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ORIGINAL PAPER

A conceptual framework for zero waste management in Bangladesh

F. Ahmed[1] · S. Hasan[2] · M. S. Rana[3] · N. Sharmin[4]

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Abstract
The rapid expansion of industrialization, urbanization, and the influx of migrant citizens into the cities has become a cause of concern for huge waste generation in Bangladesh. These wastes include solid, and liquid contaminated with chemicals, food waste, ago-waste etc. generated from multiple sources have been frequently dumped in open landfills, causing environmental degradation in the urban areas. This indiscriminate dumping of waste in the open places reveals the poor waste management capability of the city's authorities. Thus soil, air and water pollution is common phenomena in the most of the cities in Bangladesh. The main challenge is the severe land scarcity. It has dense highly population which causing more than 7000 metric ton waste generating per day only from the Capital Dhaka city. Therefore, this study aims to formulate a conceptual framework to facilitate a zero-waste management initiative in Bangladesh through analyzing an extensive existing study available in the research domain. It is expected that the application of the proposed waste management framework will inspire a number of entrepreneurs to involve themselves in waste recycling initiatives with the direct interference of the municipalities and the government's concerned ministries. Lastly this research amplifies the policy recommendations for the policymakers of Bangladesh which will enable them to manage zero waste management in Bangladesh. However, this type of research not done before in Bangladesh that can be helpful for existing literatures for further research.

Keywords Waste · Zero-waste management · Conceptual framework · Bangladesh

Introduction

In the twenty-first century waste management has been a pressing issue around the world. Almost every country on the planet is currently striving to manage waste in a sustainable manner. Unfortunately, waste infrastructure, which is desperately needed, has not been given the same priority as energy and water, especially in poor countries and many developed countries. Waste has been generated in every now and then from a number of sources. The solid and liquid waste generated from the industries, households, consumption, and constructions are the potential reason for environmental degradation as often wastes are dumped in an open place in many parts of the world. Furthermore, developing-country waste infrastructure lacks even the most basic sorting and collection capabilities. A recent study conducted by World Bank revealed that only 44% of waste is collected in the South Asia and sub-Saharan Africa regions. 93% of the collected waste in low-income countries is managed through open dumping (Kaza et al. 2018). The majority of developed countries in North America and Europe continue to rely on landfills and trash combustion. Australia, like many other industrialized countries around the world, is no exception. Many wealthy countries, such as Australia, rely on trash exportation to other countries due to a lack of local waste processing capacity (mainly to China). Since China's garbage ban in 2018, the global waste business has been in disarray, with China, Malaysia, Indonesia, the Philippines,

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✉ F. Ahmed
ferdous.ahmed@iubat.edu

[1] Department of Environmental Science, IUBAT-International University of Business Agriculture and Technology, Dhaka, Bangladesh

[2] Department of Civil Engineering, IUBAT-International University of Business Agriculture and Technology, Dhaka, Bangladesh

[3] Department of Business Policy and Strategy, Faculty of Business and Accountancy, University of Malaya, Kuala Lumpur, Malaysia

[4] Department of Chemistry, IUBAT-International University of Business Agriculture and Technology, Dhaka, Bangladesh

India, and many other emerging countries refusing to receive rubbish from any other country (Zaman and Ahsan, 2019).

Zero waste is one of the most forward-thinking waste-reduction approaches. Many cities throughout the world have stated their zero-waste vision, including Adelaide, San Francisco, and Stockholm, and are trying to become the world's first zero waste metropolis (Zaman and Lehmann, 2013). However, the most important concerns in zero waste research are how to transition our present cities into zero waste cities and how to quantify a zero-waste city's effectiveness. The waste produced by today's consumer-driven world is immense. The urban administration remains under enormous pressure to handle garbage in a more sustainable manner because of the significant amount of wastage generated from a multiple source. Nevertheless, waste management has not gotten the same level of attention in city planning as other areas such as water or electricity. As a result, there are gaps in waste management in present urban planning. The ''solid waste hierarchy," a philosophy that prioritizes measures from waste prevention to landfill, is heavily influenced by waste management. However, the solid waste hierarchy does not provide a sufficient framework for waste and resource strategy in terms of absolute material reduction, i.e., zero waste (Gharfalkar et al., 2015; Van Ewijk and Stegemann, 2016). Besides, one of the most important environmental issues affecting metropolitan areas in developing nations is solid waste management (Pfammatter and Schertenleib 1996; Sinha and Enayetullah 2000).

Many stakeholders are involved in waste management systems, which include socioeconomic, political, environmental, and technological factors. All of these factors are intertwined and change throughout time. Solid waste management is a big challenge in metropolitan areas all over the world, but especially in the developing world's fast-growing cities (Tsheleza et al. 2019). Due to rapid population expansion and rising per capita income, a vast amount of solid trash has been generated, posing a major danger to environmental quality and human health. Urban areas in developing countries must prioritize effective and efficient municipal solid waste management to keep up with the demands of rapid economic development and continued population growth, as well as the critical role of municipal solid waste management in environmental and public health protection (Jin et al., 2006).

Bangladesh is a country with a high population density. The influx of migration from villages to towns and cities has expanded dramatically as a result of fast industrialization and urbanization. As a result, urban and suburban development has resulted in an increase in population (Khan 2009; Kormoker, 2017). As a result, unplanned urbanization has occurred, resulting in massive garbage generation. The majority of the time, cities and municipalities are unable to process or treat these additional wastes. Solid waste creation has become a major concern for the government in terms of protecting public health, safety, and the environment as the population grows. Dhaka generates significantly more trash than other cities. Dhaka, Chittagong, Khulna, Rajshahi, Barishal, and Sylhet, according to Abedin & Jahiruddin (2015), contribute 69.7%, 17.1%, 6.7%, 2.2%, 1.6%, and 2.7% of the total waste stream, respectively. The country's current environmental, social, and economic demands, in fact, focus on the identification of more efficient materials to be used in the transformation industry (Barrett and Scott, 2012; Shahbazi et al., 2016), as well as the adoption of a concept based on the value of waste, which should be converted into resources without the need for reprocessing (Franks et al. 2011). According to Zaman (2015), the concept of zero waste is constantly evolving and being utilized in a variety of industries, including waste treatment and management, mining, manufacturing, and urban development. Nonetheless, academia does not offer a clear perspective on the zero-waste issue (Greyson, 2007; Curran and Williams, 2012; Zaman, 2016). Furthermore, Gharfalkar et al. (2015), Ewijk and Stegemann (2016), and "solid waste hierarchy" and zero waste (Gharfalkar et al., 2015; Ewijk and Stegemann, 2016). As a result, there is a pressing need to delve deeper into the topic of zero waste. Thus, the current study intends to clarify the concept of zero waste, identify the present obstacles of waste management in Bangladesh, and verify essential requirement for a conceptual framework for waste management procedures in Bangladesh through an extensive bibliographic evaluation of the literature. This research study has been taken palace in Dhaka City from 2020–2021.

Literature review

Bangladesh is one of the world's most developing countries, with a population of over 162.7 million people living in an area of 1, 47,570 km^2 (BBS, 2018). Bangladesh's population is growing at a rapid pace, and people are increasingly flocking to cities. For a better life and a better livelihood, many people have moved to Dhaka and other urban areas. However, Bangladesh's large centers, such as Dhaka, are currently confronted with a major issue and numerous obstacles.

According to Bangladesh Environment Conservation Act, 1995, waste is, "any solid, liquid, gaseous, radioactive substance, the release, disposal, and throwing away of which may cause deleterious changes to the environment" (Baul Sarker and Nath, 2021). A critical increment of municipal solid waste (MSW) generation has been provoked to by over-population, consumerism, urban and modern improvement and the variables like these are consistently driving an exponential increment in the rate of solid wastes to such a degree

to the point that it postures genuine risk to the regular habitat and putting weight on national assets.

Solid Waste management is the least prioritized sector not just in Bangladesh, but also in developing countries (Nahian, Ahmed, and Shams, 2018). In recent years, municipal solid waste (MSW) management has become increasingly urgent in emerging countries due to economic growth. Global MSW generation showed a two-fold increase within 10 years from 0.68 billion tons per year in 2000 to 1.3 billion tons in 2010. Moreover, it is projected to reach 2.2 billion tons per year by 2025 and 4.2 billion tons per year by 2050 (Hoornweg and Bhada-Tata-2012). Municipal Solid Waste (MSW) is a massive waste load that, if not effectively handled, will have a severe influence on sustainable living, local environment, and human health (Malav et al. 2020). Solid waste must be managed in a way that minimizes environmental and human health threats. According to certain experts' study, the success of solid waste disposal is dependent on the selection of appropriate sites. Pakistan is one of the most advanced garbage management countries in the world (Kassim and Ali, 2006; Abbas Nai'ya et al., 2011). Waste management systems have not received as much attention in the city planning process as other sectors like water or energy. The most common problems associated with improper dumping include diseases transmission, fire hazards, odor nuisance, atmospheric and water pollution, aesthetic nuisance and economic losses (Shum et. al- 2020; Song et al., 2015; and Hoornweg et al., 2011). Unmanaged trash contributes roughly 3.5% of total global anthropogenic GHG emissions, or 49,000 million tons CO_2 per year, according to (Shams et al. 2017). In 2016, solid waste management created an estimated 1.6 billion tons of CO_2 equivalent greenhouse gas emissions. This equates to roughly 5% of total global emissions. Solid waste-related emissions are expected to rise to 2.6 billion tons of CO_2 equivalent by 2050 if no changes are made in the industry (Kaza et. al. 2018).

Three major environmental crises: global warming, depletion of resources, and destruction of our ecosystem. Severe waste management problems are reported in a number of cities of different countries like China, India, Malaysia, Thailand, and Bangladesh because of rapid population growth, industrialization, and urbanization (Aliani, 2012; Cheng and Hu, 2010; Johari et al. 2012a, 2012b; Chiemchaisri and Visvanathan, 2008; and Bhuiyan-2010). The fast urbanization and population growth are liable for a large volume of solid waste production in Bangladesh. The situation of waste management in Bangladesh is very alarming, poses serious health threats to humans and nature. In Bangladesh, the solid waste management has been ignored and least studied environmental issues (Abedin & Jahiruddin, 2015). Waste generation rate in various cities of Bangladesh is ranging from 0.2 to 0.56 kg/cap/day (Ahsan et al. 2014). By 2025, trash generation in Bangladesh's municipal regions is expected to increase by 0.6 kg/cap/day (Bhuiyan, 2010). The annual garbage generation trend is increasing at a pace of 0.1343 million tons (368 tons/day). Approximately 78% of solid waste is created by the home sector, 20% by the business sector, 1% by the institutional sector, and the balance by other sectors (Ahsan et al., 2014). During the dry season, the total domestic urban trash generation is 11,808.463 tons/day (Bangladesh waste database-2014). Bangladesh's early waste management system allowed indiscriminate open dumping and burning, disposal of wastes into water bodies, landfilling, and direct disposal into agricultural land in rural areas. Early waste management in Bangladesh was a major cause of environmental damage to the environment (Ashikuzzaman & Howlader, 2020; Ahsan, et al., 2014). There is no engineering or sanitary landfill in Bangladesh. Poorly managed waste is contaminating the world's oceans, clogging drains and causing flooding (Nizar, et al., 2018). The open dumping disposal system implies that the amount of greenhouse gases produced by the landfill increases as well as the leachate water from the landfill. Bangladesh's garbage management system is one of the worst in the world. In metropolitan areas, the Water Supply and Sewerage Authority (WASA) handles evening garbage collection, while the Water Supply and Sewerage Authority in Bangladesh performs house-to-house (Ashikuzzaman & Howlader, 2020).

Waste managers and decision-makers in developing and emerging countries have to respond to these new challenges. Waste management is a major challenge for waste managers, especially in Bangladesh where almost 40% of waste goes uncollected (Kabir, 2015). Waste to energy has been viewed as a solution to the problems derived from rising waste quantities in expanding cities. Zero waste management is a holistic waste management concept. It recognizes waste as a resource and a symbol of the inefficiency of our modern society. The concept has been proposed by Nizar, et al. (2018). "Zero Waste" is a concept that aims to eliminate all non-renewable natural resources (Bartl, 2011; Phillips et al., 2011; Scarlat, et al., 2015). The term "zero waste" was first used by Paul Palmer in 1973 for recovering resources from chemicals. In a zero waste system, the same materials are used again and again until the optimum level of consumption (Murphy and Pincetl, 2013).

Zero waste is a goal that is ethical, economical, efficient and visionary. ZW means designing and managing products and processes to systematically avoid and eliminate the volume and toxicity of waste and materials. It aims to conserve and recover all resources, and not burn or bury them (Franco-García et al. 2019; Cristina et al., 2019). Waste prevention through sustainable design and consumption practices, optimal waste recovery, rather than waste management by disposal or incineration, is the focus of Zero Waste (ZW). Without damaging our natural ecosystem, zero waste management techniques ensure that discarded garbage

is recycled, recovered, or readily nourished. (Zaman, 2014). Zero Waste (ZW) is concerned with waste prevention through sustainable design and consumption practices, optimal waste recovery and not waste management by landfill or incineration. Zero waste management processes ensure that the discarded waste be recycled, recovered or easily nourished without polluting our natural environment. (Matete and Trois, 2008; Mohammedshum et al., 2014). Zero Waste New Zealand Trust in 1997 supporting waste minimization initiated the zero-waste movement in New Zealand. California took on the first comprehensive zero waste plan in the and in 2001 adopted zero waste goals as strategic waste management plans (Connett, 2013). Bangladesh's waste dumping and ultimate disposal system is not environment friendly. A huge number of solid wastes is produced per day which is not managed properly. Zero waste management can be a sustainable solid waste management approach for Bangladesh.

Materials and methods

This study has undergone a number of studies that are pertinent to waste management research. To find out relevant information, this study has explored studies published in scientific journals which are mostly indexed with web of science, Scopus and other recognized data base. The study has also explored Google Scholars, PubMed, international reports and other relevant documents. This study has explored extensive literature in order to develop a conceptual framework for the possible zero waste management practice in Bangladesh. The different steps of this model are elaborated with the current waste management scenarios. A good number of literatures have been reviewed to support the existing waste management phenomena. Lastly this conceptual model is able to establish a zero waste practices which is quite new in this country.

Results and discussion

Bangladesh is a densely populated country with a population of over 170 million people. With 330 municipalities, it is divided into 64 districts, 8 divisions, and 12 city corporations. According to the Bangladesh Bureau of Statistics, roughly 37% of Bangladesh's population lives in urban areas. However, by 2030, Bangladesh's urban population is expected to reach 46%, and by 2050, it will reach 58%. It shows that, in comparison with the rural community, solid waste creation is rapidly expanding. On the other hand, most city corporations and municipalities' infrastructures and amenities are still inadequate. As a result, it is clear that solid waste management in urban areas causes numerous environmental problems. The capital, Dhaka, is an excellent example of a city with major solid waste management issues. Dhaka is the most densely populated metropolis, with a population of almost 22 million people. In addition, Dhaka has a population density of roughly 48,000 people per km^2, which is enormous. The capital city, however, is separated into two city corporations: Dhaka City Corporation North and Dhaka City Corporation South. Both the Dhaka City Corporations North (DNCC) and South (DSCC) manage municipal solid trash in a 360 km^2 area with a population of 7 million people projected to generate 4634.52 tons of rubbish each day, with a per capita generation rate of 1.6 tons/day. Bangladesh is producing an increasing amount of waste, which is expected to reach 47, 064 tons/day by 2025. In 2025, the rate of trash creation is predicted to reach 220 kg/cap/year.

Solid waste management is one of Bangladesh's most pressing issues. Because of its vast population, it generates a large amount of waste. Aside from the fact that land area is shrinking every year, most urban areas lack sufficient room for disposal sites. As a result, solid garbage is thrown beside the road and along the river. Soil contamination, air pollution, and aster pollution are all being spread by these uncontrolled dumping sites. A large volume of methane gas is produced from biodegradable solid waste due to a lack of unplanned disposal or landfill sites, which raises atmospheric temperatures (Fig. 1). Because land scarcity is a typical concern for waste dumping or landfill, and unplanned solid waste management techniques are primarily responsible for spreading more environmental risks or pollution, the goal of this study was to develop a conceptual framework for zero waste management in Bangladesh (Fig. 2).

Solid waste collection

Solid waste collection in urban areas is becoming a difficult and complex task. Due to the enormous population, the rate of solid waste creation is increasing at an alarming rate every year. The amount of solid trash produced is related to the size of the population. Because of its large population, Dhaka produces the majority of solid trash. Despite the fact that Dhaka is Bangladesh's capital, the waste collection infrastructure is inadequate. Bangladesh's rubbish collection system is a combination of door-to-door and communal bins. Hand cart vehicles, open compact vans, or open trucks are used for rubbish collection. People place their trash in kitchen baskets, and garbage collectors arrive in an open little van to collect it. They collect rubbish from residential areas and transport it to a secondary transfer station (STS) for eventual disposal at a landfill or final disposal site. The main source of rubbish waste collection is in the residential area. Only formal organizations in the city corporation are responsible for collecting solid trash in the city corporate territory, whereas the municipality is in charge of collecting solid garbage in the municipalities' region. Dhaka South

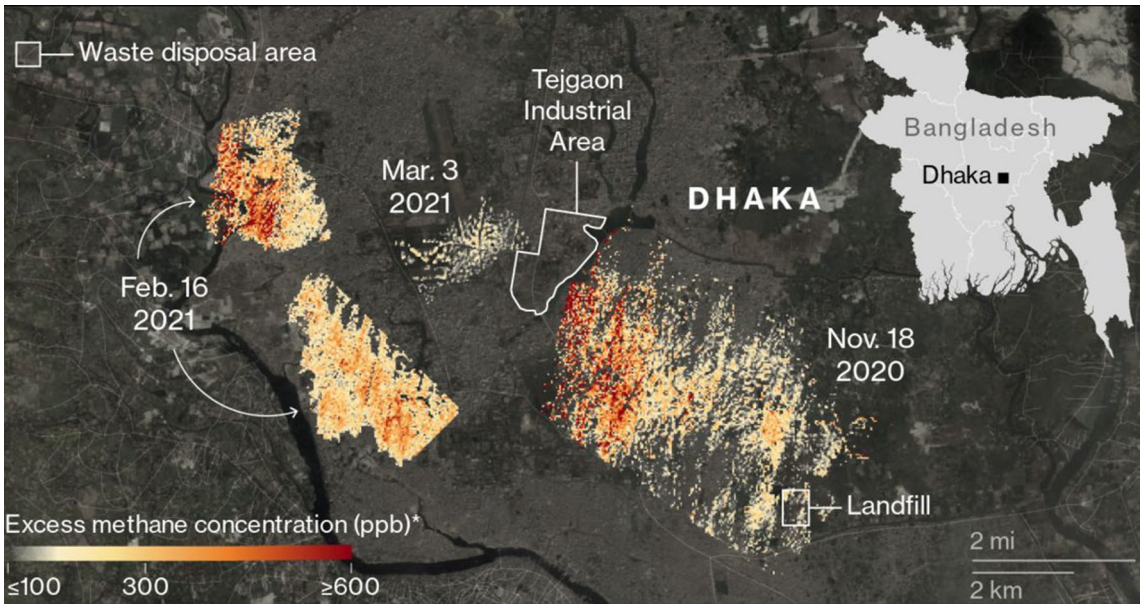

Fig. 1 Methane hotspot: strong sustained methane emissions were captured satellite imagery around Dhaka (Source: GHGS at; Satellite Image via Bing Maps; Bloomberg)

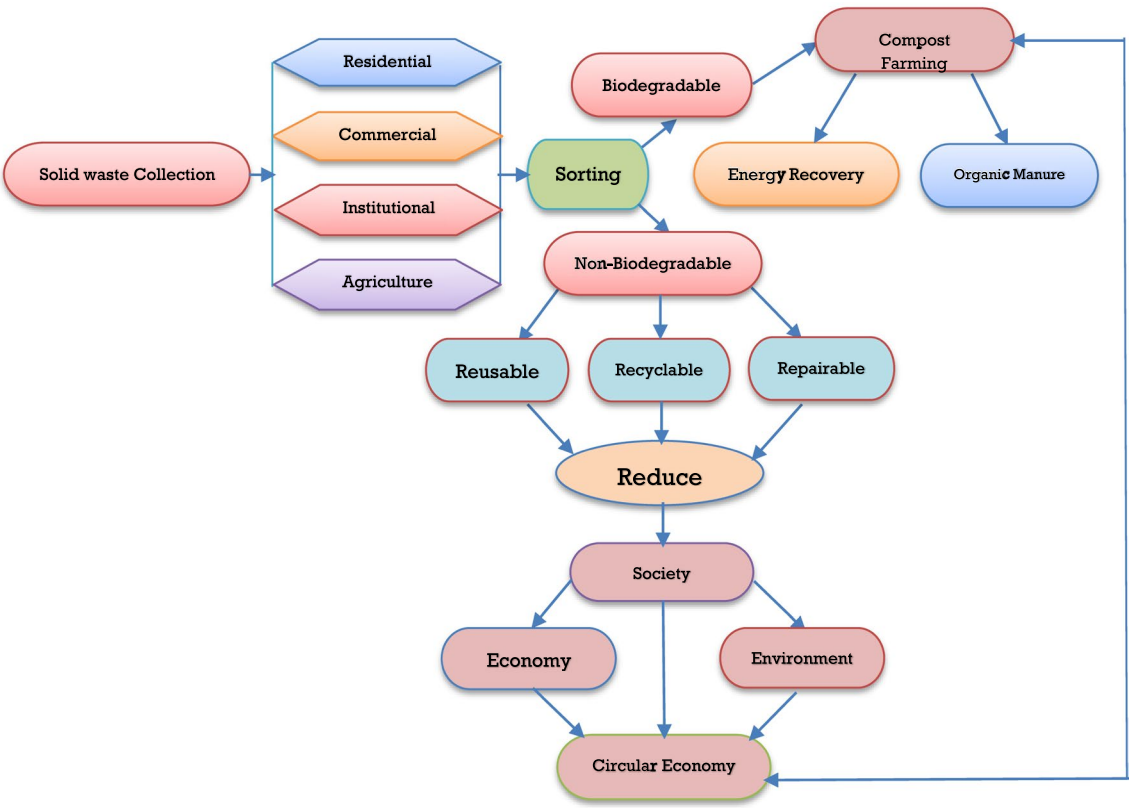

Fig. 2 Conceptual framework for zero waste management in Bangladesh (Source: Authors)

City Corporation (DSCC) and Dhaka North City Corporation (DNCC) are in charge of solid trash collection and transportation in the city of Dhaka. These two city corporations generate around 6000 tons of solid trash every day, yet only 40–50% of this waste is collected for final disposal. Small open vans or open trucks are used by those who collect solid garbage. This is harmful to the environment and promotes the spread of odors and leachate. Because the waste collection vehicle is not covered, it can be difficult to walk alongside it, and occasionally some waste falls from the van onto the road when it transports solid waste. Furthermore, those directly involved in the collection of solid trash do not wear proper clothing, masks, hand gloves, or gumboots, and are also unskilled workers. Waste collection and transportation vehicles in Bangladesh are open, non-covered trucks or compaction vehicles. Bangladesh does not employ compaction or semi-compaction vehicles. The city governments have yet to introduce covered or compacted waste collecting vans. It will reduce pollution if they can introduce a covered van for door-to-door rubbish collection and a compaction truck for large-scale waste collection instead of an open vehicle. As well as, have to provide skilled labor for waste collection.

From Table 1 highlighted the different waste materials that are generated by the six different cities in Bangladesh. These waste elements have been shown in percentage by weight. As per the 2017 statistics Barisal generated the highest amount of food waste that is mostly responsible for methane production. Although Dhaka is the mega city in Bangladesh, it does have a good number of compost industries. In addition a number of landfill and planned dumping areas have been designated nearby Dhaka. But apart from Dhaka the other cities are quite vulnerable for this ample food waste generation. Therefore the spread of compost industries outside Dhaka to other cities are very much needed to reduce the environmental pollution from solid waste generations.

Residential waste

Residential waste is the main source of producing biodegradable waste in Bangladesh. Every day a huge number of residential wastes are produced in residential areas in the urban area. But this waste is not collected properly and is not used for any effective production. In this waste, a major portion is kitchen waste and the rest of the waste is other uses things. City corporations and municipalities are responsible for collecting this type of waste. Urban areas in Bangladesh, which wastes are collected from residential areas among this waste approximately more than 70% of waste is biodegradable solid waste. The distribution (%) of total MSW generated daily of major cities by waste generation sources is Dhaka 75.85%, Chittagong 83.83%, Khulna 85.87%, Rajshahi 77.18%, Barisal 79.55%, and Sylhet 78.04% (Amin, A. N. -2017). But unfortunately, this waste is not managed properly. Waste collectors collect the waste and dump it in the dumping site and landfill site. They do not sort out this waste of biodegradable and non-biodegradable waste. As a result, after decomposing this household biodegradable solid waste is contributing a huge amount of greenhouse gas which is methane gas. Recently, Bloomberg published a report where they have reported that Dhaka is a hotspot for contributing methane emission in the atmosphere. This greenhouse gas is 80 times more potent than carbon dioxide gas. Sometimes this household biodegradable solid waste mixes with the river water and water are polluting and spread a bad smell. In addition, this household biodegradable solid waste is occurring air pollution. According to American Air Quality Index (AQI), Dhaka is one of the most polluted cities in the world. In Bangladesh, there is no government organization or other stakeholders who works with this household's biodegradable solid waste. To prevent greenhouse gas emissions and environmental pollution have to take some initiatives which can be build up compost industry or bio-waste to energy plant project (Hoang and Fogarassy 2020). The compost industry can be a viable solution to reduce adverse effects due to house biodegradable solid waste in Bangladesh. From the compost industry, that organic fertilizer will be produced that is very much environmentally friendly, and also organic fertilizer will prevent solid pollution, air pollution, and water pollution. Another solution can be there that is energy production from household biodegradable solid

Table 1 Composition of waste generation in urban areas of Bangladesh (Source: S. Shams et al., 2017)

Items	Weight in percentage						
	Dhaka	Chittagong	Khulna	Rajshahi	Barisal	Sylhet	Average
Food waste (wt%)	68.3	70.5	78.9	70.0	81.1	73.5	74
Paper (wt%)	10.7	4.63	9.5	9.0	7.2	8.6	8
Plastic (wt%)	4.3	8.7	3.1	9.0	3.5	3.5	5
Textile & Wood (wt%)	2.2	2.4	1.3	6.0	1.9	2.1	2
Leather & Rubber (wt%)	1.4	5.8	0.5	1.1	0.1	0.6	2
Metal (wt%)	2.0	2.65	1.1	3.0	1.2	1.1	2
Glass (wt%)	0.7	1.0	0.5	1.1	0.5	0.7	1
Other (wt%)	10.4	7.4	5.1	0.8	4.5	9.9	6

Fig. 3 Manual waste collection system in Bangladesh (Source: Authors)

waste or methane production. Methane can be used for cooking purposes or electricity production (Fig. 3).

Commercial waste

As a developing country of Bangladesh, commercial waste is increasing day by day. The distribution of total MSW by waste generation source in Dhaka 22.07%, Chittagong 13.92%, Khulna 11.60%, Rajshahi 18.59%, Barisal 15.52%, and Sylhet 18.48% commercial waste is generated daily (Amin 2017). Among this waste, Dhaka city percentage is high because Dhaka city is the centermost of the commercial organizations. In Dhaka city, the commercial institution is developing day by day and also other administrative cities in Bangladesh. In Dhaka city, there are lots of very big commercial institutions, from here a huge amount of solid waste is produced. Bashundhara city shopping complex, Jamuna future park are the big commercial institution and here have food coats, clothes shops, stationery shops, and other shops. From these places and shops, a significant amount of commercial solid wastes are produced. This waste management system is waste collection trucks come to this place and collects the waste. And ultimate disposal method is dumping in the dumpsite. In addition, commercial waste is not hazardous waste and this waste includes biodegradable and non-biodegradable waste. But the biodegradable waste portion is very less. But the non-biodegradable waste portion is very high like plastic waste and a significant amount of waste is recyclable and reusable. Since commercial waste is not hazardous waste, reuse and recycle can be viable solutions for commercial waste in Bangladesh. As a result, plastics and plastic products will get a great treat in this way.

Institutional waste

Institutional waste can be one of the most complex forms of solid waste management system in Bangladesh. Institutional waste is all about refuse and recyclable waste from the institutional sectors. Institutional waste is produced from public or government institutions, private institutions, offices, schools, colleges, universities, and other institutions. Institutional waste is not hazardous waste, it consists of refuse things. Most of the institutional waste is consists of paper, plastic, plastics products, paper products, and cardboard, it is all about non-biodegradable waste. In Bangladesh the amount of institutional waste generation rate per day is Dhaka 1.17%, Chittagong 1.14%, Khulna 1.02%, Rajshahi 1.22% Barisal 1.46%, and Sylhet 1.29% (Amin 2017). In the institutional sectors, paper items and plastics products are used more. Especially, in a public or private office, schools, colleges, and universities paper items are used more and after used it they just throw them in the environment. Plastics and plastic products have a great adverse on our environment. But there has no proper waste management policy about institutional solid waste management in Bangladesh. This institutional waste is mixed with other waste and the ultimate destination is the dump site which is not a proper dumpsite just an open dump. For this reason, our environment is polluting day by day. Science the institutional waste, not biodegradable waste, in this waste many items are reusable and recyclable. To prevent throw this waste into our environment reuse and recycle can be a sustainable solution for Bangladesh. For these circumstances, need to make recycling industry prevent this non-biodegradable waste problem.

Agricultural waste

Agricultural waste is produced as a result of farming activities. Bangladesh is an agriculturally dependent country, and agricultural operations produce a large amount of agricultural waste. The country generates roughly 65 million tons of agricultural trash (Department of Environment 2010). Plant and vegetable trash, leaves, husk, animal dung, and pesticide bags and bottles are among these wastes. Agricultural waste is also generated on cultivated land and transported to vegetable and food markets. Vegetable and plant trash are visible in the village area near the farming fields, but there is no management for this waste. A substantial amount of vegetable waste is created in Bangladesh, from the retail selling sector to the wholesale vegetable market. Every day, a large number of vegetables arrive from the hamlet in Dhaka and

other administrative cities and municipalities. After selling these veggies and foods, the waste portion of these vegetables and foods is discarded, resulting in a large volume of agricultural waste at the end of the day from these markets. This agricultural waste is made up of biodegradable plant waste that has a significant negative impact on the environment. With this biodegradable plant waste, there is no management system in place. As a result, when this biodegradable plant waste decomposes, a foul stench is released, as well as gases such as methane gas. Every day, agricultural waste is generated in Dhaka city's Karwan Bazar wholesale vegetable market and various retail vegetable markets. The temperature in Dhaka city is becoming increasingly hot, and this form of biodegradable garbage is to blame because biodegradable waste produces methane gas into the sky. It's a greenhouse gas that traps more heat in the atmosphere than carbon dioxide. A proper waste treatment for this agricultural waste is required to mitigate the negative environmental effects. Composting is one of the most environmentally friendly ways to dispose of agricultural waste. Government and business partners can work together to remediate this agricultural waste and develop a compost sector in both urban and rural locations (Sewak et al. 2021). Furthermore, in the village area, farmers can accomplish this alongside their farmed land on their own. As a result, they will be able to apply bio-fertilizer on their land, which will allow them to grow more vegetables and crops with less environmental impact. Local agriculture officers can also educate farmers in the village about the benefits of compost fertilizer made from agricultural waste. If it is possible, a significant amount of methane emission will reduce yearly due to this agricultural waste in Bangladesh.

Sorting

One of the most important aspects of good solid waste management is sorting. Every day, a large volume of solid garbage is collected in Bangladesh, but there is no formal sorting mechanism in place because the waste's final destination is open dumping. It is not a sanitary landfill or engineering dumping. In Bangladesh, the solid waste collection system has collected all waste without sorting it into biodegradable and non-biodegradable waste. When the waste collector collects solid waste, he strives to collect as much non-biodegradable debris as possible, such as plastic bottles, metal, polythene, and aluminum components. Another frequent image in Bangladesh is of door-to-door recyclables purchasers (Feriwalla) purchasing recyclable items and selling them in recycling shops. This is a relatively common sorting scenario in Bangladesh. Scavengers (Tokay) also try to gather non-biodegradable and recyclable rubbish when it is dumped in the secondary and final disposal sites from these locations. They then sell it in local retail stores to make money. However, this is not the correct sorting method. Because biodegradable and non-biodegradable solid waste dumps are not the same, sorting is critical to appropriate solid waste management. Non-biodegradable solid waste includes papers, metals, plastics, e-waste, glass, cardboard, and demolition waste. Biodegradable solid waste includes all types of food waste and vegetable waste. Both of these wastes are environmentally dangerous. Hazardous material (which requires specific disposal) is occasionally discovered in municipal solid waste. Organic digestion, composting, and energy recovery all employ biodegradable waste. Non-biodegradable garbage, on the other hand, is strongly suggested for 3R techniques. Sorting biodegradable and non-biodegradable waste is required for the implementation of zero waste (ZW) management.

Biodegradable waste

The amount of biodegradable and non-biodegradable garbage varies by country. The amount of biodegradable garbage in a low-income and developing country is higher than in a developed country. Bangladesh is a developing country where biodegradable garbage outnumbers non-biodegradable waste. Food waste, agricultural waste, and decomposable materials are all examples of biodegradable waste. In Bangladesh, the overall amount of MSW is 30,000 tons/day, with roughly 70% of this trash being biodegradable and the balance being non-biodegradable (Sultana et al. 2020). The majority of biodegradable solid waste is generated in residential settings. Bangladesh is a densely populated country, and a large chunk of the population's cuisine is not comparable to that of wealthy countries. This is one of the key reasons why Bangladesh produces more organic food waste. People eat a variety of vegetables, fruits, and rice as a source of nutrition. Organic waste includes vegetable peeling, fruit pulps, and peeling, and it has negative environmental consequences if it is not properly managed. Nearly half of Bangladesh's solid garbage is not collected, and organic waste decomposes in a short period of time. When organic solid waste decomposes, it emits a foul odor and methane gas. Furthermore, during the monsoon season, this organic waste causes water pollution and sewage drainage obstruction. Every river in Dhaka city is heavily contaminated as a result of haphazard municipal solid waste management. Apart from the riverbank, which is not an engineering waste dumping site, there are several dumping places. As a result, leachate, organic solid waste, and other solid waste pollute river water and the ecosystem. Although Bangladesh has a low carbon footprint, poor solid waste management is releasing massive amounts of greenhouse gases into the environment. Apart from Dhaka, places such as Gazipur, Savar, Ashulia, Nabinagor, Matuail

landfill area, and Amin Bazar landfill area are heavily contaminated as a result of poor solid waste management. Gazipur, Savar, Ashulia, and Nabinagar all have roadside dumping, making it difficult to pass through these places due to the foul odor. Organic solid waste, in particular, has a greater harmful impact on our environment. It is high time to take action against organic solid waste management issues. Environmental protection against organic solid waste should be a priority for legislators. Composting, energy recovery, organic manure, and landfill gas collection systems are all potential options (Fig. 4).

Table 2 indicates the methane (CH_4) collection or methane trapping potentials from the biodegradable waste from the different city corporations along with municipalities in Bangladesh. Dhaka has the highest energy potential from the methane collection based on organic waste generation. The municipality's biodegradable waste generation has the second largest energy potential from the methane collection. This methane generation can be a way forward to a zero waste management process in Bangladesh. Therefore each of the cities or municipalities may adopt this approach so that the energy saving process may lead to economic inflation into the national economy through this sustainable waste management process.

Compost farming

The faulty waste management system in Bangladesh is causing an increase in municipal solid waste management difficulties. Organic solid waste makes up a large component of MSW. The majority of organic solid waste in metropolitan areas comes from residential areas. In Bangladesh, the two main sources of organic solid waste are households and businesses. Households account for around 75% of total solid waste, while business sectors account for about 20%. (Guerrero, Maas and Hogland, 2013). Components of organic solid waste are quite useful for composting. In Bangladesh, the compost farming concept is not well developed.

There are not too many organizations or companies, who are involved with composting. Compost farming is a relatively recent concept in Bangladesh. The community-based composting project was originally begun in Dhaka by Waste Concern, a local non-governmental organization in Bangladesh (Halder et al. 2014). However, there is no large compost plant that can hold more garbage for composting. Compost farming is an excellent method of dealing with biodegradable trash. It has a lot of potential here as an agriculturally dependent country. Most of the farmers use chemical fertilizers for their cultivation. As a result, the soil's general features and nutrient content have deteriorated, and these harmful compounds are now

Fig. 4 Common biodegradable waste in the dumping area

Table 2 CH_4 emission potential and savings in electricity from landfill (2013) Source: Mujeri, Chowdhury, & Shahana,

City/town	Average waste generation rate (tones/year)	Potential CH_4 emission (million tones CO_2e/years)	Energy savings in million kWh (1 million tones $CO_2e = 0.172$ million kWh)	Total savings in terms of cost in * million USD (**1 kWh = 5.36 BDT or 0.067 USD)
Dhaka	1,817,179	100.17	17.23	1.15
Chittagong	572,459	25.62	4.41	0.30
Khulna	81,590	4.41	0.76	0.05
Rajshahi	61,453	3.15	0.54	0.04
Barisal	38,831	0.21	0.04	0.00
Sylhet	68,569	3.57	0.61	0.04
Municipalities	2,173,329	97.02	16.69	1.12
Other Urban Centers	387,509	16.8	2.89	0.19
Total	5,200,919	250.95	43.16	2.89

*1 USD = 79.95 BDT; **1 kWh = 5.36 BDT

entering the human body through food and water. Biomagnification is the word for it. Farmers are unfamiliar with compost fertilizer and use chemical fertilizer in an uncertain manner. Chemical fertilizers deplete the fertility of the soil. Furthermore, organic fertilizer promotes soil fertility and can improve soil moisture for the land when compared to chemical fertilizer. Organic fertilizer can retain more moisture in the soil while also maintaining the soil's PH value. Because of the decrease in organic matter in the soil, increased usage of chemical fertilizers may result in increased soil acidity. Organic fertilizers, rather than chemical fertilizers, can be beneficial to the land and the environment. Governments and local agriculture agencies should take significant initiatives to promote this practice and raise farmer awareness. Governments, NGOs, and commercial stakeholders, on the other hand, can assist new enterprises interested in compost farming. Khulna City Corporation (KCC) recently established a compost factory that is funded by ADB. This is a fantastic idea for both the city and the environment. 64 compost enterprises have official registration till December 2020, according to the Bangladesh Department of Agriculture Extension (DAE) and Bangladesh Organic Products Manufacturers Association (BOPMA). Thirty-five of these companies are working on compost fertilizer production. There are more than 100–150 composting-related organizations that are not registered.

Shams et al. 2017 reported that the composting industry may collect CH_4, N_2O and CO_2 (Table 3). Since CH_4 has the great potentiality for causing global warming and climate change, therefore increasing the number of composing industries will augment the possibility to achieve the success of zero waste management approach in the near future in Bangladesh.

Energy recovery

Organic solid waste has a significant negative environmental impact. It makes a significant contribution to the increase in greenhouse gas emissions. Due to its features, organic solid waste has the potential to produce biogas (Methane) when composted. Methane gas is created when organic solid waste decomposes during that time. This gas is more hazardous than carbon dioxide as a greenhouse gas. Waste collection and management methods in Dhaka city are extremely inadequate, adding to greenhouse gas emissions in the environment. For the environment, this is a grave concern. Methane is emitted from a composting facility. It will not be able to recover energy or collect gas if it does not have energy recovery or gas collection technology. In Dhaka, Matuail is a sanitary landfill site in Bangladesh but there has no such type of technology that is capable to collect methane gas from this landfill site. The CH_4 emission from Dhaka's waste was found about 319,027 tons/year (Shojib, Zahir, and Ahmeduzzaman, 2013). In Bangladesh, most of the waste dumping site is open dumping and there is no landfill gas collection (LFG) technology. The Matuail landfill site is a 100-acre area that serves as the disposal site of solid waste from areas under Dhaka South City Corporation (DSCC). Every day almost 2500 tons of solid waste is thrown away in this landfill site. This landfill site emits 4000 tons of CH_4 gas into the atmosphere every hour which is 80 times more potent than CO_2 gas (Antara 2021). CH_4 is a greenhouse gas, which means it raises the temperature. It would be possible to collect a large volume of CH_4 gas if an LFG gas (CH_4) collection equipment could placed in this landfill. It will also prevent greenhouse gas emissions from entering the atmosphere. There's also a good potential of getting methane gas from the compost facility. When a compost plant is built,

Table 3 CH_4, CO_2, and N_2O emission potential from composting (Source: S. Shams et al. 2017)

City/town	Waste generation rate (tones/year)	Potential **CH_4** emission (tones **CO_2e/year**	Potential **CO_2** emission (tones/year)	Potential **N_2O** emission (tones **CO_2e/year**
Dhaka	1,817,179	20,611	85,779	4814
Chittagong	572,459	95,847	27,023	77,579
Khulna	81,590	13,661	3851	11,057
Rajshahi	61,453	15,091	4255	12,215
Barisal	38,831	6502	1833	5262
Sylhet	68,569	11,481	3237	9292
Municipalities	2,173,329	363,883	102,591	294,527
Other Urban Centre's	387,509	64,881	18,292	52,515
Total	5,200,919	591,955	228,570	467,261
Total GHGs emission potential from composting (tones **CO_2e/year**)	1,287,786			

*The conversion of CH_4 and N_2O to CO_2 equivalent is based on the global warming potential of each gas, e.g., CH_4 is 21 times and N_2O is 310 times higher than CO_2

it should be considered a biogas gas collection technology with that compost plant at that time. As a result, methane gas may be extracted from the compost plant and used as a source of energy. This methane gas can be collected and used to generate energy or for other uses. Another energy recovery technology that is particularly effective for organic solid waste management is anaerobic digestion. Because of its biological features, organic solid waste is ideal for producing biogas in anaerobic digestion plants. Bangladesh has an energy deficit, and this energy recovery system can provide more energy in the form of methane gas or make electricity from it. For this benefit, gas collection technology must be installed at the landfill site, as well as taking steps to create a gas collection system in a compost plant and anaerobic digestion plants (Fig. 5).

Organic manure

Agriculture accounts for a significant percentage of Bangladesh's economy. According to a World Bank estimate, agriculture supports more than 70% of Bangladesh's population. It is the primary source of employment in rural areas. According to the Bangladesh Bureau of Statistics (BBS), total arable land is 85.77 million hectares and total crop land is 154.38 million hectares in 2017 (BBS 2017). Farmers have utilized chemical fertilizer on this vast amount of fertile land. Bangladesh also has a yearly fertilizer need of about 5 million tons, of which 2.7 million tons are urea and the rest are non–urea fertilizers, according to the Ministry of Agriculture. Fertilizer consumption was 208.7 kilos per hectare of arable land in 2013, with fertilizer use increasing year after year (Fertilizer Industry of Bangladesh 2017). This is a concerning trend, because the increased use of chemical fertilizers is extremely detrimental to the ecosystem. Chemical fertilizers have a negative impact on soil nutrients over time. Organic manure, on the other hand, is an excellent fertilizer for both soil nutrients and crops. Every nutrient in organic manure originates directly from a plant, which is extremely beneficial for the growth of soil microorganisms. Furthermore, organic manure contains a variety of micronutrients

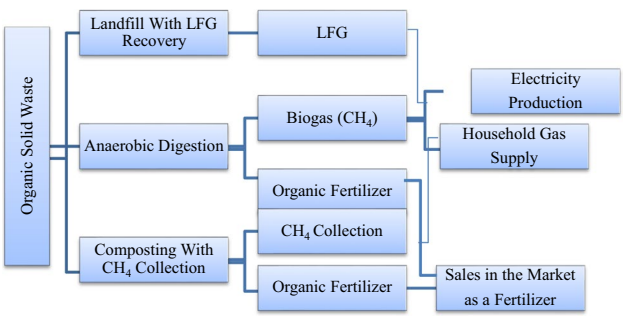

Fig. 5 Energy recovery pathway from organic solid waste (OSW)

that are important for all plants. These micronutrients also aid in the improvement of the soil's physical, chemical, and biological qualities. Organic manure can increase fertility rates while causing no long-term harm to the soil. Chemical fertilizers, on the other hand, may diminish soil fertility in the long run. In Bangladesh, as well as the rest of the world, soil fertility is declining at an alarming rate. Standard soil should have at least 3.5% organic matter, but most parts of Bangladesh have between 1 and 1.7% (4.14 mh) and certain areas (1.09 mc) have less than 1% (Fertilizer Industry of Bangladesh 2017). In addition, due to population growth, arable land is diminishing. In this situation, fast action is required to limit the usage of artificial fertilizers and to expand the compost industry. Farmers can be educated about the negative impacts of using chemical fertilizers by the local agricultural department, which can then encourage them to use organic manure. They must be taught how to produce organic manure utilizing livestock in addition to cropland. The government may create a subsidy program to help new composting entrepreneurs get started. As a result, organic solid waste will be reduced, and organic manure will be produced.

Non-biodegradable

Non-biodegradable waste cannot decompose by the biological process because of its structures. As Bangladesh develops, the amount of non-biodegradable garbage is smaller than the amount of biodegradable waste. Non-biodegradable waste output in developed countries is higher than biodegradable garbage production. Non-biodegradable garbage accounts for around 20–30% of waste in Bangladesh. Plastics and plastic items are the most common non-biodegradable waste components in Bangladesh. Bangladesh generates about 3,000 tons of plastic garbage per day and 0.8 million tons of plastic waste per year. This equates to 8% of the total garbage produced each year. Every day, 14 million polythene bags are used in Dhaka city, and 73,000 tons of plastic trash is dumped into the sea via the Padma, Jamuna, and Meghna rivers. In Bangladesh, the rate of plastic trash creation is 7.5%, whereas the rate of bio-waste production is 5.2% (Islam et al. 2019). Because of its structure, PVC is the most hazardous to the environment of all types of plastic trash. The treatment of biodegradable garbage is not the same as the treatment of biodegradable waste. Pollution of marine and soil biodiversity is caused by non-biodegradable waste. During the rainy season in Dhaka, a plastic bottle and polythene are found clogging the sewerage drainage. As a result, rainwater is unable to move through the drainage system, and the city is submerged. Non-biodegradable garbage in Bangladesh is primarily made up of plastic, plastic goods, metal, glass, building and demolition waste, electronic waste, packaging waste, leather, and rubber. Among these,

the use of non-biodegradable waste plastic is expanding at an alarming rate. Plastic is a versatile, flexible, moisture and bacterial resistant, lightweight, and environmentally friendly material. Plastic microparticles and other non-biodegradable wastes are hazardous to the environment as well as human health. The microparticles of the plastics that are disposed in landfill sites damage the soil and water. This microparticle depletes soil fertility and enters the food chain, endangering human health. The majority of non-biodegradable garbage can be reused or recycled. Recycling is the most effective approach for dealing with non-biodegradable waste, and it can help reduce the amount of waste produced. Because non-biodegradable garbage requires particular treatment, it can be treated using the 3R approach.

Reusable

Reuse is a process in which an item can be used for different uses after it has served its original purpose and still has useful components. There are various objects that can be repurposed in non-biodegradable garbage. Items such as plastic bottles, plastic bags, glass bottles, and cardboard containers can all be reused (Saji et al. 2019). Reuse reduces waste output and, in some cases, is preferable to recycling. Because the recycling process necessitates the use of energy, but reuse does not necessitate the use of energy. Reuse saves energy and reduces greenhouse gas emissions, which contribute to global warming. Reuse is a good way to reduce waste production and pollution in the environment. Furthermore, reusable goods can be used as a useful craft material for creating attractive objects for home and office décor. It has the potential to be a successful commercial system that also contributes to economic progress. In Bangladesh, handy craft is becoming a thriving and promising industry. This type of ornamental item is made by a variety of useful craft organizations, all of which contribute to economic progress. If the government and local governments aided them and provided more training on how to create these types of things from reused materials, more individuals would be able to do so. This could pave the way for reusable garbage in Bangladesh. On the other hand, some unemployed persons may be able to find work through these types of businesses.

Recyclable

It is impossible to stop the growth of solid waste, but it is possible to reduce it. There are numerous objects that can be recycled from non-biodegradable garbage. Recycling is one of the non-biodegradable waste management alternatives. Non-biodegradable trash materials with a high market value are typically recycled in Bangladesh. Plastics, iron, aluminum, copper, glass, and paper are all high-value items that can be recycled. In big cities, about 15% of total generated MSW (mostly inorganic) is recycled on a daily basis. Thus, recycling saves USD15.29 million per year in Bangladesh's urban areas (Sultana et al. 2020). Waste scavengers collect recyclable waste materials in the neighborhood and sell them at a local trade business. These trade establishments are linked to huge dealers in Dhaka and send a large amount of recyclable materials to them. Normally, poor individuals work as rubbish pickers or scavengers in this industry (Tokai). Dhaka is predicted to generate 124 tons of plastic, 260 tons of paper, 46 tons of glass, 27 tons of metal, and 99 tons of other recyclable solid trash each day, with recycling rates of 83%, 65%, 52%, unknown, and 95%, respectively (Yasmin and Rahman 2017). On a daily basis in Khulna, roughly 7.2 to 8.9% of total generated MSW (i.e., 53.2–65.9% RSW) was recycled. RSW is collected and recycled in the community, with a substantial amount of it being shipped to Dhaka for recycling (Moniruzzaman et al. 2011). Dhaka is predicted to generate 124 tons of plastic, 260 tons of paper, 46 tons of glass, 27 tons of metal, and 99 tons of other recyclable solid trash each day, with recycling rates of 83%, 65%, 52%, unknown, and 95%, respectively (Yasmin and Rahman, 2017). On a daily basis in Khulna, roughly 7.2 to 8.9% of total generated MSW (i.e., 53.2–65.9% RSW) was recycled. RSW is collected and recycled in the community, with a substantial amount of it being shipped to Dhaka for recycling (Moniruzzaman et al. 2011). According to the Waste Concern research, Bangladesh's urban regions create 633,129 tons of plastic waste every year, with 51% of that (or 3,23,000 tons per year) being recycled (Concern 2016). Plastic waste is rapidly expanding in Bangladesh, owing to the low cost of plastic products and the fact that people use more plastic than others. Bangladesh generates over 2.8 million metric tons of e-waste per year. However, without understanding the detrimental effects of e-waste, it has been deposited in open landfills, farming land, and open water bodies (Hossain et al. 2010). The majority of e-waste may be recycled. Because non-biodegradable garbage has a high market value, the development of the recycling business in Bangladesh should be encouraged. New projects for the recycling industry should be pursued by the government, which can also collaborate with commercial parties. Sorting is the most crucial phase in recycling, and it is during this phase that the general public has some duty. When they place the waste, they may distinguish the waste bins. Before dumping, deposit stations can be used to segregate biodegradable and nonbiodegradable garbage using technology. Recycling materials can also help to alleviate the strain on natural and non-renewable resources.

Repairable

Many non-biodegradable items that are discarded haven't always reached the end of their useful life. Things that have

been discarded but yet have a useful life can be repaired and repurposed. Many items, such as office equipment, lighting fixtures, and auto parts, can be repaired rather than purchased new. In Bangladesh, a large amount of e-waste is created, and many of these trashes can be repaired. Repairing saves natural resources, reduces waste, and reduces pollution in the environment.

Reduce

Bangladesh is a small country with a large population that produces a large amount of solid waste, which is a major source of worry. In 2010, the government adopted the national 3R strategy to address the problem of solid waste management. The National 3R (Reduce, Reuse, and Recycle) waste management strategy, which was participatory in nature, was introduced in 2010 in Bangladesh with the support of Japan's Ministry of Environment and the UN's Centre for Regional Development, where Waste Concern provided technical assistance in its preparation (Nasrin 2016). By 2015, the national 3R target for trash management is to eliminate waste disposal on open dumps, rivers, and flood plains, and to encourage waste recycling through required waste segregation at source, as well as to create a market for recycled products and give incentives for waste recycling (Department of Environment 2010). However, a committee to manage the national 3R initiative, as well as sources of trash separation, were required for its implementation. Furthermore, different colored bins should have been placed alongside the roadside and in residential areas for good measure. Unfortunately, it was not completed, and as a result, the national 3R project was deemed a failure. In Bangladesh, there are no formal waste management norms, policies, or laws, and the majority of waste is thrown at an open place. To reduce solid waste, it must first be separated into biodegradable and non-biodegradable garbage. Recycling is the most effective method of reducing solid waste. Although Bangladesh was late to the game, several organizations have begun to recycle waste materials. To reduce trash, the government should establish clear laws and strategies for proper solid waste management. Additionally, form a committee to implement the 3R approach, support the development of the recycling industry, and work with reusable and repairable waste materials. Nasrin (2016) recently proposed a new 5R method (Re-think, Reduce, Recycle, Recovery, and Reuse) that is more effective than the 3R strategy. The government can take steps to implement the 5R approach for trash reduction. These methods will require a good guideline, as well as the establishment of waste management laws and policies, as well as the formation of a task force to implement and monitor the major responsibility. These solutions can initially be applied to metropolitan areas. Then, step by step, other towns can follow suit. Waste separation at the source is critical for waste management, thus provide some recommendations and different colored bins for individuals to sort their trash. They will utilize these different colored containers for different forms of waste when they dump their trash in the bins. As a result, sorting garbage for various purposes will be simple. Private NGOs and stakeholders can play an important role in trash management by collaborating with the government.

Society

Rapid urbanization is one of the primary causes of Bangladesh's growing solid waste management challenge. The growing problem of solid waste management is a major impediment to a healthy social system and has a detrimental influence on society. Due to a lack of an effective waste management system, society confronts numerous issues such as health issues, environmental issues, water and air pollution. People in Dhaka, Bangladesh's main city, confront a variety of issues as a result of ineffective waste management systems. There are no proper garbage collection and management systems in some residential areas or communities. As a result, they are subjected to foul odors even when driving beside the dumpsite road. It is not only a problem in Dhaka, but also in other administrative cities in Bangladesh. During the monsoon season, it is a frequent sight in Dhaka city to see rainwater not clearing rapidly via the drainage system due to clogged drainage channels. As a result, all of the roads are submerged, and people and vehicles are unable to travel through them. Inadequate solid waste management and uncollected street sweeping rubbish are the main causes of this problem. Bangladesh's capital, according to the Economist Intelligence Unit (EIU), is the fourth-least livable city on the planet in 2021. In the EIU's livability index, Dhaka is ranked 137th out of 140 cities (Jamal et al. 2021; Tsheleza et al. 2019). Waste management is critical for a prosperous and healthy society. Recycling, energy recovery, distinct reuse, and repairable trash from holistic waste materials are examples of effective waste management systems. The society also bears some duty for waste management; they must dispose of their garbage in the designated waste bin. While putting their waste in a bin, they can play an important role in sorting waste products in their home. They can sort waste into biodegradable, non-biodegradable, reusable, and recyclable categories. They can utilize a variety of colored containers for this purpose. They will be able to fulfill a crucial role in terms of waste management while also keeping their community neat and clean, which will help society as a whole.

Economy

Waste is generated as a result of a variety of human activities. Due to a lack of an effective management system and environmental consequences, it is a significant concern in Bangladesh. Waste collection, transportation, and final disposal are the responsibility of city corporations and municipalities. However, city governments and municipalities have failed to properly record waste statistics on generation, collection, transportation, and final disposal. Policymakers are responsible for establishing a proper waste management system. Economists are unable to provide an economic estimate of solid waste management due to a lack of sufficient data. Furthermore, economic analysis of solid waste management is the most useful to local policymakers on a variety of issues, such as creating municipal waste management taxes or subsidies (Balasubramanian et al. 2020). Waste is an economic by-product; it is a by-product of economic activities, and waste management has economic implications for productivity, government spending, and, of course, the environment. Waste has an impact not just on the environment, but also on the amount of government investment required by local governments to collect and manage household waste. The economic and environmental consequences of waste provide a framework for determining whether government engagement is desirable, as well as what type of policy action is appropriate. Waste may be turned into a profitable product by recycling materials and recovering energy (Fig. 6).

Environment

In Bangladesh, there is no environmentally appropriate urban waste management system, which is a major source of concern for inhabitants. With a high rate of urbanization and a growth in urban population over the last few decades, solid waste has also increased. Furthermore, garbage generation is substantial, with waste coming from a variety of sources including residential, commercial, institutional, and industrial. Every day, a massive amount of waste is produced, but over half of it goes uncollected. In addition, Bangladesh lacks a sanitary landfill site. As a result, environmental damage is caused by uncollected rubbish and filthy dump sites. Air pollution, infectious infections, land and water pollution, drain obstruction, and biodiversity loss can all occur as a result of open dumping and uncollected waste. Leachate is produced by the organic element of trash and is a major source of water and soil contamination. The inorganic part, primarily plastic waste, is responsible for drain clogging and soil fertility loss. Waste is placed alongside the road in Dhaka city, making it difficult to walk along certain roadways due to the foul stench. Furthermore, every riverbank is littered with household and industrial garbage, resulting in nearly dry riverbeds, highly contaminated water, foul odors, and water that is nearly black in color. Most of the river that flows surrounding Dhaka city is very polluted and contaminated by solid and liquid trash. The picture is the same in all of the major cities, not just Dhaka. Furthermore, municipal solid waste contributes to the increase in greenhouse gas emissions in the environment. Uncontrolled and open dumping of solid waste contributes to the growth of greenhouse gases, which can hold more heat in the atmosphere than carbon dioxide. A landfill in Bangladesh is leaking massive amounts of the potent greenhouse gas methane into the atmosphere, according to the emissions-tracking company GHGSat Inc. In 2021, Bangladesh was a hotspot for methane emissions, a colorless, odorless gas that is 84

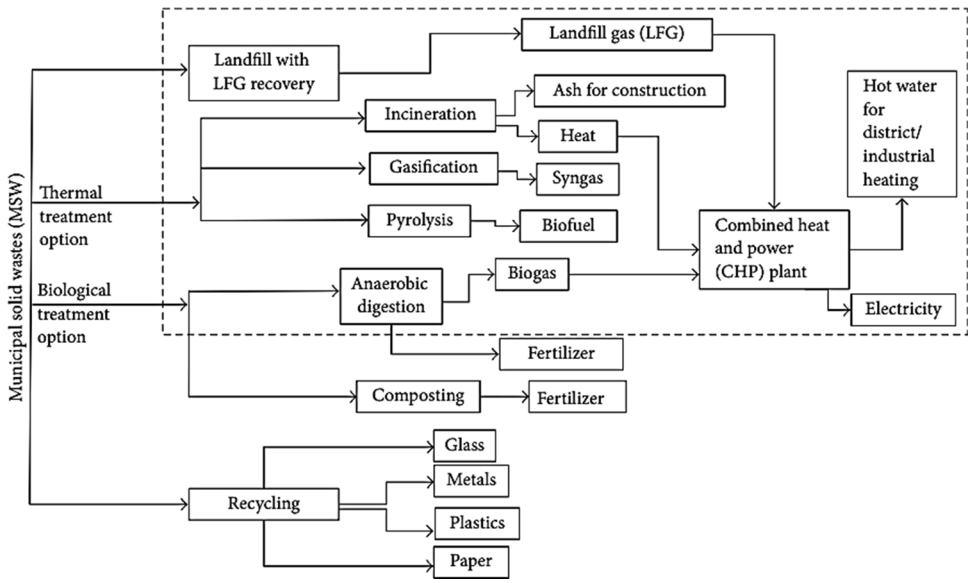

Fig. 6 MSW management pathways with potential economic product generation (Islam 2017)

times more potent than carbon dioxide in the first two decades of its existence in the atmosphere. Dhaka is a methane hotspot, with the Matuail waste site emitting 4000 kg methane per hour. It's the same as driving 190,000 regular cars for a year (Aaron Clark 2021). Due to its vast volume of generated waste, Dhaka city has the biggest potential for CH_4 emission from landfill, with 100.17 million tones CO_2 e/year, followed by Chittagong with 25.62 million tones CO_2 e/year (Shams et al., 2017). Bangladesh's and Dhaka's temperatures are rising at an alarming rate as a result of greenhouse gas emissions. Bangladesh is a low-carbon-emitting country, but it now produces a lot of methane gas. One of the main causes is an ineffective waste management system. In Bangladesh's metropolitan areas, an estimated total of 23,687.78 tons of garbage was generated every day in 2014. This works out to 710,633.34 tons per month, or 8,527,598.88 tons annually. If all of this garbage were landfilled, it would produce about 301,875.01 tons of CO_2 per month, or 3,622,500.12 tons of CO_2 per year. This equates to 418.98 kg of CO_2 every ton of mixed trash generated. Bangladesh produced 64.46 kg of CO_2 per capita per year in 2005, but by 2014, that figure has risen to 86.38 kg per capita per year (Waste Concern-2014). These greenhouse gases are largely to blame for rising atmospheric temperatures. Climate change is affecting people all across the world, and Bangladesh is no exception. As a result, policymakers should take steps to reduce greenhouse gas emissions through promoting sustainable development (Figs. 7, 8).

Fig. 7 Greenhouse gas emissions from urban waste per capita (2005 vs. 2014) Source: Waste Concern 2014

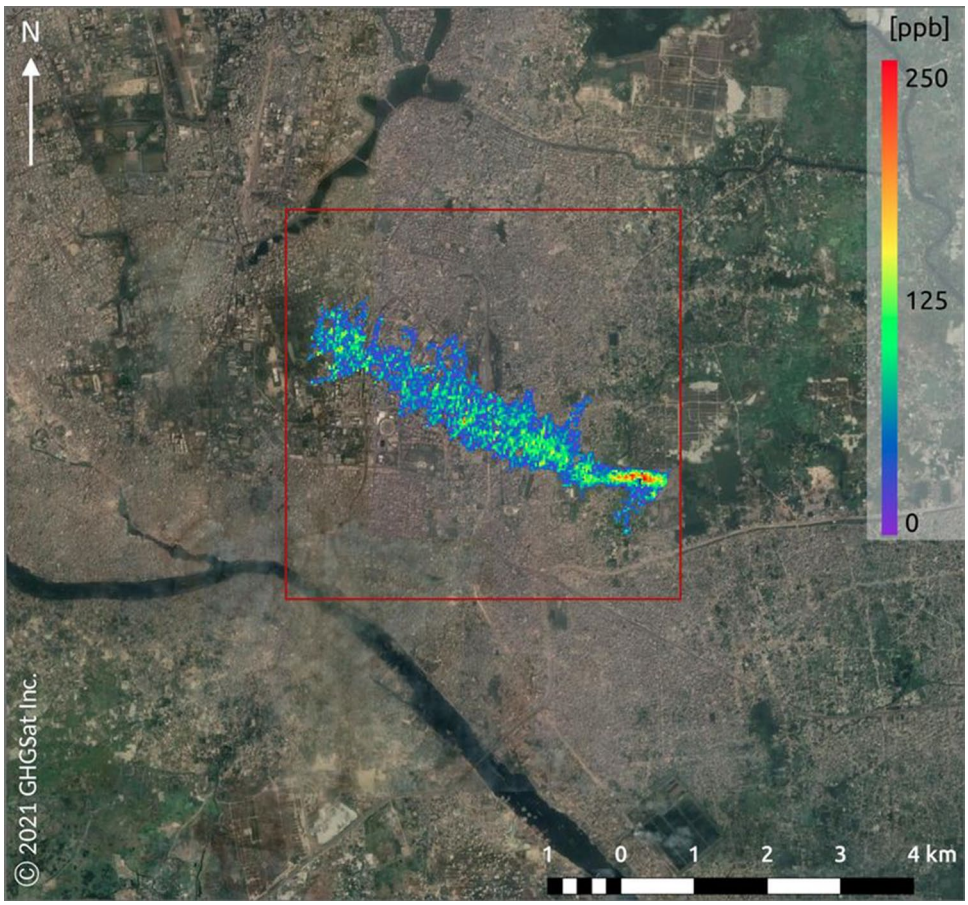

Fig. 8 Landfill methane emission over Bangladesh (Source: Google Maps; GHGSat Inc.; Bloomberg)

Circular economy

A circular economy is a closed-loop system that is the polar opposite of a linear economy. For waste management, the circular economy is more sustainable than the current linear economy structure (Ghinea and Gavrilescu 2019). The economy is a component of society, and society is a component of the environment. Take-make-waste is a common summary of a linear economic system. A circular economy, on the other hand, is a forward-thinking plan to engineer and construct items in such a way that they produce the least amount of waste as feasible. In a cyclic economy, one person's waste becomes another person's treasure. Technical materials and biological materials are the two forms of solid waste that can be found in landfills. Raw materials, manufacturing (Shahbazi et al., 2016), usage, and disposal are all part of the technical materials life cycle. It goes to the rubbish and landfill at the end of its life, but in a circular economy, nothing goes to the landfill. It is a resource for reusing, repairing, and recycling materials. After being consumed, biological materials can be used to make biogas or biochemical compost. The circular economy attempts to generate the least amount of waste while maximizing product production and long-term sustainability. Because waste is not simply trash, but also a resource, it is one of the most successful methods for solid waste management systems today. The circular economy not only provides a financial incentive to recycle, but it also addresses one of the most pressing environmental concerns of our time. In Bangladesh, a circular economy could be a more effective approach to handle solid waste. The government should assist such development in the country by enacting policies, legislation, and providing the necessary incentives. Bangladesh's current waste management system is not adequately managed, and it is critical to develop a robust, systematic waste management system in future. Bangladesh can use the conceptual framework below to achieve its zero waste and circular economy goals.

Conclusion

Solid waste management is a big challenge for Bangladesh. Only the capital city Dhaka counts more than 5000 Metric Ton solid waste generation per day. Therefore, it is easy to perceive the whole scenario of Bangladesh for solid waste management. Land scarcity is a vital factor for any landfill and dumping sites. Although much industries helping us for recycling wastes but still there is severe lacking to patronize compost industries. As a result, huge amount of solid waste mainly biodegradables are being dumped in the road side, river side, lake side and pond side which causing a serious environmental hazards like soil, air and water pollution. Therefore, this study generated a timely conceptual model which will able to stimulate a sustainable solid waste management in Bangladesh. As recommendations few issues must be considered by the policymakers to achieve the milestone toward zero waste management in Bangladesh: (a). Encouraging more entrepreneurs for recycling business and composting industry as their start up; (b). Increasing friendly loan scheme for composting or organic fertilizer industries from different banking sectors; (c). Municipalities and city corporations should build awareness for zero waste management; (d). Ministry of trade, business and economy should augment the practice of circular economy based on zero waste; (e). Ministry of agriculture and environment should build awareness for organic fertilizers among fermenters; (f). City corporations should ensure zero dumping sites and landfills; it will magnify 100% waste into resources either by composting or renewable energies; Ministry of ICT must think of their e-waste for more recycling and reusing; (g). students of all stream (primary, secondary and tertiary) must be taught about the significance of the zero waste management. Therefore, educational curriculum must be rectified to build a sustainable society maintaining zero waste in the country. All these efforts will help us to achieve the goal of the proposed conceptual model of the zero waste management in Bangladesh. This study merely tries to broaden an understanding of the waste-related problems that have been generated from multiple sources in Bangladesh and subsequently proposes a likely model that can be put in place to implement a zero-waste policy. Nevertheless, the outcomes of this study are supposed to adopt for academics, scholars, researchers, policymakers, and practitioners to delve into future endeavor to justify the proposed model before the implementation of the zero-waste policy to achieve sustainable development goals.

Declarations

Conflict of interest This manuscript doesn't carry any conflict of interest. It is not involving with any funding project. This is solely self-generated project targeting publication.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

References

Abbas II, Nai'ya R, Arigbede YA (2011) Use of remote sensing and GIS in effective and efficient solid waste management planning (a case study of Samaru, Zaria, Nigeria). Res J Earth Planet Stud 1(2):046–052

Abedin MA, Jahiruddin M (2015) Waste generation and management in Bangladesh: an overview. Asian J Med Biol Res 1(1):114–120

Ahsan A, Alamgir M, El-Sergany MM, Shams S, Rowshon MK, Daud NN (2014) Assessment of municipal solid waste management system in a developing country. Chin J Eng 2014(12a):1–11
Alam MNI, Ahmed W, Badhon SM (2018) Feasibility of waste to energy conversion in Bangladesh (Doctoral dissertation)
Aliani HA (2012) Pro Poor solid waste management-For secondary cities and small towns in Asia and Pacific. Sustainable Urban Development Unit, ESCAP
Ashikuzzaman M, Howlader MH (2020) Sustainable solid waste management in bangladesh: issues and challenges. In: Pariatamby A, Hamid FS, Bhatti MS (eds) Sustainable waste management challenges in developing countries. IGI Global, pp 35–55
Statistics B (2018) Bangladesh Bureau of Statistics (BBS) Statistics and informatics division, ministry of planning. www.bbs.gov.bd. (Accessed 9 November 2019).
Balasubramanian D, Kamaraj S, Krishnamoorthy R (2020) Synthesis of biodiesel from waste cooking oil by alkali doped calcinated waste egg shell powder catalyst and optimization of process parameters to improve biodiesel conversion (No. 2020-01-0341). SAE Technical Paper
Barrett J, Scott K (2012) Link between climate change mitigation and resource efficiency: a UK case study. Glob Environ Chang 22(1):299–307
Bartl A (2011) Barriers towards achieving a zero waste society. Waste Manage 12(31):2369–2370
Baul TK, Sarker A, Nath TK (2021) Restaurants' waste in Chittagong city, Bangladesh: current management, awareness on environmental hazard and perception towards potential uses. J Clean Prod 292:126073
BBS (Bangladesh Bureau of Statistics) (2017) Bangladesh Economic Review. Bangladesh Bureau of Statistics, Dhaka
Bhuiyan SH (2010) A crisis in governance: Urban solid waste management in Bangladesh. Habitat Int 34(1):125–133
Cheng H, Hu Y (2010) Municipal solid waste (MSW) as a renewable source of energy: current and future practices in China. Biores Technol 101(11):3816–3824
Chiemchaisri C, Visvanathan C (2008) Greenhouse gas emission potential of the municipal solid waste disposal sites in Thailand. J Air Waste Manag Assoc 58(5):629–635
Concern W (2014) Bangladesh waste database 2014. Dhaka: Waste Concern. Retrieved June, 29, 2019
Connett P (2013) The zero waste solution: untrashing the planet one community at a time. Chelsea Green Publishing
Concern W (2016) Prospects of plastics waste recycling in Bangladesh. Prospects of Plastics Waste Recycling in Bangladesh
Cristina G, Camelin E, Pugliese M, Tommasi T, Fino D (2019) Evaluation of anaerobic digestates from sewage sludge as a potential solution for improvement of soil fertility. Waste Manage 99:122–134
Curran T, Williams ID (2012) A zero waste vision for industrial networks in Europe. J Hazard Mater 207:3–7
Enayetullah I, Sinha AHMM (2000) A study on resource recovery from solid waste in Khulna City. The World Bank, Dhaka, Waste and Sanitation Program in South Asia
Franco-García ML, Carpio-Aguilar JC, Bressers H (2019) Towards zero waste, circular economy boost: waste to resources. In: Franco-García ML, Carpio-Aguilar JC, Bressers H (eds) Towards zero waste. Springer, Cham, pp 1–8
Franks DM, Boger DV, Côte CM, Mulligan DR (2011) Sustainable development principles for the disposal of mining and mineral processing wastes. Resour Policy 36(2):114–122
Gharfalkar M, Court R, Campbell C, Ali Z, Hillier G (2015) Analysis of waste hierarchy in the European waste directive 2008/98/EC. Waste Manage 39:305–313
Ghinea C, Gavrilescu M (2019) Solid waste management for circular economy: challenges and opportunities in Romania-the case study of Iasi County. In: Franco-García ML, Carpio-Aguilar JC, Bressers H (eds) Towards zero waste. Springer, Cham, pp 25–60
Greyson J (2007) An economic instrument for zero waste, economic growth and sustainability. J Clean Prod 15(13–14):1382–1390
Halder PK, Paul N, Hoque ME, Hoque AM, Parvez MS, Rahman MH, Ali M (2014) Municipal solid waste and its management in Rajshahi City, Bangladesh: a source of energy. Int J Renew Energy Res 4(1):168–175
Hoang NH, Fogarassy C (2020) Sustainability evaluation of municipal solid waste management system for Hanoi (Vietnam)—Why to choose the 'Waste-to-Energy' concept. Sustainability 12(3):1085
Hoornweg D, Sugar L, Trejos Gómez CL (2011) Cities and greenhouse gas emissions: moving forward. Environ Urban 23(1):207–227
Hoornweg D, Bhada-Tata P, Kennedy C (2015) Peak waste: When is it likely to occur? J Ind Ecol 19(1):117–128
Hoornweg D, Bhada-Tata P (2012) What a waste: a global review of solid waste management
Hossain ABMS, Boyce AN, Salleh A, Chandran S (2010) Impacts of alcohol type, ratio and stirring time on the biodiesel production from waste canola oil. Afr J Agric Res 5(14):1851–1859
Islam KN (2017) Greenhouse gas footprint and the carbon flow associated with different solid waste management strategy for urban metabolism in Bangladesh. Sci Total Environ 580:755–769
Islam R, Nazifa TH, Yuniarto A, Uddin AS, Salmiati S, Shahid S (2019) An empirical study of construction and demolition waste generation and implication of recycling. Waste Manage 95:10–21
Jamal T, Zahid M, Martins JM, Mata MN, Rahman HU, Mata PN (2021) Perceived green human resource management practices and corporate sustainability: multigroup Analysis and major industries perspectives. Sustainability 13(6):3045
Jin J, Wang Z, Ran S (2006) Solid waste management in Macao: practices and challenges. Waste Manage 26(9):1045–1051
Johari A, Ahmed SI, Hashim H, Alkali H, Ramli M (2012a) Economic and environmental benefits of landfill gas from municipal solid waste in Malaysia. Renew Sustain Energy Rev 16(5):2907–2912
Johari A, Hashim H, Mat R, Alias H, Hassim M, Rozzainee M (2012b) Generalization, formulation and heat contents of simulated MSW with high moisture content. J Eng Sci Technol 7(6):701–710
Kabir MR (2015) Municipal solid waste management system: a study on Dhaka north and South City corporations. J Bangladesh Inst Plan ISSN 2075:9363
Kassim SM, Ali M (2006) Solid waste collection by the private sector: Households' perspective—findings from a study in Dar es Salaam city, Tanzania. Habitat Int 30(4):769–780
Kaza S, Yao L, Bhada-Tata P, Van Woerden F (2018) What a waste 2.0: a global snapshot of solid waste management to 2050. World Bank Publications
Khan KS, Joergensen RG (2009) Changes in microbial biomass and P fractions in biogenic household waste compost amended with inorganic P fertilizers. Biores Technol 100(1):303–309
Kormoker T, Proshad R, Khan MM (2017) Analysis of water quality in urban water supply system of Bangladesh. J Env Analyt Toxicol 7(4):2161–2525
Malav LC, Yadav KK, Gupta N, Kumar S, Sharma GK, Krishnan S, Bach QV (2020) A review on municipal solid waste as a renewable source for waste-to-energy project in India: current practices, challenges, and future opportunities. J Clean Prod 277:123227
Matete N, Trois C (2008) Towards zero waste in emerging countries–a South African experience. Waste Manage 28(8):1480–1492
Mohammedshum AA, Gebresilassiea MA, Rulindaa CM, Kahsaya GH, Tesfay MS (2014) Application of GIS and Remote Sensing in effective solid waste disposal site selection in Wukro town,

Tigray, Ethiopia. Int Arch Photogram Rem Sens Spatial Inform Sci 2:115–119
Moniruzzaman SM, Bari QH, Fukuhara T (2011) Recycling practices of solid waste in Khulna city, Bangladesh. J Solid Waste Technol Manag 37(1):1–15
Mujeri MK, Chowdhury TT, Shahana S (2013) Energy Subsidies in Bangladesh: a profile of groups vulnerable to reform. Bangladesh Institute of Development Studies
Murphy S, Pincetl S (2013) Zero waste in Los Angeles: Is the emperor wearing any clothes? Resour Conserv Recycl 81:40–51
Nasrin F (2016) Waste management in Bangladesh: current situation and suggestions for action. Int Res J Soc Sci 5(10):36–42
Nizar M, Munir E, Munawar E (2018) Implementation of zero waste concept in waste management of Banda Aceh City. J Phys Conf Series 1116(5):052045
Pfammatter R, Schertenleib R (1996) Non-Governmental refuse collection in low–income urban areas Swiss Federal Institute for Environmental Science and Technology. SANDEC. 96pp
Phillips PS, Tudor T, Bird H, Bates M (2011) A critical review of a key waste strategy initiative in England: zero waste places projects 2008–2009. Resour Conserv Recycl 55(3):335–343
Saji A, Shahana S, Subahan S, Thasneem A, Basheerudheen A (2019) Cost effective residential building using plastic bottles-a home for the future
Scarlat N, Motola V, Dallemand JF, Monforti-Ferrario F, Mofor L (2015) Evaluation of energy potential of municipal solid waste from African urban areas. Renew Sustain Energy Rev 50:1269–1286
Sewak A, Kim J, Rundle-Thiele S, Deshpande S (2021b) Influencing household-level waste-sorting and composting behaviour: What works? A systematic review (1995–2020) of waste management interventions. Waste Manag Res. https://doi.org/10.1177/0734242X20985608
Shahbazi S, Wiktorsson M, Kurdve M, Jönsson C, Bjelkemyr M (2016) Material efficiency in manufacturing: Swedish evidence on potential, barriers and strategies. J Clean Prod 127:438–450
Shams S, Sahu JN, Rahman SS, Ahsan A (2017) Sustainable waste management policy in Bangladesh for reduction of greenhouse gases. Sustain Cities Soc 33:18–26
Shum PL, Kok HK, Maingard J, Schembri M, Bañez RMF, Van Damme V, Asadi H (2020) Environmental sustainability in neurointerventional procedures: a waste audit. J Neurointerventional Surg 12(11):1053–1057
Song Q, Li J, Zeng X (2015) Minimizing the increasing solid waste through zero waste strategy. J Clean Prod 104:199–210
Sultana A, Alam MM, Middya TR, Mandal D (2018) A pyroelectric generator as a self-powered temperature sensor for sustainable thermal energy harvesting from waste heat and human body heat. Appl Energy 221:299–307
Tsheleza V, Nakin MD, Ndhleve S, Kabiti HM, Musampa CM (2019) Vulnerability of growing cities to solid waste-related environmental hazards: the case of Mthatha, South Africa. Jàmbá J Disaster Risk Stud 11(1):1–10
Van Ewijk S, Stegemann JA (2016) Limitations of the waste hierarchy for achieving absolute reductions in material throughput. J Clean Prod 132:122–128
Yasmin S, Rahman MI (2017) A review of solid waste management practice in Dhaka City, Bangladesh. Int J Environ Prot Policy 5(2):19–25
Zaman AU (2014) Measuring waste management performance using the 'Zero Waste Index': the case of Adelaide, Australia. J Clean Prod 66:407–419
Zaman AU (2015) A comprehensive review of the development of zero waste management: lessons learned and guidelines. J Clean Prod 91:12–25
Zaman AU (2016) A comprehensive study of the environmental and economic benefits of resource recovery from global waste management systems. J Clean Prod 124:41–50
Zaman AU, Lehmann S (2013) The zero waste index: a performance measurement tool for waste management systems in a 'zero waste city.' J Clean Prod 50:123–132
Zaman A, Ahsan T (2019) Zero-Waste Strategy