WASTE CONCERN

Bangladesh **Waste Database** 2021

Prepared by **Waste Concern**

Bangladesh

Waste Database

2021

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Abbreviation

3R	Reduce, Reuse, Recycle
CEGIS	Centre for Environmental and Geographic Information Services
CO_2	Carbon Dioxide
kg	Kilogram
m^3	Cubic Meter
sq. km	Square Kilometer

Introduction

This report is based on the findings from the 2019 – 2021 study conducted by Waste Concern under the project titled "**Promotion of 3R (Reduce, Reuse and Recycle) Principle in the Solid Waste Management Sector in Bangladesh**". Based on the study waste generation projections are made for the years 2021, 2030, and 2041. Moreover, a GIS database on waste generation has also been prepared. The database has information on population, waste generation, land availability, land requirement, GHG emissions, and faecal sludge generation for all 340 urban local bodies.

Objectives

The objectives of this report are to provide an:

- Estimation of the total quantity of waste generated in the urban areas of Bangladesh;
- Estimation of the quantities of waste generated by the different cities and pourashavas of Bangladesh;
- Analysis of the composition of waste in urban areas of Bangladesh;
- Estimation of land area required for landfilling in Bangladesh;
- Estimation of greenhouse gas emissions from landfilling activities in Bangladesh;
- Identification of co-benefits of emissions reductions through improved waste management practices in Bangladesh;
- Review of the current waste management policies and legislation in Bangladesh.

Methodology

This report covered 340 urban localities in Bangladesh of which 12 were city corporations, 183 were Category A pourashavas, 104 were Category B pourashavas, and 41 were Category C pourashavas.

The sum of all total waste generation amount of the 340 pourashavas and city corporations were added to the estimated total waste generation amount of non-pourashava urban areas to establish a figure for the total domestic urban waste generation; here, it was 20,157.48 tons per day during the dry season.

To include the portion of waste generated from non-domestic sources in the estimates, the total domestic urban waste generation amount was multiplied by a factor to calculate the amount of total urban waste generation, which was found to be 9,888.46 tons per day.

The study recognises that waste generation rates during the wet season were estimated to be approximately 40% higher than during the dry months of a year. Accordingly, to estimate the total daily urban average waste generation rate, the wet season was assumed to last for 120 days, while the dry period was assumed to last for 245 days.

Thus, the total daily urban waste generation average was estimated to be 33,574.30 tons per day, or 0.52 kg per capita per day.

A previous field survey conducted by Waste Concern in 2005 and published as *Urban Solid Waste Management Scenario of Bangladesh: Problems and Prospects*, was used as a comparative backdrop and a scale against which the findings in this report were compared. The 2005 field survey involved a questionnaire along with physical measurements of waste generated at households and at landfill levels. The next field survey was conducted by Waste Concern in 2020. The data for 2021 was estimated from the field survey conducted for the study titled "**Promotion of 3R (Reduce, Reuse and Recycle) Principle in the Solid Waste Management Sector in Bangladesh**".

Table 1: Number of Pourashavas by Waste Generation Amount

Range of Total Generated Waste (Tons per day)	Count	Percentage (%)
Upto 20	209	61.47
20-40	79	23.24
40-60	16	4.71
60-80	11	3.24
80-100	1	0.29
100+	24	7.05
Total	**340**	**100.00**

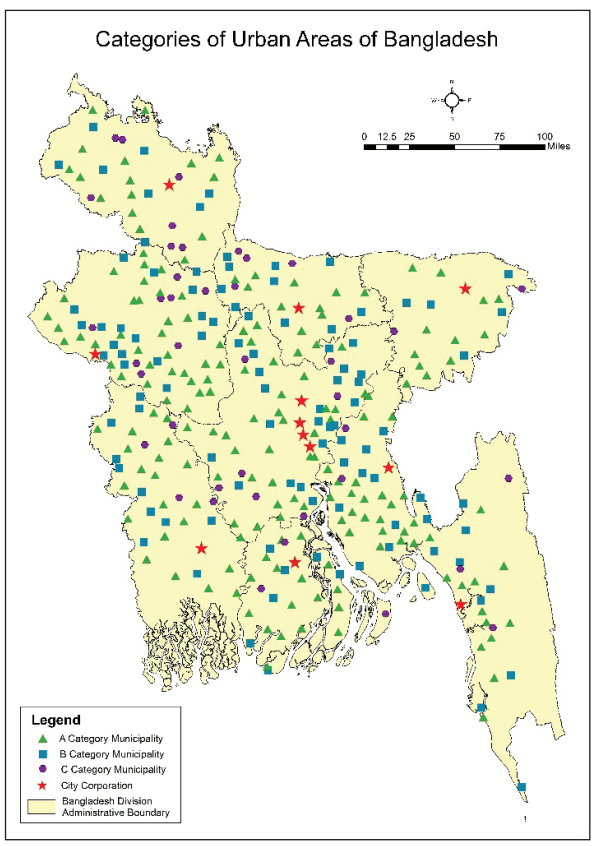

Image 1: *Categories of Urban Areas (2021)*

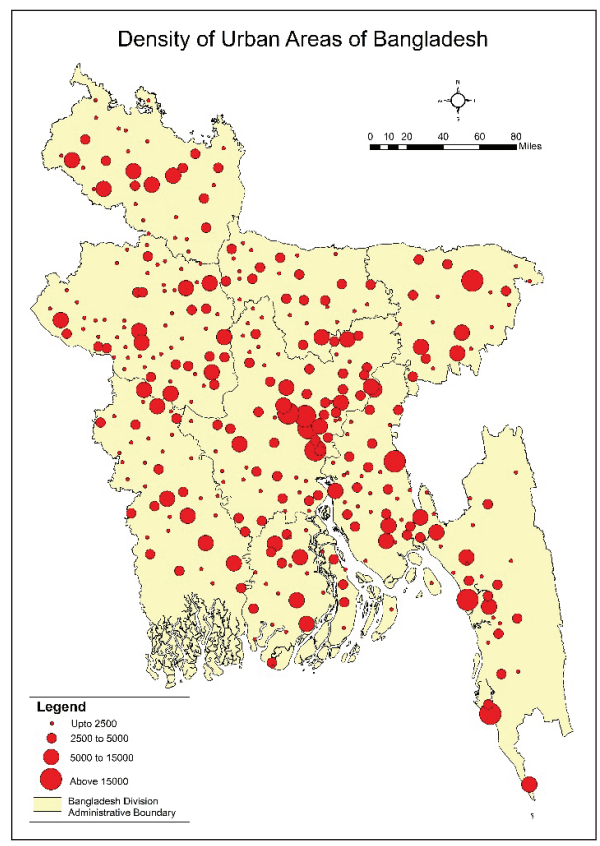

Image 2: *Population Density (2021)*

Data for the maps was collected from the Urban Area Report of 2011. Next, it was projected for 2021. Bangladesh's total 340 urban areas are depicted in Image 1. Of these urban areas, there were 12 city corporations, 183 A class municipalities, 104 B class municipalities, and 41 C class municipalities. The densities of urban areas are shown in Image 2.

Image 3 depicts the waste generation rates of urban areas. Eighty six percent of the urban areas with a population of up to 1 lakh had a waste generation rate of 0.36 kg/person/day. Seven percent of the urban areas had a waste generation rate of 0.37 kg/person/day, while rest seven percent of the urban areas had a waste generation rate higher than 0.37 kg/person/day. Image 4 represents the total waste generation amount of urban areas. Almost 93% of these urban areas had a waste generation amount less than 85 tons per day. However, 3 urban areas had a higher waste generation rate of 400 to 850 tons/day; the other 5 urban areas had a waste generation rate exceeding 850 tons/day.

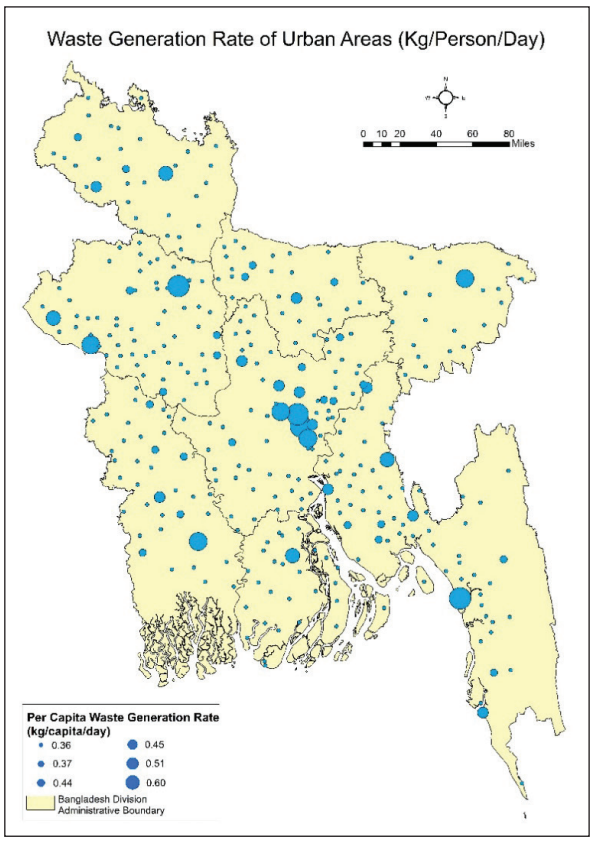

Image 3: *Map of total waste generated (2021)*

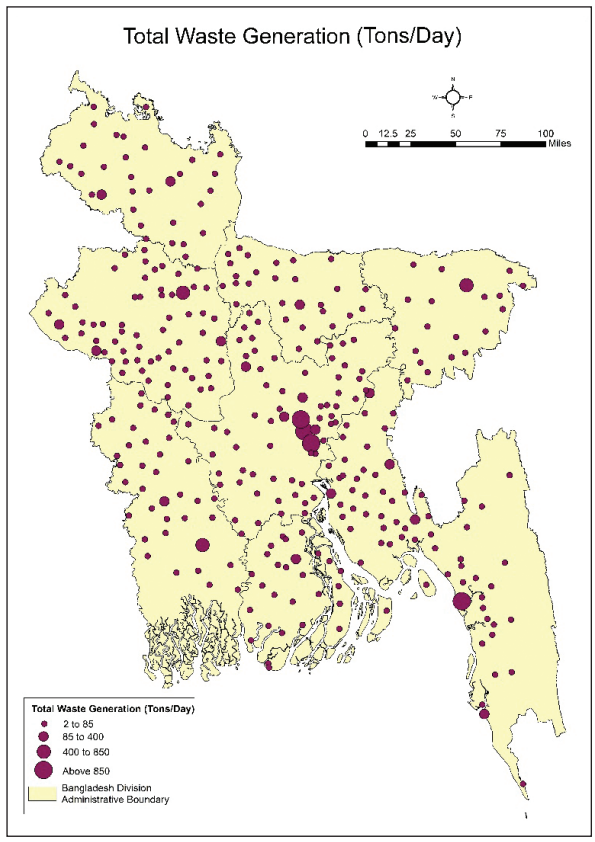

Image 4: *Map of per capita waste generation rate (2021)*

Waste Generation

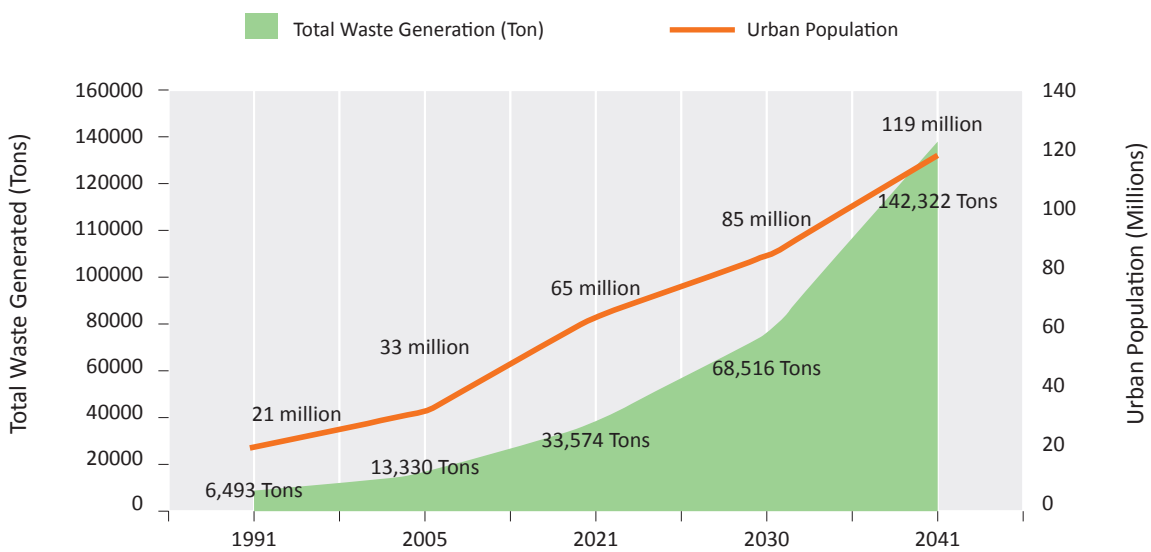

Figure 1: *Total Waste Generation vs. Urban Population*

The total amount of waste generated every day in Bangladesh has been increasing annually since 1991. In 1991, the urban areas of Bangladesh were generating approximately 6,493 tons per day of municipal solid waste; by 2005, that figure had more than doubled to reach 13,330 tons per day. In 2014, it was estimated that Bangladesh generated 23,688 tons per day in its urban areas. At the same time, the total urban population of Bangladesh has increased from 21 million in 1991 to 33 million in 2005 due to rapid urbanisation. The population of 2021 is estimated to be 65 million. The total urban population is estimated to be as high as 85 million by 2030 and 119 million by 2041. Similarly, the total waste generation is expected to reach 142,322 tons per day by 2041. Hence, there is a link between greater amounts of waste generated and a higher urban population. Interestingly, since 2005, the rate of change of daily total waste generated has exceeded the rate of change of the population growth due to an increase in the average daily per capita waste generation rate.

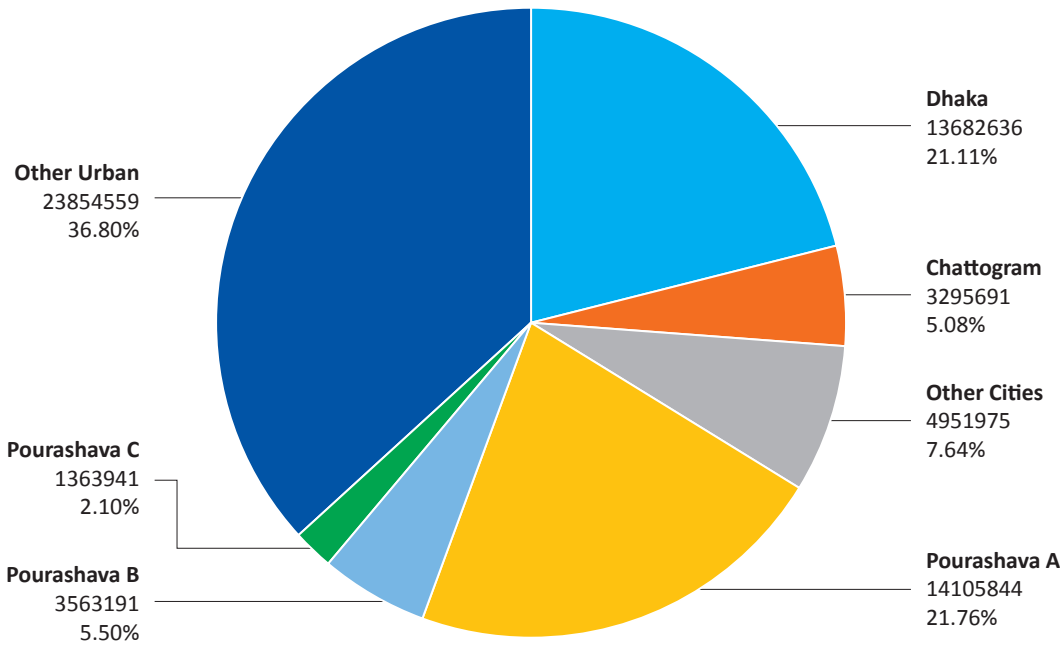

Figure 2: *Urban Population of Bangladesh*

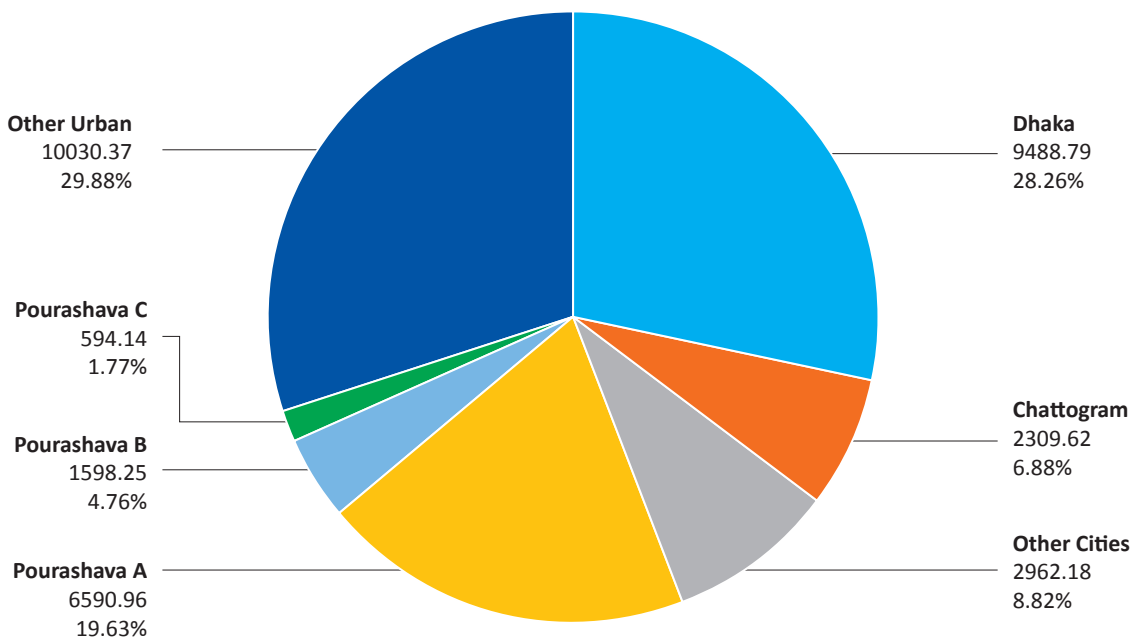

Figure 3: *Urban Waste Generation Tons Per Day (2021)*

When comparing the percentages of the urban population with the percentages of waste generation, interesting patterns emerge in the waste generation of the two largest cities in Bangladesh. Dhaka, being the largest city in Bangladesh, is inhabited by 21.11% of the country's urban population and generates 28.26% of the country's urban waste. Similarly, the second largest city in Bangladesh, Chittagong, is populated by 5.08% of the country's urban population, but generates 6.88% of its urban waste. Alternatively, other much smaller urban areas, those not categorised as cities or pourashavas, collectively constitute 36.80% of the urban population of Bangladesh, but only generate 29.88% of its urban waste.

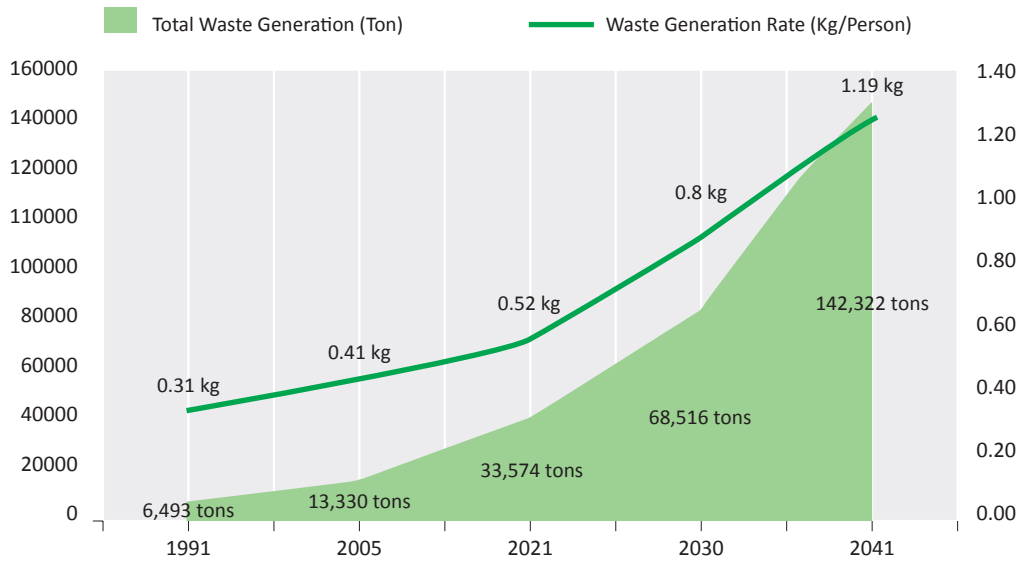

Figure 4: *Total Waste Generation vs. Per Capita Waste Generation Rate*

In 1991, the daily waste generation rate per person was estimated to be 0.31 kg per capita per day (World Bank, 1998). By 2005, this rate had increased to 0.41 kg per capita per day (Enayetullah et al. 2005). The waste generation rate was estimated to be 0.52 kg per capita per day for 2021. According to projections, the daily waste generation rate is expected to reach 0.80 kg per capita per day by 2030 and 1.19 kg per capita by 2041.

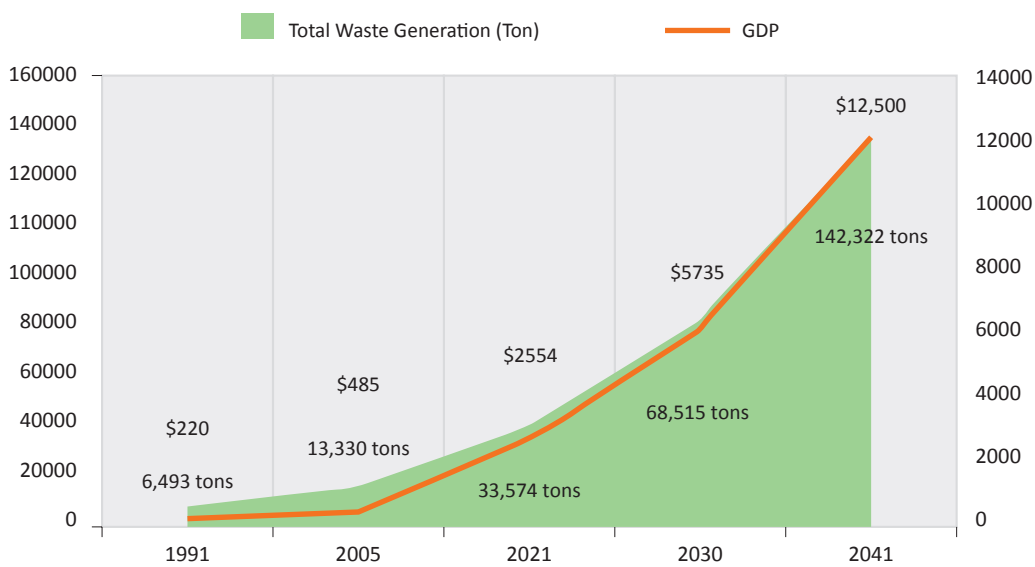

Figure 5: *Total Waste Generation vs. GDP*

While the per capita per day waste generation rate has been increasing, the GDP of Bangladesh has similarly experienced growth. From 1991 to 2005, the GDP of Bangladesh has increased from $220 to $485 (UMP 1999). The rate of GDP growth increased exponentially from 2005 onwards, reaching $2554 by 2021. A distinct correlation exists between an increasing waste generation rate and a higher GDP.

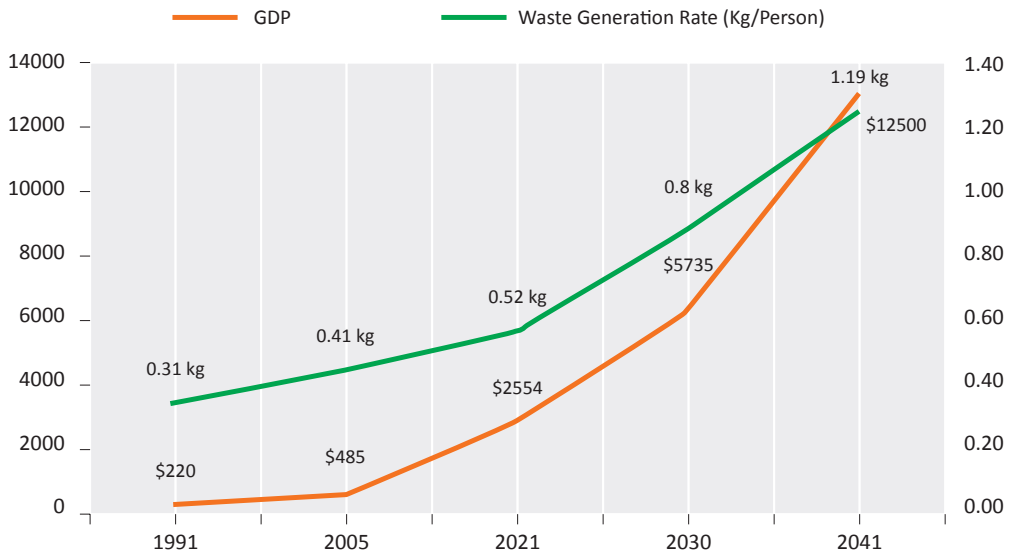

Figure 6: *Per Capita Waste Generation Rate vs. GDP*

In a business-as-usual scenario, with both the GDP and the per capita waste generation rate increasing at current rates, Bangladesh would expect its GDP to reach $5,735 by 2030 and $12,500 by 2041 and its waste generation rate to reach 0.80 kg and 1.19 kg per capita per day respectively.

Waste Composition

The composition of municipal solid waste in Bangladesh vis-a-vis different waste types during the years 2005, 2014, and 2021 are depicted below. The study differentiates the waste composition in cities as different to the waste composition in pourashavas. The umbrella term *"urban areas"* is used to refer to cities and all categories of pourashava.

On average, in urban areas of Bangladesh, food waste still constitutes the majority of waste ending up at the landfill at 77.70% of total waste generated in 2014. This is an increase of +9.01% from the 2005 urban average of 68.69%. The percentage of food waste in pourashavas experiences a similar increase from 2005 to 2014, with data recording an increase of +7.08% from 70.70% to 77.78%. Similarly, the percentage of food waste in cities increased +6.32% from 69.32% in 2005 to 75.64% in 2014. In case of 2021, the food waste constitutes 79.5% of total generated waste. There is an increase in urban areas, pourashava, and cities by +1.8%, +2.96%, and +4.26% respectively, from 2014 to 2021 as food waste makes up 79.9% and 80.74% in city and pourashava area respectively.

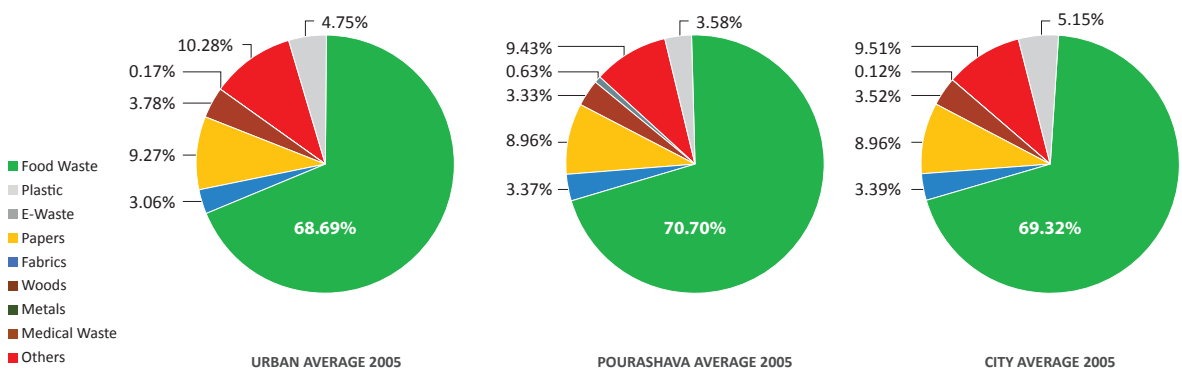

Figure 7: *Average Composition of Waste 2005 (Source)*

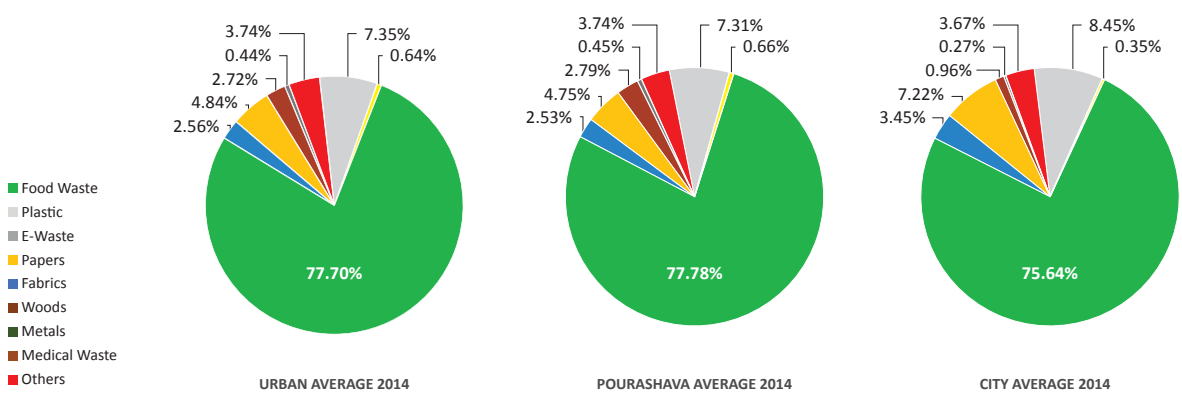

Figure 8: *Average Composition of Waste 2014 (Source)*

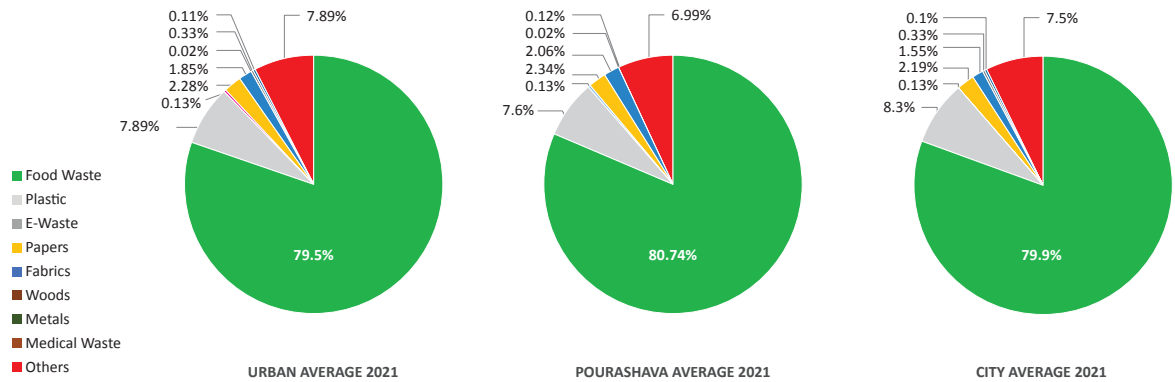

Figure 9: *Average Composition of Waste 2021 (Source)*

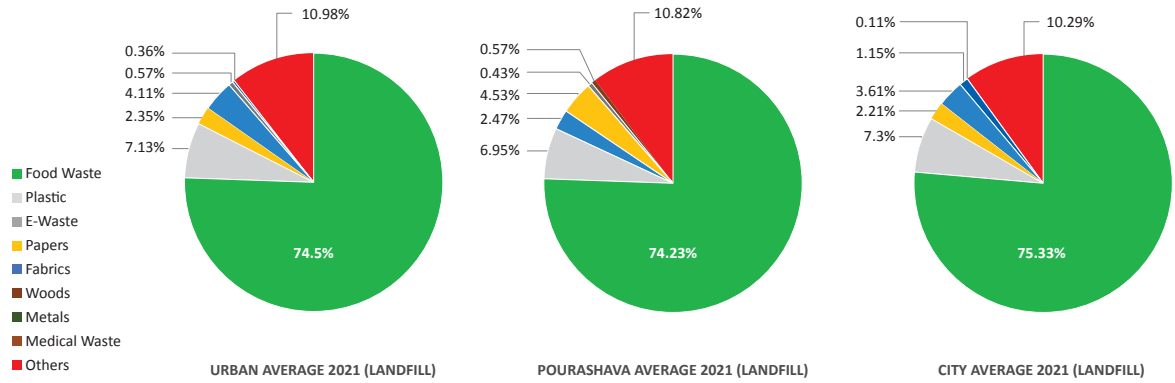

Figure 10: *Average Composition of Waste 2021 (Landfill)*

Overall, in urban areas of Bangladesh, the percentage of plastics in waste ending up at the landfill has gone up by +2.60% from 4.75% to 7.35% between 2005 and 2014. This is predominant in cities of Bangladesh where the amount of plastic waste has increased by +3.30% from 5.15% to 8.45% over the same time period. Pourashavas have also experienced an increase in quantities of plastic waste, with a change of +3.73% from 3.58% to 7.31%. From 2014 to 2021, the percentage of plastic waste has increased by +0.54% and +0.29% in urban areas and pourashava respectively but decreased by -0.15% in cities as the percentage of plastic waste in urban, pourashava, and city areas are 7.89%, 7.6%, and 8.3% respectively.

Alternatively, the percentage of paper waste has decreased in urban areas of Bangladesh from 2005 to 2014, with a reduction of -4.43% from 9.27% to 4.84%. A similar reduction in paper waste is witnessed in the cities, with a decrease of -1.77% from 8.99% to 7.22%. The percentage of paper waste in pourashavas has also decreased by a corresponding -4.21% from 8.96% in 2005 to 4.75% in 2014. From 2014 to 2021, paper waste consists of 2.28%, 2.34% and 2.19% respectively. Therefore, a decrease can be seen by -2.56%, -2.41%, and -5.03% respectively in urban, city and pourashava areas.

The increase in plastic and decrease in paper waste is perhaps indicative of changes to the selection of packaging materials in Bangladesh, with plastic packaging becoming preferred over paper packaging.

Electric and electronic waste, also referred to as e-waste, was not recorded in its own distinct category in 2005, falling under the more generic *"Other"* category at the time of the 2005 publication. The latest study categorises electric and electronic waste as its own distinct waste type, constituting 0.64% of the urban total, 0.66% of pourashava total, and 0.35% of city total in 2014. In 2021,the percentage of e-waste decreased to 0.13% in urban, pourashava and city areas.

In cities, the percentage of wood in total waste generated has decreased from 3.52% to only 0.96%, meaning a decrease of -2.57% from 2005 to 2014, while on average in urban areas the percentage of wood has decreased by -1.06% from 3.78% to 2.72% over the same time period. Similarly, in pourashavas the percentage of wood in landfill waste has decreased by -0.54% from 3.33% to 2.79%. This may be interpreted as a sign of urban dwellers in Bangladesh having improved access to alternative fuel sources, reducing reliance on wood for energy and heating. In 2021, wood waste in urban areas reduced to 0%, whereas the decrease in urban and pourashava areas is -2.68% and -2.77% respectively, as wood waste comprised 0.02% in both urban and pourashava areas.

On average, in pourashavas and in urban areas in general, the percentage of fabrics and textiles in total generated waste has decreased. From 2005 to 2014, the percentage of fabrics decreased from 3.37% to 2.53% in pourashavas (resulting in a decrease of 0.84%), and from 3.06% to 2.55% in urban areas (meaning a decrease of 0.51%). However, the percentage of fabrics in the total waste generated in cities increased by +0.06% from 3.39% to 3.45%. This is perhaps indicative of an increasingly prominent consumer culture in the cities of Bangladesh as a result of a higher GDP and greater purchasing power. In 2021, fabric and textile waste constituted of 1.85%, 2.06% and 1.55% of total generated waste respectively.

The percentage of metals in municipal solid waste in the pourashavas, cities, and urban areas has remained at a near constant, with only small variations between 2005 and 2014. In urban areas as a whole, the percentage of metals has increased by +0.27% from 0.17% to 0.44%, and similarly in the cities of Bangladesh the percentage of metals has increased by +0.15% from 0.12% to 0.27%. In pourashavas, a decrease of 0.18% has been observed in the percentage of metals in mixed waste, changing from 0.63% to 0.45% over the same time period. In 2021, metal waste in pourashava reduced to 0%, whereas the percentage decreased by 0.11% in urban areas increased by +0.06% in pourashava area.

Waste classified under the "*Other*" category has decreased in Bangladesh. Urban areas have seen a decrease of 6.54% from 10.28% to 3.74%, while pourashavas have seen a decrease of 5.69% from 9.43% to 3.74% Similarly, cities had a decrease of 5.84% from 9.51% to 3.67% between 2005 and 2014, which can be interpreted in a number of different ways. The "*Other*" category is, in this case, defined to include various waste types, including clinical and hazardous waste, construction waste, ash, sand, rocks, as well as other items not falling under the existing categories. On the other hand, in 2021, other category waste has increased. Compared to 2014, in urban areas +4.15%, in pourashava +3.25%, and in cities +3.83% of increase can be seen in 2021.

In 2021, the "*medical waste*" category was taken into consideration due to the COVID-19 pandemic. In urban areas, this category comprised 0.11% of total generated waste. In the case of pourashava and city areas, the percentages were 0.12% and 0.1% respectively.

Notably, the increases in food waste, plastics, and various types of e-wastes are symptomatic of an increase in the GDP of Bangladesh. With enhanced purchasing power, an increasingly consumerist-driven society, the advent of plastic packaging materials, and greater and more equitable access to electric and electronic goods, the composition of waste in Bangladesh is altering over time. While the differences in waste composition between pourashavas and bigger cities deserve a careful analysis, it is also beneficial to study the differences in waste composition between different income levels, particularly due to the increasing GDP.

In 2021, the majority of the total generated waste that ultimately reached the landfill was food waste, which comprised 74.5%, 74.23% and 75.33% respectively in urban, pourashava, and city areas. Of the total generated waste, plastic waste constituted 7.13%, 6.95% and 7.3% respectively in urban, pourashava, and city areas. Whereas 2.35%, 2.47% and 2.21% comprise of papers, 4.11%. 4.53% and 3.61% were found to be fabrics in urban, pourashava, and city respectively. Metal and medical waste comprise of very low percentage. Metal waste consists of 0.57%, 0.43%, and 1.15%, while medical waste consists of 0.36%, 0.57%, and 0.11% respectively. Others wastes comprise of comparatively higher percentage than plastics, 10.98%, 10.82% and 10.29% respectively in urban, pourashava, and city areas. Wood waste was not discovered in the landfills.

Waste Composition by Income Level

The 2013 study by the Centre for Environmental and Geographic Information Services has been used as a platform to analyse the composition of waste by income level (CEGIS 2013, p.62-66). To determine the average waste composition percentages for waste from domestic sources for pourashava, the averages of 17 Category A pourashavas were used. Averages of these pourashava were calculated for three different income level groups: low income, middle income, and high income.

An increase in the amount of food waste is recorded as the income level decreases from high income to low income. In the case of plastics, high income level has the highest percentage of plastic waste compared to others. A similar situation may be observed with paper waste. While reviewing the different income levels for their average waste composition, no noticeable differences were discovered between the percentages of fabrics, metals, e-waste, medical, or other wastes.

Careful analysis indicates that the percentages of plastic waste and food waste are increasing, while wood waste is decreasing. These changes to the composition of urban waste, particularly the increase in plastics, also signifies that the calorific value of waste in Bangladesh is changing.

Land Required for Disposal of Waste

With the amount of generated waste increasing on an annual basis, the demand for land available for landfilling is also increasing in Bangladesh. Furthermore, climate change combined with an increasing population, and a prevailing scarcity of available land will exacerbate the issue of landfilling and land available for landfilling in Bangladesh in future years.

For the purposes of this study, area required for landfilling is given in hectares, assuming landfills have a shallow depth of 5m. Unless otherwise specified, the amounts for area required also assume that 100% of generated waste is collected and that 100% of this collected waste reaches the landfill.

In 1991, 43.09 hectares of landfill area were required to accommodate the 2,369,945 tons of waste generated in the urban areas of Bangladesh that year, equivalent to 6,493 tons per day. By 2005, 88.46 hectares of landfill area were required, with waste generation reaching 4,865,450 tons per annum, or 13,330 tons per day. In 2014, 157.20 hectares of landfill area were required to accommodate the 8,646,120 tons per annum, or 23,688 tons per day, of waste generated. In 2021, 222.81 hectares of landfill area were required to accommodate the 12,254,623.15 tons per annum, or 33,574.31 tons per day, of waste generated.

Hence, increased waste generation and increased dependence on landfilling are having a significant impact on the greenhouse gas emissions of Bangladesh, contributing towards climate change.

Greenhouse Gas Emissions

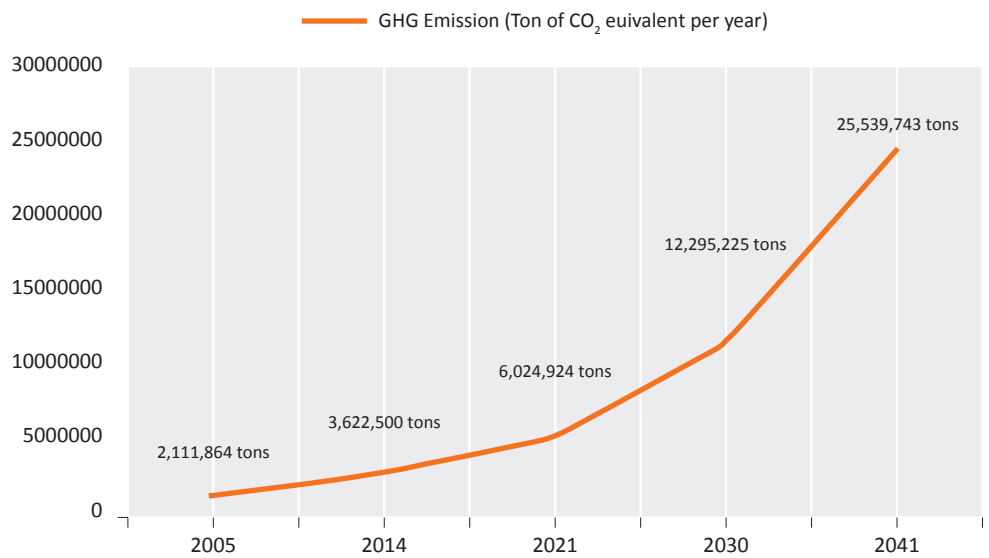

Figure 11: *Greenhouse Gas emissions from total urban waste generated*

On average, an estimated total of 23,688 tons of waste were generated every day in the urban areas of Bangladesh in 2014. This amounted to 720,510 tons per month, or 8,646,120 tons per annum. If all of this waste was landfilled, approximately 301,875 tons of CO_2 would have been produced per month, or 3,622,500 tons of CO_2 per annum. This was equivalent to 418.98kg of CO_2 per ton of mixed waste produced.

Figure 12: *Greenhouse gas emission from urban waste per capita*

In 2005, less waste was being generated in the urban areas of Bangladesh, and hence less greenhouse gases were emitted. On average 13,330 tons of waste was being generated every day, totalling 405,454 tons per month, or 4,865,450 tons per year. Had all that waste being landfilled in 2005, 175,989 tons of CO_2 would have been produced per month, or 2,111,864 tons of CO_2 per annum. The amount signifies that 434 kg of CO_2 would have been produced per ton of mixed waste.

In 2005, Bangladesh emitted 64.46 kg of CO_2 per capita per year from the waste it generated. However, by 2014, that figure had increased to 86.38 kg of CO_2 per capita per year. This means that in 2005 the average urban household in Bangladesh was emitting 304.25 kg of CO_2 per year, with an average household size of 4.72 persons. In 2014, the average household in Bangladesh was emitting 380.07 kg of CO_2 per year, with an average household size of 4.40 persons. Currently, Bangladeshi households are generating more waste than in the past, and the people of Bangladesh are also currently emitting more CO_2 compared to past records through existing waste management practices.

In 2021, 33,57.31 tons of waste were generated on average every day throughout urban areas of Bangladesh. This amounted to 1,021,218.59 tons per month, or 12,254,623.15 tons per annum. If all of this waste was landfilled, approximately 502,077.01 tons of CO_2 would have been produced per month, or 6,024,924.20 tons of CO_2 per annum. This is equivalent to 491.65 kg of CO_2 per ton of mixed waste produced.

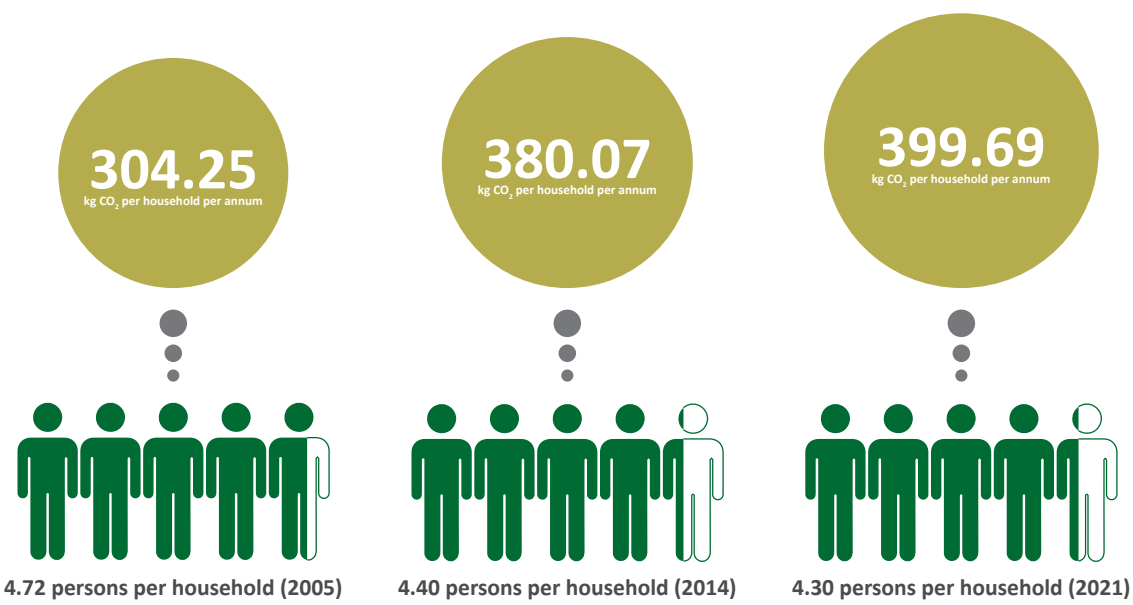

Figure 13: *Greenhouse Gas emissions from urban waste per household*

In 2021, 92.95 kg of CO_2 per capita per year was emitted, which means the average household in Bangladesh was emitting 399.69 kg of CO_2 per year. Here, the average household size is considered to be 4.30 (BBS, 2020).

The percentage of organic waste generated in 2021 was utilized for reference in order to estimate the greenhouse gas emissions for 2030 and 2041.

In 2030, an average of 68,516 tons of waste are estimated to be generated every day in urban areas of Bangladesh. This amounts to 2,084,028 tons per month, or 25,008,340 tons per annum. If all the wastes were to be landfilled, this would approximately produce 1,024,602 tons of CO_2 per month, or 12,295,225 tons of CO_2 per annum, which is equivalent to 492 kg of CO_2 per ton of mixed waste.

In 2041, an average of 142,322 tons of waste are estimated to be generated every day in urban areas of Bangladesh. This amounts to 4,328,961 tons per month, or 51,947,530 tons per annum. If all these wastes were to be landfilled, then approximately 1,796,645 tons CO_2 would be produced per month, or 25,869,870 tons of CO_2 per annum. This would be equivalent to 498 kg of CO_2 per ton of mixed waste produced.

Therefore, in 2030 and 2041, 145 kg and 217 kg of CO_2 per capita per year are projected to be emitted respectively.

The difference in the amount of CO_2 produced per ton of mixed waste from 2005 to 2041 can be explained by the change in the average composition of urban waste, with percentages of fabrics, paper, and other waste decreasing, while plastics, food waste, and metal waste increasing.

The composition of waste is also significant in its potential to address the issue of greenhouse gas emissions from urban waste. The high portion of organic waste in the urban waste of Bangladesh has the potential to be recycled, considerably reducing greenhouse gas emissions, as well as having other co-benefits in job creation, biogas production, compost production, landfill savings, crop yields, and fertiliser uses.

Faecal Sludge Generation

As a constituent element of waste management, improved sanitation remains one of the key challenges for Bangladesh. Despite claims of significant improvements to sanitation and access to sanitation in the country, faecal sludge and the hygienic management of human excreta continue to represent a significant challenge to the urban areas of Bangladesh. Despite Dhaka being the only urban area with a large-scale faecal sludge treatment facility, its sole treatment plant is meeting the needs of only 20% of the capital's population (Opel, 2012). Thus, nearly all the faecal sludge generated in the urban areas of the country remain untreated, usually disposed of through open dumping.

For the purposes of this study, it is estimated that on average the per capita per annum rate of faecal sludge production in Bangladesh is 0.04 m^3/day per capita per year (Housing and Building Research Institute (1993). However, other studies have estimated faecal sludge production rates to be as high as 0.07 m^3 per capita per annum.

While the collective pourashava population produces 1,070,214.64 m^3 of faecal sludge per annum, the non-pourashava urban population of Bangladesh produced 607,235.84 m^3 of faecal sludge in 2014. Altogether, the total urban population of Bangladesh produces an estimated 1,677,450.48 m^3 of faecal sludge per annum.

In 2021, the total urban population produces an estimated 3,250,000 m^3 of faecal sludge per annum.

In 2030 and 2041, the amount is expected to increase gradually. In 2030, the total urban population is estimated to produce 4,250,000 m^3 of faecal sludge per annum while in 2041 it will reach to 5,950,000 m^3 of faecal sludge per annum.

Current Policies and Government Legislation

Table 2: Current Policies and Government Legislation

Policies/Legislations	Description
Solid Waste Management Rule, 2021	The main objective of this rule is to maximize resource recovery from waste in a hierarchical process. Before final waste disposal, steps like waste reduction, reusing, recycling, recovering, and refining should be followed sequentially. According to this rule, the local government is responsible for producing an 'Annual Waste Report' every fiscal year. Specific regulations regarding composting and incineration are compiled in this rule. In the landfill guideline section, site selection and emission monitoring indicators are specified.
National Environmental Policy, 2018	To combat the impacts of climate change, the Bangladesh government has formulated an environmental policy. The main focus of this policy is to preserve and utilize natural resources in a sustainable manner to protect ecosystems and work towards combating the myriad impacts of climate change. It contains policies for effective management of resources such as land, water, and air.
National 3R Strategy for Waste Management, 2010	To help towards mitigating some of the environmental, social, and economic effects arising from existing disposal practices, a national strategy was adopted. The objective of this strategy was to identify major issues and challenges regarding waste management, define the roles of various actors in order to promote 3R, and provide guidance towards creating and enabling conditions for success in the implementation of 3R in Bangladesh. Some guiding principles and 3R related policy guidelines were explained in this strategy. Relevant stakeholders and their roles were identified. Guidance regarding developing action plans were provided.
National Policy for Safe Water Supply and Sanitation, 1998	The main goal of this policy was to ensure safe water and sanitation services for all at an affordable cost. To achieve this goal, separate policies were adopted for rural and urban water supply and sanitation. Policy principles included basic needs, value of water, participation of users, role of women, technology options, capacity building, environmental integrity, etc.

Conclusion

The generation of waste in the urban areas of Bangladesh is increasing on an annual basis. Not only is Bangladesh generating more waste due to a growing population, the per capita rate of waste generation and GDP are also increasing. At current rates, earlier projections will be surpassed by 2025 and Bangladesh will be generating more waste than the amount previously envisaged. Under these circumstances, increasing pressure will be placed on existing waste management systems and practices in Bangladesh with an accumulative reliance on landfilling. This may prove to be an undesirable outcome for a country already restricted by the amount of available land.

The findings of this study bear implications for the selection of waste management technologies as Bangladesh prepares to move forward to more sustainable models of waste management in its urban areas.

The high percentage of organic waste (both food waste from domestic sources and other organics from non-domestic sources) signifies that immense potential lies in recycling organic waste into organic fertiliser through aerobic composting or into biogas to electricity through anaerobic digestion.

The growing consumption of plastics in Bangladesh, signified by the higher percentage of plastics appearing in urban waste, is symptomatic of a rising GDP. While the increase in plastics can be viewed as a challenge for Bangladesh, it also carries with it some room for opportunities. Through best practice source separation and resource recovery, plastic waste may be recycled into a fuel source in the form of refuse derived fuel pellets. Currently at an experimental research phase in Bangladesh, the development and production of refuse derived fuel combines plastic, paper, cardboard, fabric, and textile wastes along with other waste types to produce a new material that can be used as a source of fuel.

The country's brick industry contains opportunities for the utilization of refuse derived fuel, with the potential to reduce reliance on coal and timber used to fire brick kilns. Further discussions with all relevant stakeholders are required to draft a holistic picture of the potential in resource recovery of plastics.

To conclude, the findings in this study underline the need for a low carbon development path for the waste sector in Bangladesh. With climate change producing myriad adverse effects throughout Bangladesh, there is a growing need for stronger mitigation actions from the waste sector through reductions in carbon emissions traced to waste management and resource recovery.

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Annexure

Table 3: Population and Waste Projection Scenario - 1

Year	Urban Population	GDP (US dollar)	Total Waste Generation (Tons/day)	Waste Generation Rate (Kg/Person/day)
1991	20,800,000	220	6,493	0.31
2005	32,760,000	485	13,330	0.41
2021	64,817,837	2554	33,574	0.52
2030	85,258,584	5735	68,516	0.80
2041	119,188,925	12500	142,322	1.19

The Urban Population, GDP and Total Waste Generation (Ton) data from 1991 and 2005 was collected from waste database prepared by Waste Concern (Waste Concern, 2014). The World Bank has published the data of Urban population for Bangladesh in 2019 as 60,987,421 and in 2020 as 62,873,466 (World Bank, 2020). From this data urban population for 2021 can be projected.

Growth Rate, r $= (P_n / P_o)^{\wedge(1/n)}-1$

$= (62,873,466/60,987,421)^{\wedge(1/10)}-1$

$= 0.0309$

Population of 2021 $= 62,873,466\ (1+0.0309)$

$= 64,817,837$

With this growth rate of 3.09% urban population of 2030 and 2041 is projected. The total waste generated in 2021 was calculated from Waste Concern's own field survey. Waste amount for 2030 and 2041 was projected from the data of 1991, 2005 and 2021 as the waste generation is proportional to GDP.

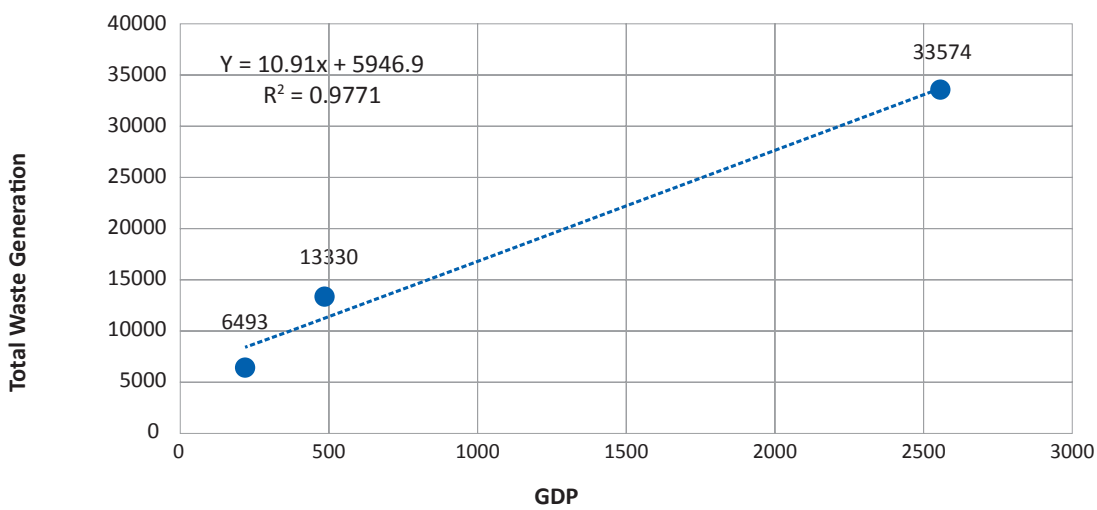
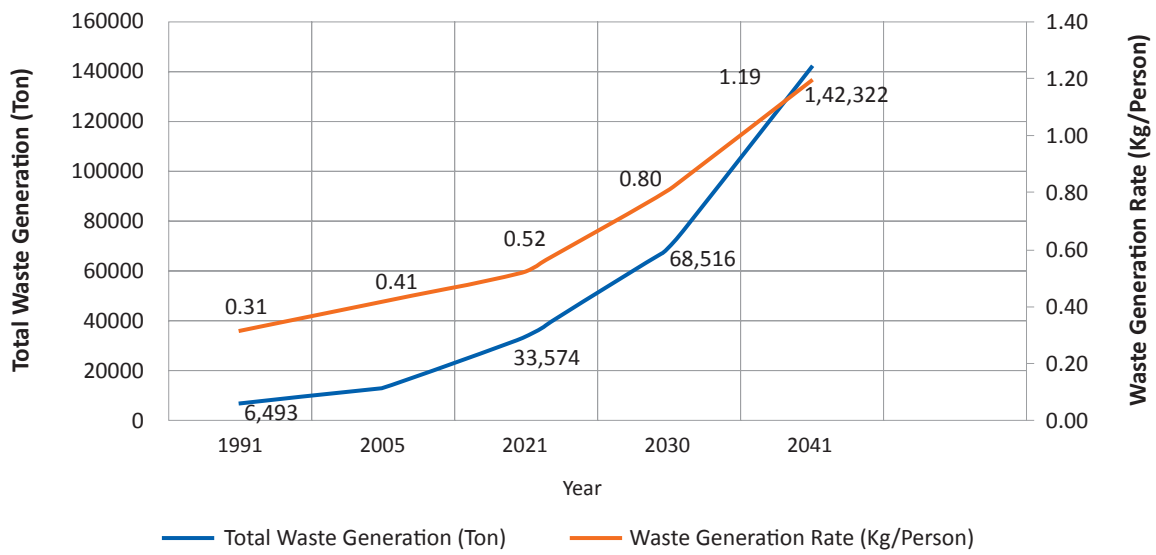


Figure 11: *Greenhouse Gas emissions from total urban waste generated*

Total Waste Generated in 2030 = 10.91 *5735 + 5946.9 = 68516

Total Waste Generated in 2041 = 10.91 *12500 + 5946.9 = 142322

The Bangladesh Bureau of Statistics (BBS) has updated the per capita income of Bangladesh in 2021 to $2,554 (BBS, 2021). In 2030 Bangladesh per capita income will be $5735 (Standard Chartered Global Research, 2019). In 2041 the per capita income of Bangladesh is projected to be $12500 by Bangladesh Government vision 2041 (Bangladesh Planning Commission, 2020).



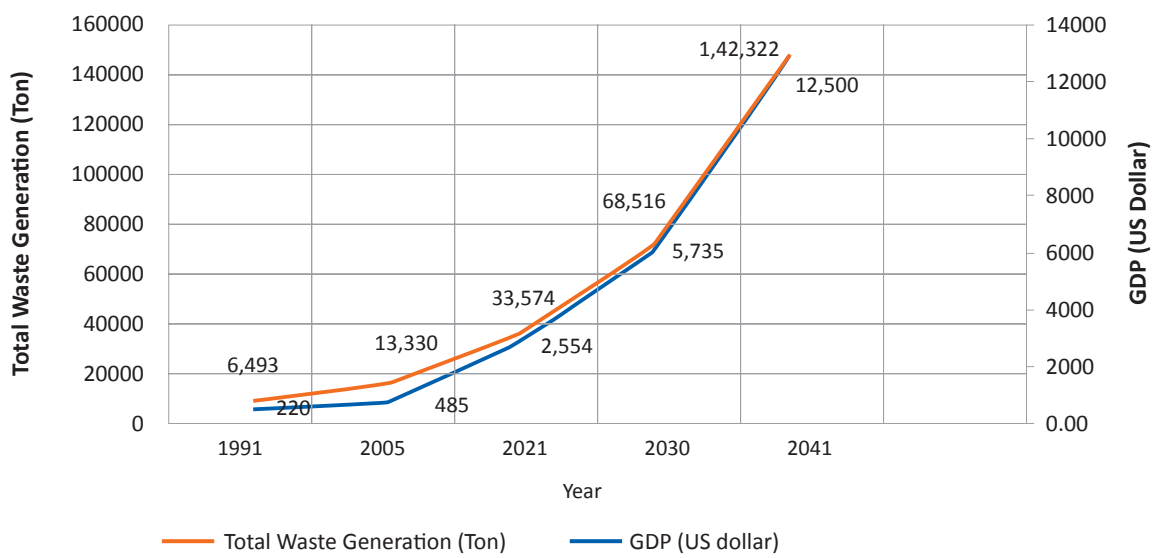


Table 4: Population and Waste Projection Scenario - 2

Year	Urban Population	GDP (US dollar)	Total waste generation (Tons/day)	Waste Generation Rate (Kg/Person/day)
1991	20,800,000	220	6493	0.31
2005	32,760,000	485	13330	0.41
2021	64,817,837	2554	33574	0.52
2030	85,258,584	4588	56002	0.66
2041	119,188,925	10000	115047	0.97

If the GDP growth is 20% less in 2030 and 2041, the Waste generation will reduce to 56002 tons/day in 2030 and 115047 tons/day in 2041.

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