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Polyethylene Terephthalate (PET) Recycling in Bangladesh: Current Status and Future Sustainability Prospects

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Abstract

The rapid growth in plastic consumption, particularly Polyethylene Terephthalate (PET), amidst the surge of population and urbanization in Bangladesh, underscores the urgent need for effective recycling strategies to combat environmental degradation and foster a sustainable future. This qualitative study delves into the current state of PET recycling in Bangladesh, unveiling the strides and hurdles within the sector. It reveals that significant advancements, such as the shift to mechanical, hot washing processes, have markedly improved PET recycling efficiency and economic value. Notably, the textile industry emerges as a key consumer of recycled PET, offering a potential boost to recycling demand. However, challenges persist, including consumer unawareness, inadequate infrastructure, and a raw material supply gap, with the country facing an annual demand for around 2 lakh tons of plastic scraps against a meager supply of 70,000 tons. Major PET-consuming brands like Unilever and Coca-Cola have played pivotal roles in enhancing the recycling landscape through integrating recycled PET into their products and fostering consumer education and strategic partnerships. Innovations such as chemical recycling technologies and AI-assisted sorting present promising prospects for the sector, alongside governmental incentives like a 10% cash rebate for exporting recycled products. The study concludes that while Bangladesh has made notable progress in PET recycling, significant opportunities for improvement remain. Addressing the identified challenges and leveraging technological advancements can amplify the impact of PET recycling on achieving Sustainable Development Goals, promoting a circular economy, and ensuring a greener, more sustainable Bangladesh.

Keywords

Polyethylene Terephthalate, Recycling, Waste Management, Circular Economy, Environmental Sustainability

1. Introduction

Polyethylene Terephthalate (PET) is a strong, transparent plastic widely used for packaging a variety of beverages, including soft drinks, water, energy drinks, iced teas, and even sensitive drinks like beer, wine, and juices (Siraj et al. 2023). Despite its robustness and clarity, there's a gap in understanding how these plastics might get contaminated during their first use or when they're collected for recycling. This gap has historically made it difficult to recycle PET bottles directly back into bottle manufacturing, mainly because the processes for removing contaminants weren't well understood. However, by 1991, significant progress was made in the United States when recycled PET received approval for direct contact with food, marking a significant step forward in PET recycling (Sarda et al. 2022).

PET is a major player in the packaging industry, constituting about 16% of Europe's plastic consumption in this sector and accounting for a significant portion of the global market with over 70 million tons produced annually (Güçlü and Orbay 2009; Carniel et al. 2021). While Europe leads with a recycling rate of 50%, showing a strong commitment to environmental sustainability, the U.S. lags behind with a recycling rate of about 29% (Alves 2023; Bhanderi et al. 2023). In Asia, countries like China and India are key to the PET recycling effort, even though the worldwide average recycling rate hovers around 20 to 30%. This disparity underscores the urgent need for improved recycling methods and international collaboration to promote a circular economy, where reusing PET can help decrease the production of new plastics and reduce environmental damage.In Bangladesh, the challenge of recycling PET is intertwined with the country's rapid economic and urban growth. Despite a significant increase in plastic consumption—tripling per capita in urban areas over the last 15 years—the recycling rates have not kept up. In 2020, only about 31% of the 9.77 lakh tons of plastic waste produced was recycled, a steep drop from 51% in 2006 (The World Bank 2021; The Daily Star 2023). This decline is concerning, especially as most post-consumer PET is recycled into lower-quality flakes, and the remainder contributes to environmental pollution by ending up in landfills.

Dhaka, the capital, sees a particularly high level of plastic consumption, more than three times the national urban average, at 22.25 kg per capita. The city collects about 646 tons of plastic waste daily, accounting for 10% of the country's total waste generation. However, only a small fraction of this is recycled, contributing to significant pollution in urban areas, waterways, and exacerbating problems like flooding.This situation emphasizes the urgent need for better waste management and recycling policies in Bangladesh. Improved systems are needed to handle the growing volumes of PET waste effectively, protect the environment, and capitalize on the economic opportunities of the recycling industry. Currently, the recycling of PET in Bangladesh faces multiple obstacles, including insufficient collection systems, a lack of sorting facilities, and limited infrastructure for recycling. Addressing these challenges is critical to enhancing the country's recycling efforts and ensuring a sustainable future.

Amid this situation, several research questions (RQ) arise:

- RQ1. What is the current scenario of PET recycling in Bangladesh?
- RQ2. What are the prospects for PET recycling in the country?

1.1 Objectives

To address these research questions, this article is structured around the following specific research objectives:

- RO1. Understand PET and its recycling process.
- RO2. Examine the status and challenges of the PET recycling industry in Bangladesh.
- RO3. Assess the role of global and Bangladeshi corporations.
- RO4. Explore the prospects of PET recycling in Bangladesh.

To the best of the authors' knowledge, this ongoing research represents one of the first attempts to explore the PET recycling industry in Bangladesh, which makes it novel.

2. PET and PET Recycling

2.1 Chemical and Mechanical Properties of PET

PET or PETE is a versatile thermoplastic belonging to the polyester polymer family. It is distinguished by its semi-crystalline structure and is widely appreciated for an impressive combination of properties that include strength, thermal resistance, chemical resistance, and dimensional stability. Its molecular structure is represented by the chemical formula $(C_{10}H_8O_4)$ n (see Figure 1).

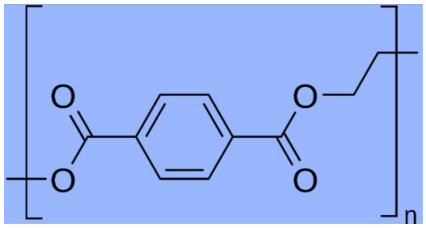
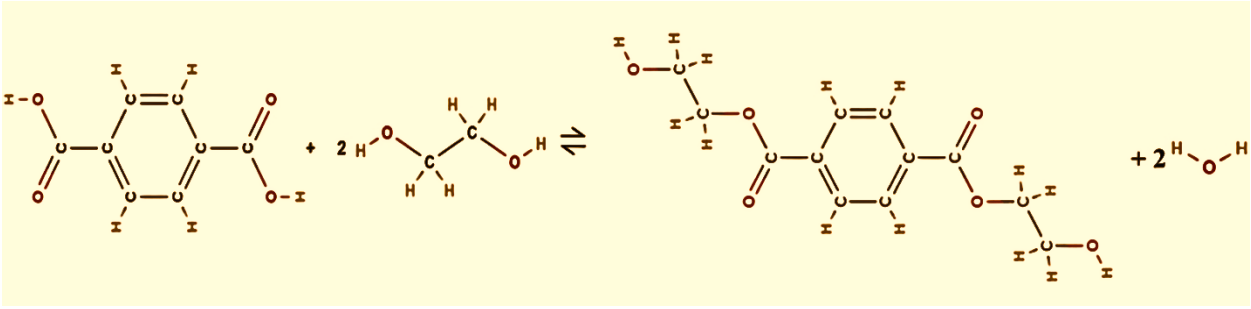
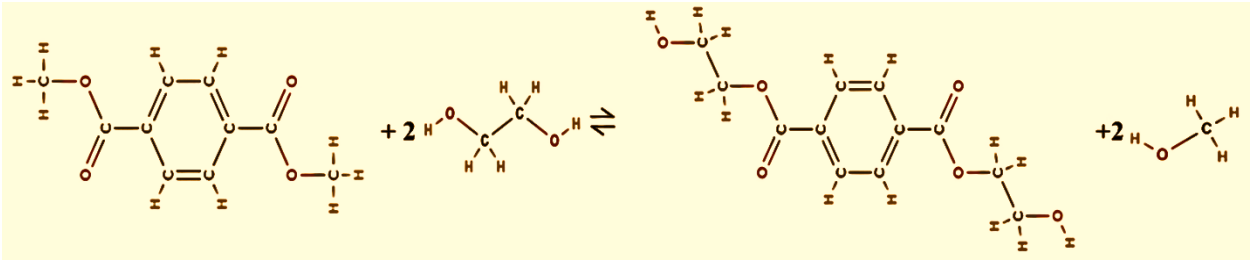


Figure 1. Structure of PET

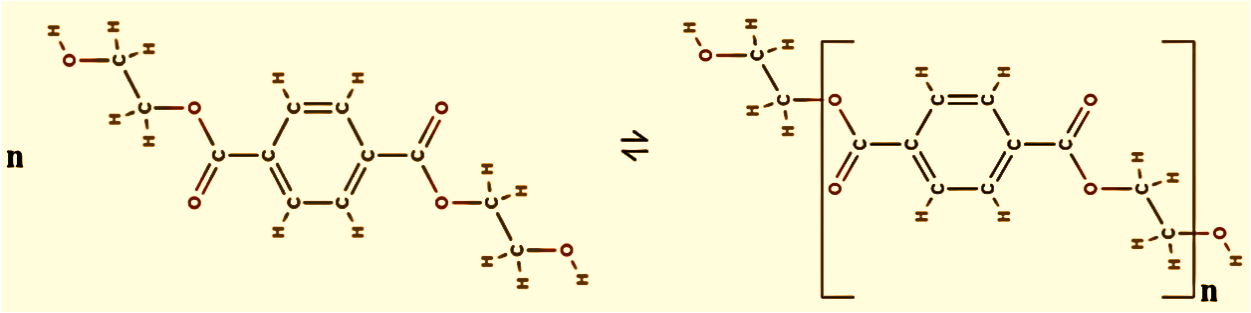
PET is an aliphatic polyester produced through a polycondensation reaction, which can proceed via two methods: esterification, involving the reaction of terephthalic acid with ethylene glycol, and transesterification, involving the reaction between ethylene glycol and dimethyl terephthalate (Elamri et al. 2017) (see Figure 2).



Esterification to form Bis(2-Hydroxyethyl) terephthalate



Transesterification to form Bis(2-Hydroxyethyl) terephthalate



Polymerization to form PET

Figure 2. Chemical reactions to produce PET

The production of PET results in a molten and viscous mass, which can be transformed into fibers or shaped into various forms through extrusion or molding. The selection of PET in manufacturing and product development is largely due to its remarkable properties, such as:

- Flexibility and Transparency: PET is naturally colorless and can range from semi-crystalline to rigid, depending on its processing. This makes it suitable for a wide variety of applications.
- Mechanical Strength and Stability: PET exhibits excellent dimensional stability, impact resistance, moisture resistance, heat distortion temperature (HDT), and stiffness.
- Barrier Properties: It is an effective barrier against gases like oxygen and carbon dioxide, as well as moisture, which is crucial for packaging applications.
- Temperature Range: PET can be used across a broad temperature spectrum, from -60°C to 130°C, accommodating various environments and applications.
- Electrical Insulation: Its excellent electrical insulating properties are valuable in electronic and electrical applications.
- Durability: PET is known for its resistance to breakage and shattering, making it an ideal replacement for glass in some uses.
- Recyclability: PET can be recycled multiple times. Combined with its approval for food and beverage contact by regulatory agencies worldwide, this makes it an environmentally and health-conscious choice.
- Chemical Resistance: It shows excellent resistance to a wide range of substances including alcohols, oils, and diluted acids and has moderate resistance to certain alkalis and hydrocarbons.

The glass transition temperature (Tg) of PET varies with its crystallinity level, generally falling between 67°C and 80°C, while its melting temperature is around 270°C (Demirel et al. 2011). The degree of crystallinity significantly influences its physical properties; PET can reach a crystallinity of 40-50%. Additionally, fillers like glass fibers or carbon nanotubes (CNTs) can be added to enhance its impact strength, surface finish, and reduce warpage.

2.2 Recycling of PET

PET is considered an eco-friendly material because it fits well into closed-loop recycling systems,

Table 1. PET recycling process

Stage	Description	Branches To
Collection	The process starts with the collection of PET bottles for recycling.	Opening
Opening	The collected PET bottles are then opened in preparation for further processing.	Pre-sorting and washing
Pre-sorting and washing	The opened bottles go through pre-sorting to remove caps, materials like PVC, PE, then washed.	Color sorting
	Branches out: Caps, PVC, PE.	
Color sorting	The pre-sorted and washed bottles are sorted based on color, separating clear from colored ones.	Chopping
	Branches out: Colorless, Green, Red bottles.	
Chopping	The color-sorted bottles are chopped into smaller pieces for further processing.	Float separation
Float separation	The chopped pieces undergo float separation to segregate PET from PE, PVC, PP, and solid waste.	Washing
	Branches out: PE, PVC, PP, Solid waste.	
Washing	The separated PET pieces are thoroughly washed with chemicals and water to remove contaminants.	Effluent treatment
Effluent treatment	The water used is treated to remove waste, ensuring environmental responsibility.	Rinsing
Rinsing	The PET pieces are rinsed to remove any residual chemicals or contaminants.	Drying
Drying	The clean, rinsed PET pieces are dried to prepare them for the next processing stage.	Melt-extrusion
Melt-extrusion	The dried PET pieces are melted and extruded to create a uniform, malleable material.	Fiber Spinning
Fiber Spinning	The extruded PET material is spun into fibers, transforming them into a new, usable form.	Finished fibers
Finished fibers	The process concludes with the production of finished fibers, which can be used for a variety of new products, such as textiles.	

which are designed to reuse materials repeatedly (Siraj et al. 2023). Even when PET waste comes in various forms and compositions, it can still be effectively broken down and purified. This recycling capability keeps PET valuable in a circular economy, where the goal is to minimize waste and make the most of resources. According to Muthu (2020), the recycling process of PET is as Table 1.

3. PET Recycling Industry in Bangladesh

3.1 Industry Overview

In Bangladesh, the conventional recycling of PET often yields low-quality flakes, contributing to environmental pollution (see Figure 3). To address this issue, post-consumer PET bottles are now being recycled through a mechanical, hot washing process. This method not only improves the quality of the recycled PET but also capitalizes on the bottles' full recyclability (Ghasemi et al. 2021). The resultant PET waste recycling aligns economic incentives with environmental benefits, as these bottles are transformed into various high-value products such as fabrics, monofilaments, and home goods, thus reducing pollution and creating market opportunities (Choudhary et al. 2019; Hossain et al. 2024).

This initiative's context highlights a stark contrast with the realities faced by informal waste collectors, as a field survey along the Karnaphuli Riverbanks, Patenga Beach in Chattogram, and Cox's Bazar municipality beaches has shown. These workers, who play a crucial role in the recycling value chain, endure hazardous and unhealthy conditions to collect materials like PVC, PP, HDPE, and PET bottles, which are highly valued in the recycling market (Yoshijima et al. 2021).

PET stands out in the recycling industry due to its bulk collection and premium market price, leading to a notably small presence in landfills in Bangladesh. In Dhaka alone, there are 300 facilities dedicated to recycling PET, a number that was on the rise as PET pellets could fetch higher prices on the international market, ranging from BDT 80 to 120 per kilogram—a figure surpassing domestic market values (Yoshijima et al. 2021). However, the fluctuation of oil prices has recently made PET recycling a less lucrative venture. Despite this, the textile industry in Bangladesh holds the potential to significantly bolster the demand for recycled PET, thereby reinforcing the sustainability of the plastic life cycle.

Figure 3. Low-Quality PET flakes with varied flake sizes, unsorted colors, and PVC contamination

The recycling of PET plastic waste in Bangladesh involves a multi-stage process that engages various stakeholders from the informal sector, which is instrumental in the labor-intensive collection and recycling practices. Initially, PET bottles and containers reach the end of their consumer life and are separated from other waste due to their economic value. The clean PET materials are often sold directly by consumers to itinerant waste collectors.

Figure 4. Collected PET bottles at scrap shops from waste pickers

In urban areas, van collectors and municipal crews collect soiled PET waste from households and transport it to dump sites. Here, informal waste pickers retrieve valuable PET materials, which are then sold to scrap shops (see Figure 4). Finally, these shops sort, clean, and prepare the PET waste before selling it to recycling facilities, where it is processed into pellets and granules. These recycled materials are then supplied to manufacturers who create new PET products, thus completing the cycle and reintroducing the material into the consumer market. The supply chain of the PET recycling industry in Bangladesh operates as shown in the following Table 2.

Table 2. Supply chain of the PET recycling industry in Bangladesh

Stage	Entities
Source	Households, waste bins, containers, dump sites
Collectors	Tokais (waste pickers), waste collectors (feriwalas or traveling collectors, vans and rickshaws waste collectors), Municipal crews
Buyers	Vangari dokans (scrap shops), wholesalers, brokers
Manufacturers	Pellet and granule manufacturers and recyclers, informal small industries that produce plastic products, formal plastic product manufacturers.

Despite recycling initiatives, only 34% PET waste is recycled (see Figure 5). Presently, the Bangladesh PET Flakes 'Manufacturers and Exporters Association' boasts a membership of 82 entities. Within this membership, a distinct minority, about 10%, possess the infrastructure required for hot washing processes in their facilities, a more costly yet

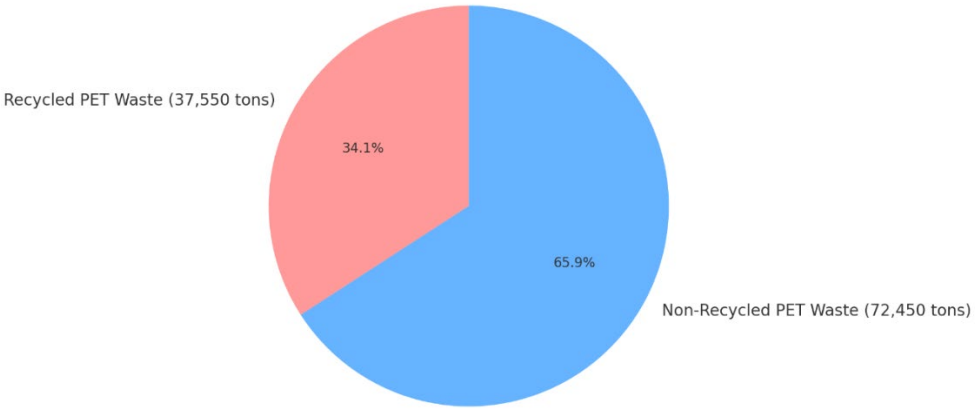


Figure 5. PET recycling scenario in Bangladesh (Yoshijima et al. 2021)

effective cleaning method. In contrast, the vast majority, 90%, operate with cold washing facilities, a choice driven by lower operational costs.

It is common practice among the leading exporters of PET flakes to acquire plastic flakes from numerous small-scale processors distributed throughout the nation. These flakes undergo further sorting and processing before being exported internationally. PET recycling operations in Bangladesh engage in exporting a variety of products, including PET straps, PET palettes, and shredded PET, primarily to nations like India, China, Thailand, Vietnam, Austria, Ukraine, the Philippines, Taiwan, and several European countries.Recently, Bangladesh has experienced a significant increase in PET recycling efforts, particularly in its northern areas such as Rangpur and Dinajpur. In these regions, almost 1,000 plastic recycling plants have emerged across eight districts (Karmaker 2022). This growth is primarily attributed to young entrepreneurs who have leveraged online resources like YouTube to gain recycling knowledge. These initiatives are making strides in tackling the issue of plastic waste while simultaneously generating employment opportunities.

3.2 Challenges of PET Recycling

In South Asian nations, the rapid acceleration of population growth, urbanization, and consumerism has led to a significant increase in plastic consumption, especially of PET products (Hossain et al. 2022). Improper disposal of these materials has contributed to increased environmental degradation, underlining the urgency to adapt feasible recycling solutions. As the economies of these countries continue to expand, the challenges in the PET recycling industry have only increased.The dominant challenges faced by the PET recycling industry in Bangladesh have been identified from a literature review, expert opinions, and feedback from recycling industry stakeholders. The challenges are as follows:

Lack of PET Consumer Awareness:

A key step in PET recycling involves sorting bottles by color and distinguishing them from other types of plastics (Muthu 2020). This preliminary sorting significantly simplifies the recycling process when end-users conscientiously dispose of bottles in designated color-sorted bins or separate them from other plastics. However, due to widespread unawareness about the importance and mechanics of recycling, many PET bottles are indiscriminately discarded, leading to their accumulation in landfills or waterways (Yoshijima et al. 2021). Such careless disposal contributes to environmental issues, including blocked water sources that can cause urban flooding. This widespread lack of understanding about the recycling process emerges as a major obstacle to effective PET recycling in Bangladesh. PET bottles are ubiquitously sold at roadside shops, restaurants, canteens, and cafeterias, creating a pervasive challenge. Typically, individuals purchase a water or soft drink bottle, consume it on the go, and then toss it aside without consideration for proper disposal.

Lack of Essential Infrastructure:

The efficient recycling of PET waste heavily depends on the availability of compatible infrastructure. Currently, the absence of such facilities impedes the collection, sorting, and processing stages of PET waste management, contributing to the escalation of plastic pollution. Investment is primarily minimal, originating mostly from young entrepreneurs whose machines and technical support lack structure and efficiency (Karmaker 2022). Consequently, this inadequately structured industrial infrastructure fails to produce high-quality PET flakes. Moreover, small-scale PET recyclers, aiming for a quick return on investment, merely cut and wash low-quality flakes (see Figure 6). Such processes do not yield export-quality PET flakes suitable for the reproduction of PET bottles and other items. Additionally, this approach fails to attract large investors capable of providing large-scale, high-quality machinery requiring substantial initial investments. This situation can be identified as one of the most significant challenges facing the PET recycling industry in Bangladesh.

Figure 6. A small-scale PET recycling factory in Khulna division, Bangladesh

Inadequate Raw Materials Supply: According to the Ministry of Commerce, there is a demand for around 2 lakh tons of plastic scraps in the industry (Ali 2021). The total supply of plastic scraps in Bangladesh, including local supply and import, is around 70,000 tons which is one-third of the total demand (see Figure 7).

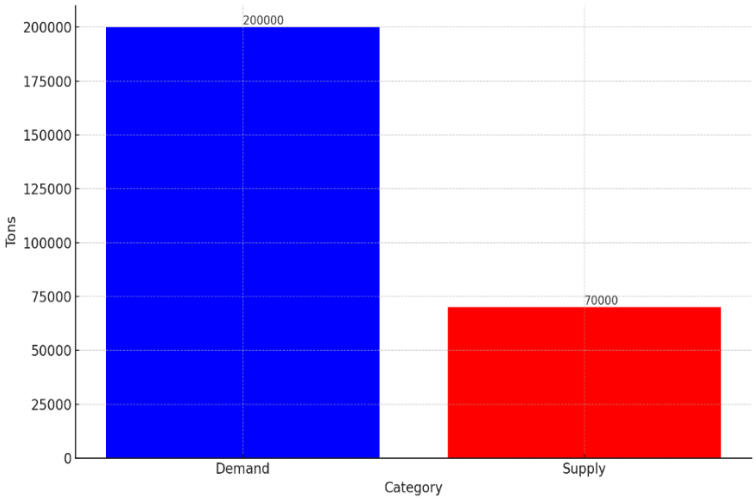


Figure 7. Demand vs Supply of plastic scraps in Bangladesh (annual)

In a recent report by the Bangladesh Trade and Tariff Commission, it's highlighted that Bangladesh imports approximately 100,000 tons of raw materials annually for producing PET bottles (Ali 2021). Out of these, only 20% of the bottles find a second life through reuse. The remaining 80% is unfortunately turned into plastic waste (see Figure 8).

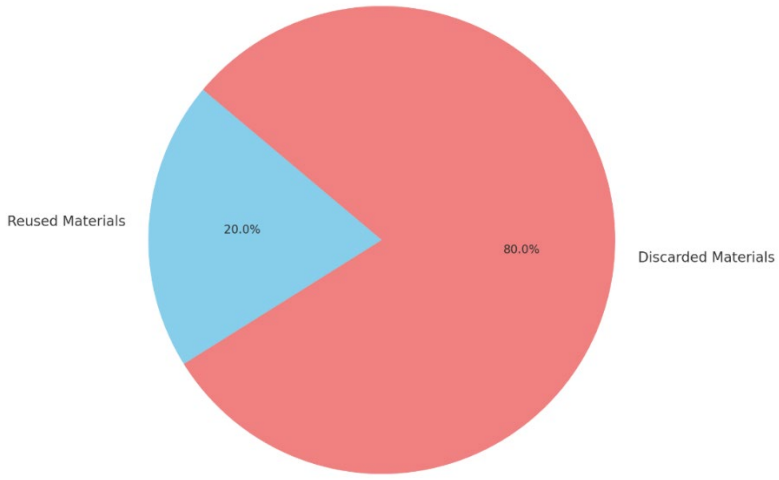


Figure 8. Status of imported PET bottle materials

Despite this, the shortage of raw materials is mainly due to the lack of properly organized waste gathering systems. Individual waste pickers walk beside the municipal drain, canal, and river side, some collect from the waste basket and collect PET bottles in their sack. Some buy from the household users or restaurants at a low price. All these collections are not significant enough to contribute to the PET recycling industry of Bangladesh. Therefore, the lack of organized raw material supply chain is another major challenge for PET recycling industry in the country.

Energy Crisis from Fossil Fuel Supply Disruption: PET recycling factories require consistent energy supply to operate their machinery, which can be powered either by electricity or directly by engines that run on fossil fuels. However, the global disruption in fossil fuel supply, compounded by Bangladesh's electricity crisis stemming from such disruptions, poses a significant challenge. This situation has led to hesitation among small entrepreneurs, who fear the high investment risks associated with potential energy supply interruptions. The resulting energy crisis, driven by the instability in fossil fuel supply, not only threatens the operational feasibility of these recycling ventures but also jeopardizes their profit margins (Yoshijima et al. 2021). Currently, this energy dilemma stands as a formidable obstacle for Bangladesh's PET recycling industry.

Inadequate Source of Information: A critical barrier to the growth of the PET recycling industry in Bangladesh is the lack of accessible, reliable information for potential investors. Currently, there are no government or corporate initiatives to guide new entrants through the supply chain, offer insights into potential customer bases, or outline opportunities for adding value to recycled PET products. Information sources are predominantly informal and lack reliability, with no dedicated platform consolidating relevant data for easy access. This absence of structured information hampers the industry's ability to attract entrepreneurs and investors, particularly those with advanced educational backgrounds, technical expertise, and managerial skills, who are notably scarce in this sector.
Furthermore, this information deficit obscures significant labor issues within the industry, including the employment of child labor and the underpayment and poor working conditions faced by women laborers. These practices remain largely unseen by the public and potential industry stakeholders. Interviews conducted with industry stakeholders for this study confirm that this challenge not only undermines the ethical standards of the industry but also poses a considerable threat to its sustainable development.

Inadequate PET Recycling National Policy: Bangladesh has achieved several key milestones in its efforts to manage plastic pollution. In 2005, the government instituted a ban on polyethylene bags through a regulatory order under the 1995 Environment Act. A significant advancement was made in 2012 with the launch of the 3R (Reduce, Reuse, Recycle) pilot initiative in Dhaka and Chittagong, which aimed to mitigate plastic pollution. Another critical development was the introduction of the 7th draft of the National Plastic Industry Development Policy in 2020, setting the stage for future plastic management strategies and the Plastic Industry Development Policy of 2023, designed to promote a circular economy in plastic usage.

Despite these initiatives, community engagement in PET recycling remains minimal due to the lack of widespread awareness campaigns by the government and corporate sectors in Bangladesh. Additionally, there is a noticeable absence of a direct policy targeting PET recycling that would compel corporations to adopt specific corporate social responsibilities for reducing environmental pollution through PET recycling.

3.3 Role of Corporations in PET Recycling Initiatives

Major PET-consuming brands can significantly shape the PET recycling landscape through their influence on consumer behavior, supply chain choices, and sustainability efforts (Ertz et al. 2023). Their market dominance allows them to boost the demand for recycled PET by incorporating it into their products. This not only diminishes the need for new PET but also sets a standard for other companies to emulate. Furthermore, these corporations can leverage their visibility to educate consumers about the importance of PET recycling and encourage proper disposal practices. Unilever, for example, recognizing the environmental toll of plastic waste, has committed to reducing its plastic footprint. In Bangladesh, Unilever has partnered with companies like Coca-Cola, Nestlé, and PepsiCo, alongside NGOs and recycling plants, to promote ethical PET waste handling. The company has increased its use of post-consumer recycled (PCR) plastic to 21% of its total packaging and is aiming for a 50% reduction in virgin plastic usage by 2025. Innovations like recyclable toothpaste tubes and single-plastic-type triggers exemplify their commitment.

Coca-Cola has undertaken a substantial project to escalate its PET recycling efforts. By implementing a robust use of PCR in its packaging and introducing 100% recycled PET bottles in Bangladesh and other countries, the company is advancing towards a target of 50% recycled material in its packaging by 2030. Coca-Cola's collaborations with various foundations to improve waste management underline its dedication to a circular economy.

Akij Food and Beverage Ltd, part of a major Bangladeshi conglomerate, has begun producing recycled PET for its beverage containers. With a Starlinger (a world-renowned recycling brand) system, the company turns PET flakes into pellets, tackling both environmental and economic issues while ensuring high-quality PET granulate production. PRAN-RFL Group has actively engaged in plastic recycling, processing around 30,000 tons of waste annually, and turning the majority into raw materials. The group's substantial investment in recycling has yielded significant environmental benefits and economic opportunities. With plans to open a PET bottle recycling plant that could produce fabric, PRAN-RFL is reinforcing its commitment to innovation in recycling.

Despite these initiatives, there's room for improvement. Companies could invest in research to refine recycling processes, collaborate with industry partners to amplify their efforts, and integrate informal waste collectors into a formal recycling framework, ensuring fair compensation and better working conditions (Scheinberg et al. 2016). Incentivizing consumers to return used PET products can bolster waste collection rates. Furthermore, corporate support for recycling-friendly policies and regulations could catalyze progress (Wan et al. 2019).

In essence, while prominent brands have markedly advanced the PET recycling sector in Bangladesh through awareness campaigns, sustainable practices, and infrastructure development, opportunities abound for further enhancements. These include technological innovation, policy advocacy, consumer engagement, and collaborative industry action. However, by continuing to refine their strategies and by leveraging their considerable influence, these brands can affect even greater positive changes in PET recycling.

4. Prospects and SDGs Achievement

4.1 Prospects of PET Recycling

As policymakers, researchers, and practitioners around the world continue to strive for a sustainable globe, there is much to be done in the PET recycling industry, especially at the Bangladeshi level. There are numerous prospects in this specific sector that can elevate PET recycling to a higher level. The prospects are as follows:

Chemical Recycling Technologies: Chemical recycling and depolymerization are forefront technologies enabling the breakdown of PET into fundamental components for new PET or valuable materials production (Jehanno et al. 2022). These methods surpass traditional mechanical recycling by accommodating complex waste streams. Furthermore, the application of enzymes for PET breakdown presents an eco-friendly avenue for improving recycling processes, offering a potent solution to the challenges of plastic waste (Babaei et al. 2024).

Upcycling: This process transforms recycled PET into higher-value products with enhanced qualities, thereby opening new markets for recycled materials in the textiles, packaging, and 3D printing sectors (Zhang et al. 2024). This presents a significant opportunity for the industry in the coming days.

Smart Sorting and Collection: Leveraging Artificial Intelligence (AI), machine learning, and robotics can revolutionize PET waste sorting and collection, minimizing contamination and maximizing high-quality recycled material output (Salem et al. 2023).

Government Regulations and Incentives: Stricter environmental policies and financial incentives are key drivers in advancing the recycling of PET (Kalita et al. 2023). Such measures spur investments in research and recycling technologies, making embracing closed-loop systems essential for establishing the PET recycling industry. Moreover, investing in an extensive network of recycling centers is critical. Thoughtfully distributed across both urban and rural areas, these centers should offer easily accessible drop-off points for PET waste (Willis et al. 2023). At this moment, the government of Bangladesh is offering financial incentives to boost the recycling sector. One notable initiative is a 10% cash rebate to encourage the export of recycled PET bottles and products.

Consumer Consciousness: Increasing consumer consciousness regarding the environmental footprint of products is fueling the demand for items made from recycled PET (Raj et al. 2023). This shift towards more eco-conscious consumption is propelling recycling efforts, as consumers make choices that support sustainability. Industries, governments, non-profits, and academic institutions are coming together to drive innovation in PET recycling. This synergy is not only hastening technological advancements but also smoothing the path for widespread adoption of these recycling technologies.

Waste-to-Energy Solutions: For PET waste that is heavily contaminated, waste-to-energy technologies present a practical solution by converting plastics that cannot be recycled into energy. A waste-to-energy facility of 42.5 MW capacity is slated for construction at the Aminbazar landfill in Dhaka, with an estimated cost of approximately $300 million (Gulfam-E-Jannat et al. 2023). This plant is anticipated to offer a promising approach to managing unsorted and contaminated PET waste.

4.2 Achieving SDGs through PET Recycling

The PET recycling industry is a dynamic force driving progress across several Sustainable Development Goals (SDGs). It champions SDG 12 by promoting responsible consumption and production, facilitating a circular economy through the recycling of PET, thus diminishing the reliance on virgin plastics. This process is pivotal for SDG 13, as it substantially lowers carbon emissions—recycled PET results in only 0.45 kg of CO_2 per kilogram compared to 2.15 kg for its virgin counterpart, aiding in the fight against climate change (Muthu 2020).

In urban areas, the industry advances SDG 11 by enabling cleaner cities through efficient waste management and reduced pollution. Job creation within the recycling sector supports SDG 8, fueling economic growth and providing valuable employment opportunities, while also contributing to SDG 5 by employing women and supporting gender equality in the workforce. Moreover, the export revenue from recycled PET products bolsters SDG 17 by enhancing global partnerships and economic resilience. Lastly, the industry exemplifies SDG 9 by establishing industrial innovation and infrastructure through continuous improvement in recycling technologies, setting a benchmark for sustainable industrial practices.

5. Conclusion

This research embarked on an exploratory journey to dissect the complexities and potentialities of PET recycling in Bangladesh, a subject of paramount importance for the country's environmental sustainability and economic development. Through an in-depth analysis, this study has addressed the posed research questions (RQs) and fulfilled its specific research objectives (ROs), thereby shedding light on the multifaceted nature of PET recycling in Bangladesh and charting a path forward.

Addressing RQ1, the study unveiled the current scenario of PET recycling in Bangladesh as a landscape marked by significant achievements and enduring challenges. The transition to mechanical, hot washing recycling processes underscores a notable improvement in recycling efficiency and the economic value of recycled PET, highlighting progress towards RO1 and RO2. Despite this, the research identified critical obstacles, including consumer

unawareness, inadequate infrastructure, and a mismatch between supply and demand of plastic scraps, directly speaking to RO2.

In response to RQ2, our exploration into the prospects for PET recycling illuminated a promising yet untapped potential within the sector. The advent of innovative technologies such as chemical recycling and the application of AI in sorting processes herald a new era for PET recycling, aligning with RO4. Moreover, the study emphasized the instrumental role of major PET-consuming corporations in Bangladesh, including Unilever and Coca-Cola, in advancing the recycling agenda through their sustainability initiatives, thereby addressing RO3. These corporations not only integrate recycled PET into their products but also actively participate in consumer education and form strategic partnerships, fostering a more circular economy.

The research further highlighted the significant impact of governmental incentives, such as the 10% cash rebate for exporting recycled products, in bolstering the recycling industry—a critical aspect of RO2 and RO4. Consumer consciousness and demand for products made from recycled PET were identified as pivotal in driving the recycling market forward, affirming the importance of societal engagement in achieving sustainability goals.This qualitative article comprehensively addressed the research questions and objectives by presenting a detailed analysis of the current state and prospects of PET recycling in Bangladesh. It underscored the importance of technological innovation, corporate responsibility, government policy, and consumer awareness in shaping a sustainable recycling ecosystem. While challenges remain, the pathways identified for enhancing the efficiency and effectiveness of PET recycling efforts offer a hopeful outlook for not only mitigating environmental impacts but also contributing to the economic resilience of Bangladesh. As the country stands at the crossroads of environmental responsibility and economic opportunity, this study serves as a foundational piece for policymakers, industry stakeholders, and the academic community to build upon for a sustainable future.

This study has limitations, chiefly its reliance on accessible data and possible variations in recycling practices across Bangladesh. It also lacks depth from the perspective of informal waste collectors, critical to a full understanding of the recycling landscape. Future research should expand data sources, include more detailed analyses of technological impacts on recycling, and investigate the socio-economic implications of enhanced recycling methods. Addressing these gaps will enrich the dialogue on sustainable PET recycling and contribute to broader sustainability efforts.

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