Paper ID: CE 416

Socio-Environmental Role of Stakeholders of Recycling Waste Trade in Khulna City

A. A. Hasan[1], Q. H. Bari[2], I. M. Rafizul[3], J. A. Saju[4], E. Kraft[5], P. Lorber[6]

[1]Institute of Disaster Management, Khulna University of Engineering and Technology, Bangladesh (aahasan.esdm@gmail.com)
[2]Department of Civil Engineering, Khulna University of Engineering and Technology, Bangladesh (qhbari@ce.kuet.ac.bd)
[3]Department of Civil Engineering, Khulna University of Engineering and Technology, Bangladesh (imrafizul@ce.kuet.ac.bd)
[4]Department of Civil Engineering, Khulna University of Engineering and Technology, Bangladesh (jobaerahmed.ce@gmail.com)
[5]Bauhaus-Universität Weimar, Bauhaus-Institute for Infrastructure Solutions (b.is) Weimar, Germany (eckhard.kraft@uni-weimar.de)
[6]Bauhaus-Universität Weimar, Bauhaus-Institute for Infrastructure Solutions (b.is) Weimar, Germany (philipp.lorber@uni-weimar.de)

Abstract

The exponential expansion of urban centers has resulted in a surge of municipal solid waste (MSW) production, presenting a significant conundrum in ensuring secure and efficient disposal at designated sites. The recycling process is deemed as the most advantageous approach to handling MSW. The study delves into and scrutinizes the contribution of stakeholders in attaining economic and environmental benefits from plastic recycling in specific regions of Khulna City. Data and information were gathered through a comprehensive questionnaire survey conducted on stakeholders of recycling waste trades namely waste collectors, recycling waste traders (RWT), and Recycling Shop (RS) owners to accomplish the desired objective of the study. The findings of the study revealed that a seamless recycling value chain exists among the stakeholders. Waste collectors, RWTs, and RS owners hold a pivotal role as primary stakeholders in the recycling sector of Khulna City. As per the results, the cost of recycling 1 kg of plastic is only 10.79 BDT and the price of 1 kg of recycled plastic is 70 BDT. 1 kg of virgin plastic is sold at 168 BDT. The emission of greenhouse gases from recycling 1 kg of plastic is 1.823 kg CO_2e lower than the production of 1 kg of virgin plastic. Recycling plastic waste mitigates greenhouse gas (GHG) emissions by circumventing virgin materials from the manufacturing process. Hence, recycling plastic waste not only curtails GHG emissions but also bolsters economic benefits.

Keywords: *Recycling, plastic, stakeholders, GHG, benefits*

1 Introduction

The management of waste is a matter of paramount significance for the country of Bangladesh (Abedin & Jahiruddin, 2015; Shams et al., 2017). The increasing populace coupled with limited land resources presents a significant conundrum in the area of waste management in numerous developing nations, including Bangladesh. The annual waste output in Bangladesh stands at 5.2 million tonnes (Shams et al., 2017). The quantity of municipal solid waste in metropolitan areas is rising because the population is growing (Abedin & Jahiruddin, 2015). The six major cities of Bangladesh - Dhaka, Chittagong, Khulna, Rajshahi, Barisal, and Sylhet - are highly unlikely to produce 7690 tons of municipal solid waste on a daily basis, as found by Alamgir and Ahsan's study. Among these cities, Dhaka accounts for 69% of the total waste stream. The wholeness of the trash stream is composed of 74.4% biological matter, 9.1% paper, 3.5% plastic, 1.9% fabric and lumber, 0.8% hide and elastic, 1.5% metal, 0.8% glass, and 8% miscellaneous waste materials(Alamgir & Ahsan, 2007). Plastic materials have a proclivity to persist in the environment for a prolonged duration and display no biodegradability. Landfills are unsafe for plastic waste because it releases toxic chemicals that can contaminate

soil, water, and aquatic life. Hence, civic authorities face a major problem in dealing with plastic waste (Sangawar & Deshmukh, 2012).

Developing countries like Bangladesh face challenges in managing plastic waste due to inadequate facilities, infrastructure development and insufficient budget. These factors contribute to improper plastic management in the country (Mourshed et al., 2017). "Recycling" represents a pivotal action that is currently available to mitigate environmental pollution and conserve resources (Hopewell et al., 2009). Bangladesh harbors immense potential for the operation of the recycled plastic industry. Nevertheless, the industry is bereft of the necessary governmental and institutional support (Hossain & Shams, 2020).

A reuse chain that operates silently, systematically, smoothly, and cleanly has been successfully established in the city of Khulna. The entire management of this chain lies solely with the private sector. Private sectors are involved in the endeavor of reusing and recycling 38.80 metric tons of solid waste on a daily basis. This amount accounts for 7.65% of the overall waste generated within the city of Khulna (Bari et al., 2012). The act of collecting solid waste by the private sector has resulted in a noteworthy annual revenue savings of 13,404,140.28 Tk (Moniruzzaman et al., 2011).

Recycling presents the most favorable approach to addressing plastic waste management from both an environmental and socioeconomic perspective (d'Ambrières, 2019). Reducing GHG emissions from plastics can be achieved by recycling, which is a potential strategy. Through this process, there can be a reduction in carbon-intensive virgin polymer production. Furthermore, recycling materials can have a substantial impact on preventing greenhouse gas emissions from particular end-of-life processes such as burning (Zheng & Suh, 2019). It's not only concerning the reduction of landfill waste and net energy consumption when recycling PET bottles, it also produces a net benefit of 1.5 tonnes of CO_2-e for each tonne of recycled PET. As a helpful policy guideline, an average net reduction of 1.45 tonnes of CO_2-e per tonne of recycled plastic has been approximated (Hopewell et al., 2009).

The substantial economic advantages of plastic recycling are noteworthy (García, 2016). The utilization of recycled plastic can yield significant economic advantages through the reclamation and reuse of waste materials (Satapathy, 2017). In Khulna City, for example, The reuse scheme had a total of 859 individuals engaged in various activities (Bari et al., 2012). In the city of Khulna, an estimated 2000 individuals are engaged in the task of collecting approximately 34 tons of residential solid waste (RSW) on a daily basis, which is subsequently sold to dealers within the locality. The process of recycling this waste material involves a significant number of 450 dealers (Moniruzzaman et al., 2011).

From an environmental perspective, recycling plastic can reduce greenhouse gas emissions, conserve natural resources, and prevent pollution. From an economic perspective, recycling plastic can create jobs, save costs, and generate revenue. By recognizing and supporting the role of stakeholders, including waste collectors, RWT, and RS owners in plastic waste recycling, these benefits can be further maximized, contributing to sustainable development in Khulna City and beyond. The paper aims to evaluate the environmental and economic benefits of plastic recycling by stakeholders in Khulna City.

2 Research Methodology

2.1 Study Area

Khulna, located in the southwestern region of Bangladesh, holds the position of the third-largest city in the country. It is positioned on the banks of the river Rupsha and Bhairab. The city serves as the second port entry in Bangladesh, and its official recognition as a city corporation transpired on August 6, 1990. Khulna's geographic location can be pinpointed between 21.38' and 23.1 north latitude as well as 88.58 east longitude. Covering 45.65 sq. k. m., the Khulna City Corporation is composed of 31 wards (KCC, n.d.). These wards are the smallest administrative urban geographic units, which comprise mahallas and have ward council institutions. The urban centre has a population of approximately 1,500,689 and a total of 177,852 households (BBS, 2013; KCC, n.d.). Ward-9, one of the most extensive wards of Khulna City Corporation, covers 3.58 sq. k. m. and has 7451 households with 31,882 populations (BBS, 2014). The study conducted a comprehensive field survey on Ward-9, which covered plastic recycling involving stakeholders, including a significant number of waste collectors, RWT and, two RS of Ward-9. Ward-9 can be observed in Figure 1.

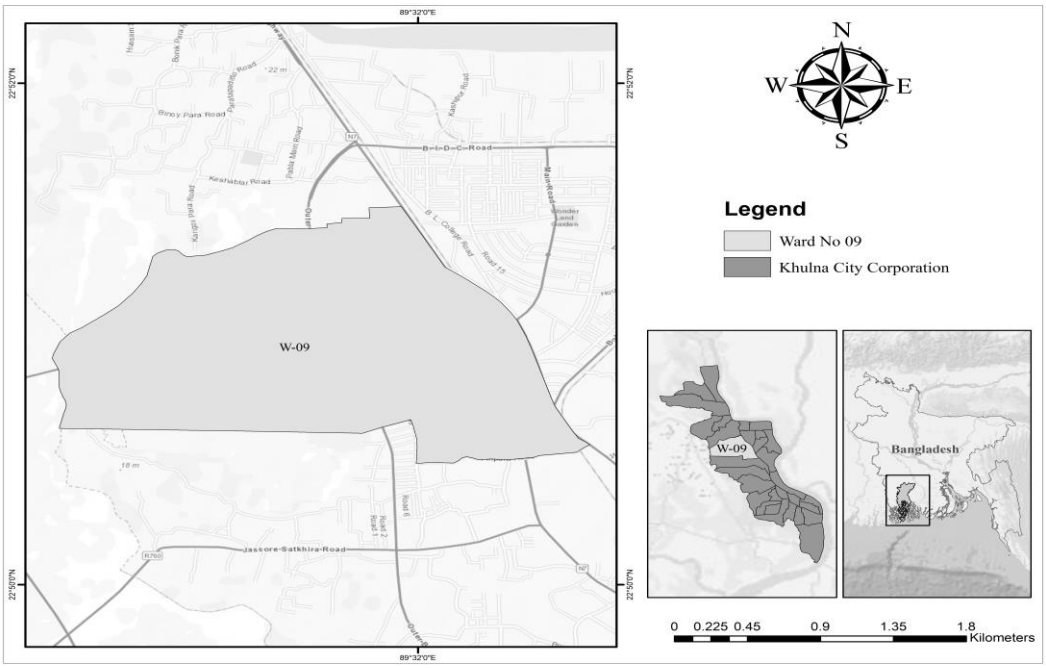

Figure 1. A location map of Ward-9 within the Khulna City of Bangladesh is contemplated within the context of the study.

2.2 Questionnaire Survey

The present study employs both quantitative and qualitative data, gathered through questionnaire surveys. The stakeholders involved in plastic recycling in Khulna City, namely waste pickers, hawkers, recycling waste traders (RWT), and recycling shop (RS) owners, were interviewed using semi-structured questionnaire forms. To enhance the questionnaire's effectiveness, a preliminary survey was conducted at the RTW of the Fulbarigate area of Khulna City. The questionnaire forms were tailored to suit the specific stakeholders.

In Ward-9 of Khulna City, there are 94 hawkers and 43 waste pickers associated with 17 RWT. Most waste collectors are designated to sell the waste they gather to RWT as part of the well-developed value chain that enables the recycling process in Khulna City. The RWT provides three-wheelers and advanced payment to the designated hawkers so that they sell the waste to the same RWT. After sorting and compacting, the RWT sells the goods to RS. The RWT also takes advanced payment from RS owners to provide the goods. In Khulna City, there are 35 RS, where plastic waste is sorted, cut into plastic flakes and ultimately undergone a washing and drying process before they are sold to the recycling industry or utilized to create new end products. Only six RS are capable of making new end products from plastic flakes, while the rest are sold to the recycling industry.

3 Results and Discussion

3.1 Waste Collection by Waste Collectors

Two distinct categories of waste collectors operate within the urban confines of Khulna City, both of whom engage in this activity for entrepreneurial purposes. These individuals are identified as hawkers and waste pickers. Generally, the former relies on three-wheeled vehicles to transport waste, while the latter carries a sack over their shoulder as they move about their work. In Ward-9 of Khulna City, there exists a total of 94 hawkers and 43 waste pickers who are closely associated with 17 RWTs. Notably, 95% of the hawkers utilize electric three-wheelers while the remaining 5% rely on foot-driven three-wheelers. The collection cost is exclusively borne by the hawkers due to their use of three-wheeler vehicles. Conversely, waste pickers are not encumbered by any cost in the collection of waste. The present study endeavours to gather data from a sample of ten hawkers. It was discovered that plastic waste accounts for 20% of the waste collected by hawkers. Therefore, the cost incurred for the collection of plastic waste is estimated to be 20% of the total collection cost.

It has been ascertained from the conducted questionnaire survey that, a total of 10 hawkers amass a cumulative amount of 3,300 kilograms of plastic every month. Upon careful analysis of Table 1, it can be deduced that the cost of collecting a single kilogram of plastic amounts to 0.48 Bangladeshi Taka. In the present questionnaire study, it is noteworthy that all three-wheelers were exclusively electric in nature. The focus is primarily on the expenses related to electricity consumption and maintenance. It is important to note that for the study, the repairing cost or other associated expenses of three-wheelers fall under the category of ' Miscellaneous cost'. Capital expenditure or purchase cost of three-wheelers are not taken into account. This is because, ultimately, a significant portion of the purchase price of three-wheelers can be recuperated by selling the vehicle at the end of the business cycle or at any given time.

Table 1. The monthly expenditure incurred in the recycling of plastic waste

Steps of plastic waste recycling	Electricity billing cost	Wages of workers	Miscellaneous cost	Total cost	Cost of regarding plastic waste
Plastic waste collection	5,000 BDT	-	3,000 BDT	8,000 BDT	1,600 BDT
Sorting and separating at RWT	8,500 BDT	-	51,000 BDT	59,500 BDT	10,710 BDT
Transportation of plastic waste from RWT to RS	4,900 BDT	-	10,900 BDT	15,800 BDT	15,800 BDT
Processing of plastic waste to flakes or grains at RS	21,000 BDT	375,100 BDT	154,000 BDT	550,100 BDT	550,100 BDT

At the stage of collection, the discharge of greenhouse gas is predominantly occasioned by the utilization of electricity for the purpose of recharging the battery of electronic three-wheelers. Ordinarily, waste pickers obtain refuse via ambulation. Thus, the quantification of greenhouse gas emissions at the collection phase can be achieved by computing the aggregated unit usage as revealed on the electricity bill. The relevant calculation is presented in Table 2.

According to a circular issued by the government, viable as of February first 2023, the new rate for electricity has been set at 7.82 BDT per kilowatt-hour (kWh) (Rahman, 2023). Hence, during the collection process, an electricity bill of 1,000 BDT shall be accountable for the consumption of 127.88 units (kWh) of electricity. The production of electricity in Bangladesh is heavily dependent on coal, diesel, and natural gas power plants, which respectively release 0.90 kg/kWh, 0.76 kg/kWh, and 0.566 kg/kWh of CO_2e (Karmaker et al., 2020). Therefore, the electricity-generating power plants in Bangladesh release 0.742 kg CO_2e/kWh of greenhouse gas, and 127.88 units (kWh) are responsible for 94,886.96 gCO_2e. Thus, during the collection of 1 kg of plastic, it discharges 28.75 gCO_2e of greenhouse gas.

3.2 Waste Sorting and Separation at RWT

The waste collectors are responsible for vendoring the waste to RWT, as per the waste management system in the place. Ordinarily, predetermined waste collectors vend their products to designated shops, whereas autonomous waste collectors vend their goods at any establishment as they operate their enterprises with their investments. Primarily, the first stage of waste sorting and segregation is executed at RWT. Manual sorting and separation of waste are conducted, and no machinery is utilized. The comprehensive cost of waste sorting and segregation at RWT is evaluated and presented in Table 1. It has been discovered that 17 RWTs handle 28 tons of plastic waste every month, which constitutes 18% of the total waste segregated and sorted. Therefore, the cost of sorting and segregation for plastic waste at RWT is 18%. Based on the calculations presented in Table 1, the cost of sorting and operation for 1 kg of plastic waste will be 0.38 tk. Investment costs are not taken into consideration. Only monthly electricity expenses, and sundry expenses are taken into account when arriving at the cost of segregation and sorting at RWT.

In the sorting and segregation stage, the Recycling Waste Trade (RWT) does not employ any machinery to manage waste, instead relying solely on manual labour. Thus, the recycling waste trade in Khulna City cannot be held responsible for emitting greenhouse gases, with the only source of such emissions arising from electricity usage. Specifically, the collective electricity bill of the 17 RWT entities in Ward-9 amounts to 8,500 BDT, with 1530 BDT (18%) of this bill attributed to the plastic waste segment.

Table 2. Monthly GHG emissions resulting from electricity usage in plastic waste recycling

Electricity billing cost	Cost of regarding plastic waste	Consumed electricity	GHG emissions
5,000 BDT	1,000 BDT	127.88 unit (kWh)	94,886.96 gCO_2e
8,500 BDT	1,530 BDT	195.65 unit (kWh)	145,172.3 gCO_2e
4,900 BDT	4,900 BDT	626.6 unit (kWh)	464,937.2 gCO_2e
21,000 BDT	21,000 BDT	2,685.42 unit (kWh)	1,992,583 gCO_2e

Based on the aforementioned data, this plastic waste segment accounts for the consumption of 195.65 units (kWh) of electricity, which in turn leads to the production of 145,172.3 gCO_2e of greenhouse gas. Within the 17 RWT entities located in Ward-9 of Khulna City, 28 tons of plastic waste are processed, with the processing of 1 kg of plastic waste by the RWT resulting in emissions of 5.18 gCO_2e of greenhouse gas.

3.3 Transportation of Waste from RWT to RS

For the most part, the proprietors of RS establishments acquire plastic waste from RWT and assume responsibility for transporting said waste from RWT to their respective RS facilities. For the purposes of the study, conducted a survey of two RS facilities located in Ward-9 were conducted, wherein it was discovered that the RS proprietors themselves are responsible for transporting the materials procured from RWT, utilizing electric vehicles which they personally own. The monthly costs associated with said transportation are itemized in Table 1. The individuals who possess the RS solely manage the plastic waste. The investigation of the study revealed that a duo of shops deal with an impressive 57 metric tons of plastic waste per month. According to Table 1, it is evident that the conveyance expense for the aforementioned quantity of plastic waste amounts to 15,800 BDT. Therefore, each kilogram of plastic waste is accountable for 0.28 BDT.

Two RS were surveyed, and from the findings, it has been ascertained that the vehicle employed for the conveyance of plastic waste from RWT to RS operates on electricity. Thus, the origin of the greenhouse gas emissions is traceable to the utilized electrical energy, which serves to charge the vehicle's battery. A comprehensive breakdown of the greenhouse gas emissions has been provided in Table 2. From the tabulated data, it is unequivocally evident that two commercial establishments are accountable for a total of 464,937.2 gCO_2e of greenhouse gas emissions on a monthly basis, by means of transporting 57 metric tons of plastic waste. It is noteworthy that at the transportation level, each kilogram of plastic waste engenders 8.16 gCO_2e of greenhouse gas emissions on a monthly basis.

3.4 Sorting, Shredding, Washing, Drying and Making Grains at RS

The RS proprietors hold a crucial position among the stakeholders in the plastic recycling value chain operating in Khulna City. Numerous activities are conducted at this stage. Upon the transportation of plastic waste from RWT to RS, the workers at RS sort the plastic waste into distinct local grades. Subsequently, these materials are subjected to cutting through a shredding machine, thereby producing flakes. Following the production of the flakes, they are washed and subsequently dried in an open area. The dried flakes are subjected to a machinery system where they are transformed into grains, which are ultimately recycled. The monthly expenses associated with plastic waste recycling at RS are presented in Table 1.

It is evident that for the purpose of sorting, cutting, washing, and drying plastic waste, the cost per kilogram amounts to 9.65 BDT. The study conducted by two RS proprietors utilized electrically powered machinery to manufacture plastic flakes, as well as plastic granules. The sole origin of greenhouse gas discharges in RS is the utilization of electricity. The meticulous computation of greenhouse gas emissions in RS is expounded upon in table 2. All plastic waste emanating from RWT undergoes processing and recycling in RS. The observations are revealed that two surveyed RS facilities generate an average of 34.96 g CO_2e of greenhouse gas emissions for every 1 kg of plastic waste subjected to sorting, cutting, washing, drying, and ultimately, granulation.

3.5 Economic and Environmental Benefit of Recycled Grain

The economic ramifications and greenhouse gas emissions associated with each stage of plastic recycling in Khulna City are computed, with the objective of converting 1 kilogram of plastic waste into granules on an individual basis. A comprehensive account of the aggregate economic cost and greenhouse gas emission for producing 1 kilogram of recycled plastic granules is provided in detail in Table 3.

Table 3. Cost and GHG emissions of 1 kg recycled plastic grain

Steps of plastic waste recycling	Cost of recycling (BDT)	GHG emission (gCO_2e)
Waste collection	0.48	28.75
Activities at RWT	0.38	5.18
Transportation	0.28	8.16
RS	9.65	34.96
Total	**10.79**	**77.05**

Regarding the expenditure incurred on recycled plastic pellets, the analysis was solely taken into account the processing expenses and did not incorporate the procurement costs of plastic waste resources. Nevertheless, the study uncovered that the proprietors of RS enterprises vend the recycled plastic granules at a rate of 70 BDT per kilogram. On the contrary, it is noteworthy that the mean cost of virgin plastic grains stands at 168 BDT per kilogram (Hestin et al., 2015). In contrast, the cost of recycled granules is 98 BDT lower than that of recycled plastic granules per kilogram. On average, the generation of virgin plastic emits 1.9 kg CO_2e per kg (*Virgin vs. Recycled Plastic Life Cycle Assessment Energy Profile and Life Cycle Assessment Environmental Burdens*, 2020). Conversely, the investigation revealed that recycled plastic granules are accountable for a mere 0.077 kg CO_2e per kg.

3.6 Roles of Stakeholders in Plastic Recycling

In the domain of plastic recycling, stakeholders fulfill essential roles that collectively enhance the efficient and ecologically responsible governance of plastic waste. The investigation undertaken in Khulna City elucidates the multifaceted involvement of diverse stakeholders in the plastic recycling value chain. Waste collectors, comprising hawkers and waste pickers, serve as the initial participants by actively gathering plastic waste from households and the environment. Recycling Waste Traders (RWTs) emerge as pivotal intermediaries, receiving waste from collectors, conducting sorting and segregation, and

eventually supplying the waste to Recycling Shop (RS) owners. The RS proprietors are instrumental in the subsequent stages of recycling, where plastic waste is transformed into flakes and granules suitable for reuse. Through manual sorting, cutting, washing, and drying procedures, RS owners ensure the conversion of waste into valuable materials. Collectively, these stakeholders establish a symbiotic relationship, each contributing unique expertise and efforts that culminate in the successful recycling of plastic waste. This collaborative effort not only fosters economic benefits through job creation and cost savings but also significantly mitigates greenhouse gas emissions, promoting environmental sustainability in Khulna City and beyond.

Conclusion

It is of great significance to recycling that the recycling of plastic is vital in reducing the burden on landfills and cutting down the necessity for incineration, both of which culminate in the emanation of perilous greenhouse gases (GHGs). the study reveals that substituting virgin plastic grains with recycled grains decreases carbon dioxide equivalent (CO_2e) by 1.823 kg per kg. Furthermore, it is imperative not to overlook the economic advantages of plastic recycling. The recycling sector generates job opportunities, triggers local economies, and fosters creativity. In the study, it was discovered that recycled granules have a cost that is 98 BDT lower than that of recycled plastic granules per kilogram. Moreover, the economic benefits are also applicable to the realm of energy conservation. The process of recycling plastic necessitates less energy as opposed to the manufacturing of fresh plastic from basic substances. However, notwithstanding the apparent advantages, there exist impediments that require attention in order to fully optimize the potential of plastic recycling. These obstacles consist of augmenting collection and sorting systems, amplifying consumer awareness and engagement, cultivating advanced recycling technologies, and establishing efficacious regulatory frameworks that incentivize recycling practices. In summary, plastic recycling presents a persuasive resolution to combat the ecological and economic quandaries posed by plastic waste, particularly concerning the reduction of greenhouse gas emissions. Through embracing recycling practices, a sustainable future can be promoted wherein the unfavorable impacts of plastic pollution are minimized, resources are conserved, and economic expansion is attained in concert with environmental preservation. It is essential for stakeholders from diverse sectors to collaborate, invest in study and development, and implement comprehensive strategies that prioritize plastic recycling, ultimately propelling us towards a more verdant and prosperous world.

References

Abedin, M. A., & Jahiruddin, M. (2015). Waste generation and management in Bangladesh: An overview. Asian Journal of Medical and Biological Study, 1(1), 114–120. https://doi.org/10.3329/ajmbr.v1i1.25507

Alamgir, M., & Ahsan, A. (2007). MUNICIPAL SOLID WASTE AND RECOVERY POTENTIAL: BANGLADESH PERSPECTIVE. 4(2).

Bari, Q. H., Mahbub Hassan, K., & Haque, R. (2012). Scenario of solid waste reuse in Khulna city of Bangladesh. Waste Management, 32(12), 2526–2534. https://doi.org/10.1016/j.wasman.2012.07.001

BBS. (2013). District Statistics 2011 Khulna (p. 128). http://203.112.218.65:8008/WebTestApplication/userfiles/Image/District%20Statistics/Khulna.pdf

BBS. (2014). POPULATION & HOUSING CENSUS-2011 (National Series, p. 640). http://203.112.218.65:8008/WebTestApplication/userfiles/Image/National%20Reports/Population%20%20Housing%20Census%202011.pdf

d'Ambrières, W. (2019). Plastics recycling worldwide: Current overview and desirable changes. Field Actions Science Reports. The Journal of Field Actions. https://www.semanticscholar.org/paper/Plastics-recycling-worldwide%3A-current-overview-and-d%E2%80%99Ambri%C3%A8res/4bb8778dfe7037d3ae613b7f90975034245c9082

García, J. M. (2016). Catalyst: Design Challenges for the Future of Plastics Recycling. Chem, 1(6), 813–815. https://doi.org/10.1016/j.chempr.2016.11.003

Hestin, M., Faninger, T., & Milios, L. (2015). Increased EU Plastics Recycling Targets: Environmental, Economic and Social Impact Assessment (p. 54). Plastic Recyclers Europe.

Hopewell, J., Dvorak, R., & Kosior, E. (2009). Plastics recycling: Challenges and opportunities. Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1526), 2115–2126. https://doi.org/10.1098/rstb.2008.0311

Hossain, M., & Shams, A. (2020). Export Potential of Recycled Plastic: A Study on Bangladesh. Asian Social Science, 16(3), 12. https://doi.org/10.5539/ass.v16n3p12

Karmaker, A. K., Rahman, Md. M., Hossain, Md. A., & Ahmed, Md. R. (2020). Exploration and corrective measures of greenhouse gas emission from fossil fuel power stations for Bangladesh. Journal of Cleaner Production, 244, 118645. https://doi.org/10.1016/j.jclepro.2019.118645

KCC. (n.d.). About KCC. Official Website of Khulna City Corporation. Retrieved May 8, 2023, from http://www.khulnacity.org/Content/index.php?page=About_KCC&a2g&pid=0

Moniruzzaman, S. M., Bari, Q. H., & Fukuhara, T. (2011). Recycling Practices of Solid Waste in Khulna City, Bangladesh. The Journal of Solid Waste Technology and Management, 37(1), 1–15. https://doi.org/10.5276/JSWTM.2011.1

Mourshed, M., Masud, M. H., Rashid, F., & Joardder, M. U. H. (2017). Towards the effective plastic waste management in Bangladesh: A review. Environmental Science and Pollution Study, 24(35), 27021–27046. https://doi.org/10.1007/s11356-017-0429-9

Rahman, A. (2023, February 1). Retail power price: Hiked again, in just 3 weeks. The Daily Star. https://www.thedailystar.net/environment/natural-resources/energy/news/retail-power-price-hiked-again-just-3-weeks-3235606

Sangawar, V., & Deshmukh, S. (2012). A Short Overview on Development of the Plastic Waste Management: Environmental Issues and Challenges. Scientific Reviews and Chemical Communications. https://www.semanticscholar.org/paper/A-Short-Overview-on-Development-of-the-Plastic-%3A-Sangawar-Deshmukh/dd346e732fb3761d08d918e773a11a65a127f309

Satapathy, S. (2017). An analysis of barriers for plastic recycling in the Indian plastic industry. Benchmarking: An International Journal, 24(2), 415–430. https://doi.org/10.1108/BIJ-11-2014-0103

Shams, S., Sahu, J. N., Rahman, S. M. S., & Ahsan, A. (2017). Sustainable waste management policy in Bangladesh for reduction of greenhouse gases. Sustainable Cities and Society, 33, 18–26. https://doi.org/10.1016/j.scs.2017.05.008

Virgin vs. Recycled Plastic Life Cycle Assessment Energy Profile and Life Cycle Assessment Environmental Burdens (p. 3). (2020). The Association of Plastic Recyclers.

Zheng, J., & Suh, S. (2019). Strategies to reduce the global carbon footprint of plastics. Nature Climate Change, 9(5), 374–378. https://doi.org/10.1038/s41558-019-0459-z