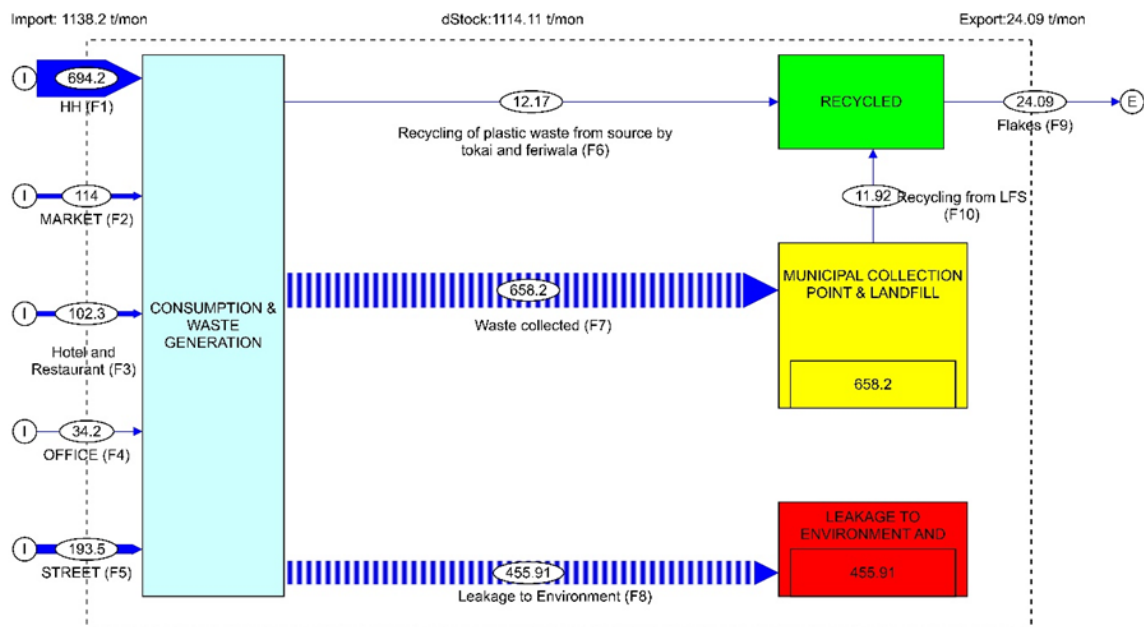


Figure 4 The solid waste flow of 41 No. Patenga ward, Chattogram

#### Plastic Waste Flow

Figure 5 provides a detailed depiction of different plastic waste flows and management within CCC. The figure reveals that CCC receives approximately 93.21 tons per day of final plastic products (Flow 1), highlighting the extensive use of plastic across various sectors. Households generate the most plastic waste (59.04 tons/day) due to the extensive use of plastic products in daily life (Flow 9). Among different plastic types, LDPE (53.05 tons/day) in Flow 5 stands out as a major contributor to plastic waste due to its prevalent use in single-use applications like packaging for fruits, groceries, and snack wrappers. The production of PET as finished plastic goods, particularly for beverage and oil bottles, contributes significantly (24.41 tons/day) after LDPE (Flow 2).

Flows 29, 30, and 34 indicate that approximately 31.31 tons of plastic waste (Flow 33) are recycled monthly via scrap collectors and Tokai. Despite the collection and recycling of plastic waste, an estimated 61.90 tons per month of plastic waste remains inadequately managed. This unmanaged

waste ultimately ends up in landfill sites, contributing to environmental pollution, including contamination of water bodies.

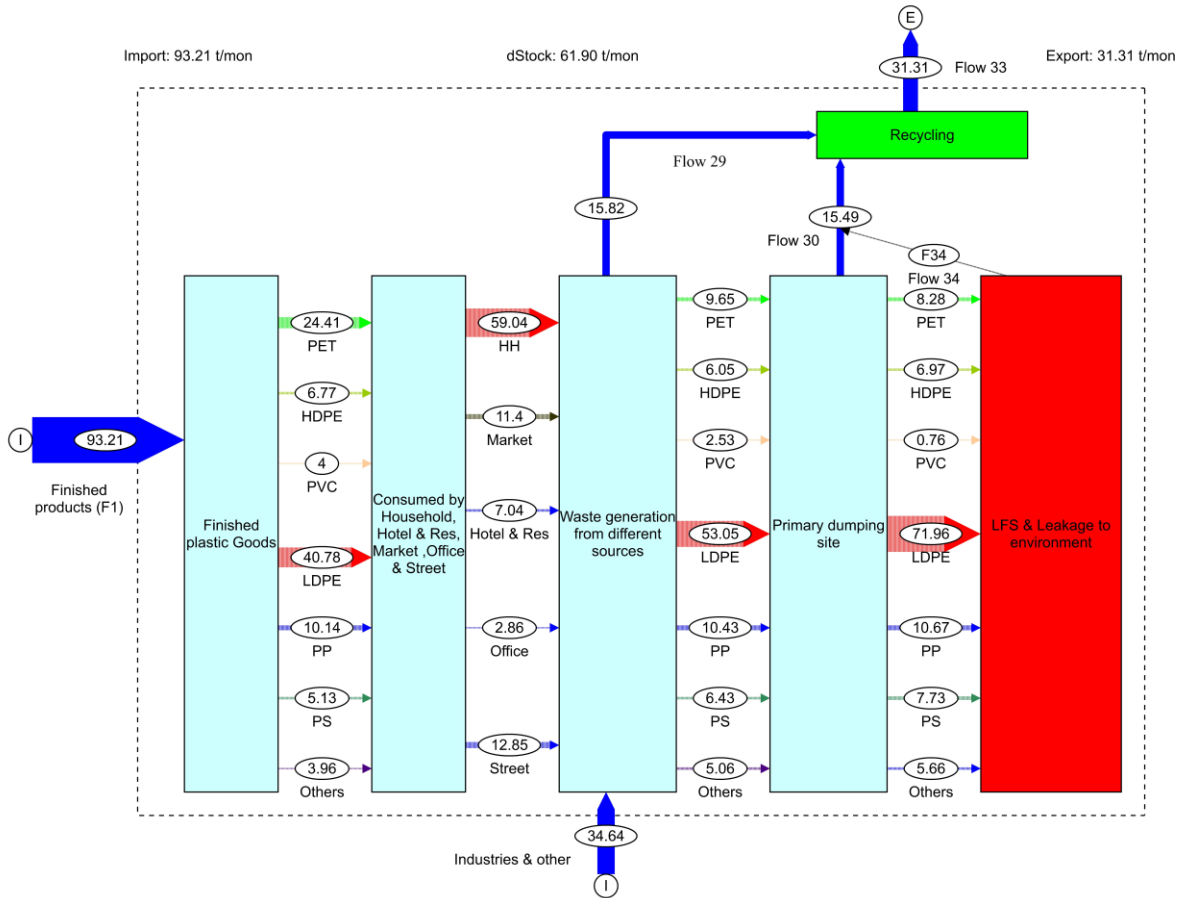


Figure 5 Plastic waste Flow at 41 No. Patenga ward, Chattogram

### Current Recycling Practices Plastic waste

Currently, approximately 31.31 tons per month of plastics are recycled at various stages within the CCC. The typical process of plastic recycling involves several key steps. First, plastics are collected from various sources and sorted by type and color. Once sorted, the plastics undergo cleaning and drying to remove contaminants and moisture. The clean, dry materials are then shredded into smaller pieces to facilitate further processing. Next, the shredded plastic is melted down, transforming it into a malleable state. After melting, the material is cooled to allow it to solidify into a manageable form. This solidified plastic is then processed into small pellets, which can be easily transported and reused. Finally, these pellets are packaged for distribution to manufacturers, where they can be transformed into new plastic products. This systematic approach is shown in Figure 6.



Figure 6 Typical step-by-step process of plastic recycling

## SUGGESTIONS

For plastic waste in CCC, a systematic and scientific approach should be adopted to effectively implement the 3R (Reduce, Reuse, and Recycle) strategies for managing plastic waste. Initially, the focus should be on minimizing plastic use by promoting alternative materials such as paper, cardboard, glass, and metal for sustainable packaging solutions. Bioplastics like Polylactic Acid (PLA) and Polyhydroxyalkanoate (PHA), derived from plant starch and bacterial fermentation, are also utilized in packaging and disposable items. Additionally, natural fibers including cotton, jute, wool, durable silicone, and fast-growing bamboo should be employed for various applications, providing environmental benefits such as biodegradability and a reduced carbon footprint. Subsequently, it is essential to encourage reuse and facilitate recycling through Extended Producer Responsibility (EPR) to maximize resource efficiency. Furthermore, Bangladesh could enhance its regulatory framework, public awareness, and recycling infrastructure with the following proposed method (Figure 7) for implementing EPR without incurring extra costs for producers by incorporating recycling costs into product prices. This method allows consumers to sell their waste to intermediate agents, who then sort and categorize the waste based on its type. Finally, the producer receives their waste and pays the intermediate agent. Since the producer includes the recycling cost in the initial product price, the entire process incurs no additional cost to them.

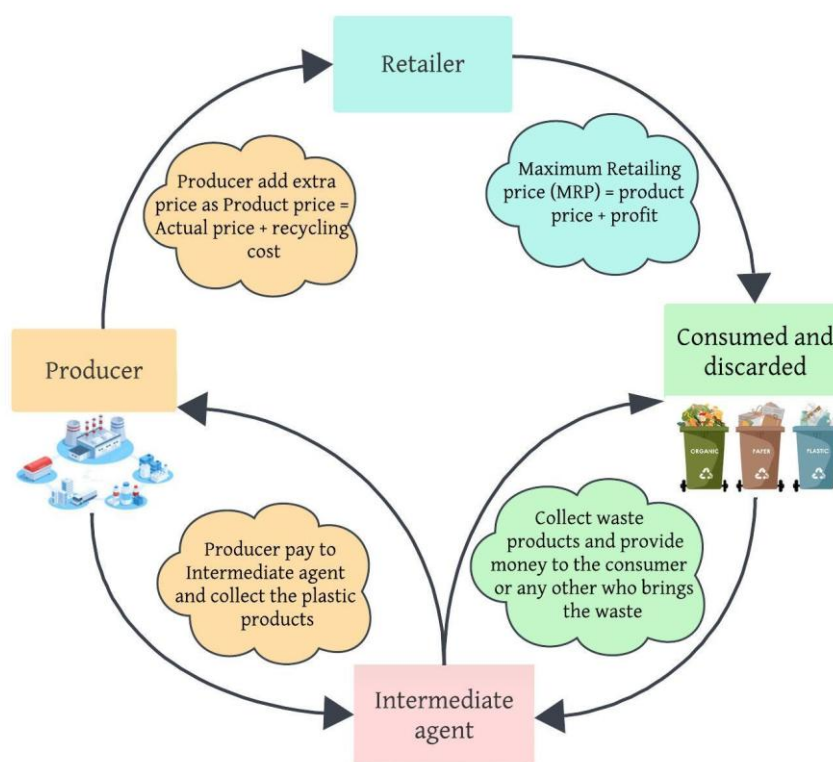


Figure 7 Proposed EPR implementation technique

## CONCLUSIONS

This study examines the generation and recycling of municipal solid plastic waste, particularly single-use plastics (SUP), in Patenga Ward. It reveals that responsible authorities are failing to effectively collect plastic waste at various stages, leading to significant environmental pollution. Additionally, recyclers exhibit limited interest in collecting SUP due to its lower profitability compared to other plastics. However, informal recyclers play a vital role in the material recovery process, integrating into the initial waste collection phase and thereby improving current recycling rates. This study and suggestions support city officials and policymakers to develop sustainable urban development plans for enhancing recycling initiatives across governmental and non-governmental organizations for environmental sustainability and protecting public health. However, a thorough investigation is necessary to compare different waste management strategies with existing methods, focusing not only on the quantity of waste but also on the potential for waste-to-energy (WtE) solutions.

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