Open Access

SCHOLARENA

Journal of Waste Management and Disposal

RESEARCH ARTICLE

ISSN: 2641-8827

Characterization of Municipal Solid Waste: A Case Study in Patuakhali City

Md Shahin[1*], Aktar S[2] and Paul N[3]

[1,3]Department of Disaster Resilience and Engineering, Patuakhlai Science and Technology University, Dumki, Patuakhali, Bangladesh
[2]Department of Environmental Science, Patuakhlai Science and Technology University, Dumki, Patuakhali, Bangladesh

[*]**Corresponding author:** Md Shahin, Department of Disaster Resilience and Engineering, Patuakhlai Science and Technology University, Dumki, Patuakhali, Bangladesh, Tel: 01764389044, E-mail: shahin_dre@pstu.ac.bd

Citation: Shahin M, Aktar S, Paul N (2019) Characterization of Municipal Solid Waste: A Case Study in Patuakhali City. J Waste Manag Disposal 2: 306

Article history: Received: 16 September 2019, **Accepted:** 11 December 2019, **Published:** 13 December 2019

Abstract

Patuakhali city in the southern coastal belt of Bangladesh collects all types of solid waste together in a single bin and dumps in the open space without treatment causing environmental threats. This process hikes the cost of waste collection and disposal, but energy recovery might compensate for the cost. This study aims to investigate the potentiality of Municipal Solid Waste as a source of renewable energy. Each type of waste was sorted and measured at six pre-selected locations for six days, including weekends and weekdays, to represent the variation of waste generation. The ratio of waste composition was estimated from field measurement. The municipality generated 14 tons (14000kg) of solid waste every day which was composed of food waste (53.39%), plastic (20.92%), paper (13.23%), tin-can and steel (1.83%), wood/trimming (2.65%), and hospital waste (7.90%). This study suggests food waste for biofuel production, plastics for fuel production, and paper for recycling. Food waste can produce 2743.19m^3 biogas, and plastic can contribute 1464 liter of fuel every day in the study area at a low cost. Tin-can, wood/trimming, and hospital waste after burning could be deposited into the landfill. The design life of the landfill was 34 years, targeting 2050. The proposed strategy will reduce 87.62% of the volume of landfill hence reduce cost, air pollution, and electricity uses. The renewable energy will contribute to the mitigation of greenhouse gas emissions to promote disaster resilience.

Keywords: Solid waste; Sanitary landfill; Renewable Energy; Environment; Resilience

Introduction

Global Agenda 21 has urged developing countries to achieve sustainable solid waste management through complementary collective action having though the limited resources. It is assured that the developed and industrialized countries produce huge quantities of industrial and commercial waste, whereas the developing countries produce vast quantities of domestic waste, including food, clothes, wood, hospital waste, etc. The developing countries have less capacity to collect, process, dispose, or the reuse of solid wastes in a cost-effective manner compared to developed countries as they also produce food waste [1]. In developing countries, problems associated with municipal solid waste (MSW) management have gained an alarming situation during the last few decades. This problem has been increased tremendously due to rapid urbanization and industrialization, population growth, and improved lifestyle, as well as a high rate of economic activities as the solid waste quantity and composition, depending on population density, source diversity, economic activity, and income level of the people.

As a developing country, Bangladesh has been facing the same problem, vast population growth, rapid urbanization due to rural-urban migration, high consumers, and a high rate of solid waste produced in the urban area. Moreover, major urban areas of Bangladesh are facing environmental threats in terms of unorganized loads of solid waste, and improper waste management [2]. MSW has become a serious dispute in the vicinity of its generation and disposal for the urban dwellers [3]. Furthermore, a lack of training on advance solid waste management practices turns the management systems more complicated. Besides this, proper waste management policy without considering a comprehensive plan along with poor management techniques and lack of appropriate technology creates the situation more harmful for the environment and public health. Inefficient and illogical disposal of solid waste causes serious environmental degradation and a significant threat to the health of living beings in the present time [4].

Patuakhali municipality is one of the oldest cities in the southern coastal belt of Bangladesh. The city dwellers generate food waste, plastic, paper, tin-can and steel, wood/trimming, and hospital waste. Most of the dwellers in the city dispose of their wastes in the vicinity of the household, nearby ditches, bin, canals, open drains, and vacant places. As a result, most of the streets are littered with garbage, which is polluting the town seriously. The city requires a minimum 200 human resources, but it has only 149 workforce, 60 trolleys, six-vans, and four trucks, which are not adequate to work in nine wards of the town properly. Nevertheless, the authority emphasized daily waste collection. The waste is disposed of in an open dumping site without proper treatment, which could include sorting of hazardous waste, reuse, recycling, and energy recovery as well as sanitary landfilling of waste. The recycling and reuse can also minimize the volume of waste, and it can also be economically viable. However, it appears that the waste management system in the Patuakhali municipality is not well developed, threating public health and the city environment. Well planned solid waste management is an urgent issue for the Patuakhali city.

Nowadays, this is well known that waste is resource could be mobilized for the betterment of the city life. Through this process, food, paper, plastic, wood, and other waste can be used for an alternative source of energy production and landfilling. [5] summarized the co-digestion of food waste with cattle manure and sewage sludge increase biogas production. After mixing 70% manure, 20% food waste, and 10% sewage sludge (total solid concentration around 4%) at 36 ˚C, for an Organic Loading Rate (OLR) of 1.2 g VS/L day biogas production yields 603 LCH4/kg VS feed. With the increase in temperature and OLR, methane production will be decreased. According to [6], the combined composition of food waste and straw with different mixing ratios yields biogas. The optimal mixing ratio of food waste and straw 5:1 reaches 0.392 m^3/kg-VS with straw particle size 0.3-1 mm. However, the gas production (GP) and methane potential yield (MPY) were reaching 0.58 m^3/kg-VS and 67.62%, respectively. Up to 10% polyethylene and 7.5% polyvinyl chloride can be used for the modification of bitumen to prepare a high strength bituminous concrete [6,7]. The plastic can be a reliable source of low-cost fuel production and is being used in producing fuel, including petrol, diesel, and kerosene in Jamalpur district and Dhaka division of Bangladesh [8].

Few NGOs with local community and city corporation authority try to manage the solid waste through small scale recycling and landfilling techniques [9]. As the study area is located in the remote coastal part of Bangladesh, so, a very few research was conducted on waste management in the Patuakhali municipality. There are several pieces of research on MSW management in many cities in Bangladesh, including Narayanganj, Mymensingh, Chuadanga, Barishal, Rangpur, Chittagong, Pabna, and many others [1-4, 9-12]. These initiatives are also absent in the Patuakhali municipality, facing a challenge of solid waste management. Therefore, this study was conducted to explore the overall waste management system and a potential source of renewable energy at a low cost in Patuakhali city.

Methodology

The method described here is simple and sensitive to the accuracy of the investigation. The method of forecasting the future population, waste generation, volume of waste, and area for landfilling is widely used in the field of solid waste management. The empirical investigation focused on Patuakhali, a municipality in the southern part of Bangladesh. The background information like jurisdiction area, number of population, population growth rate, waste generation, existing waste management scenario etc. were collected and studied from of Patuakhali municipality. The total amount of generated waste is presented, and the required volume of the sanitary landfill after reuse and recycling of waste is proposed. The waste collection points were decided to focus on multi categories of waste as representative of the municipality.

Site Selection

This study selected Six routes for qualitative and quantitative data collection, such as types of waste, and the amount of waste produced every day. The waste collection routes were (1) Sher-E-Bangla road, Thana para, Baitulaman, (2) Katpotti, (3) Sabujbagh, (4) Charpara, (5) Puran Bazar and (6) Goarstan Road. The routes included nine waste collection points, (1) beside jubilee school, (2) chalkbazar, (3) titas cinema more, (4) in front of himi clinic, (5) west side of DC office, (6) beside fire service station, (7) kalatola more, (8) patuakhali clinic, and (9) patuakhali polytechnic institute. Data collection focused on the major waste generation sites, and they were also selected because of getting the mixture of different waste types of wastes. The sites were emphasized due to its multi-stakeholder nature; for example, it covered residential area, commercial area, hospital, clinic, and domestic areas as well. By representing these sites, we are possibly able to characterize the total generated waste in Patuakhali Municipality daily.

Data Collection

This study focused on practiced waste management scenario, reuse and recycling of generated waste and required landfilling area for final disposal of remaining waste. To find out the composition, the actual amount of solid waste including residential, commercial, and clinical waste and present waste management practice in the study area primary data were collected from selected sites along with the people who are responsible for waste collection, processing and disposal. We collected data about total quantity and composition of generated waste, specific waste quantity after sorting, weighting and overall transportation and disposal system. The dustbin beside the road site was also visited and monitored for understanding its situation and data collection. The waste was manually separated to quantify food waste, papers, polybags/plastics, wood/trimming, hospital waste, and tin-cans. By using this data, we can identify the suitable recycling and reuse options for different types of waste through waste volume reduction and can suggest required landfilling or proper management.

Secondary data, i.e., solid waste management, the existing total population in the municipality area, population growth rate, the manpower of waste management, equipment, van, trucks, and frequency of waste collection, were collected. Waste collection and management department in Patuakhali Municipality helped to proceed with the research activities. The secondary data are summarized in Table 1, which comprises general information for waste management in the municipality area, where total service coverage is 65%. Approximately 162 manpower is involved in waste cleaning from the road, drain, waste carrying, truck driving, and other purposes. For waste collecting and transportation 60 hand trolleys, 06 vans and 04 trucks being used. Wastes are collected daily, and the time for that collection is approximately 5 am to 8 am. About 14 ton of solid wastes collected daily in one landfill site where open dumping is a regular scenario. There is no waste treatment plant, and hazardous waste is handled without special consideration, including hospital waste.

Table 1: General information about waste management (source: municipal office record)

Items	Services
Coverage of the service	65%
Manpower (1) Labour (drain section) (2) Labour (road section) (3) Truck driver (4) Office staff	26 126 04 06
Vehicle used in waste collection and transport (1) Hand trolley (2) Van (3) Truck	60 06 04
Frequency of waste collection	Daily
Time of waste collection	From 5 am to 8 am
Waste Treatment Plant (WTP)	Not at all
Landfill site	One dumping site
Special care for hazardous waste handling	No
Amount of solid waste collected daily	14 tons

Equipment

The processing of the waste in generation points and sorting sites require some mechanical and manual equipment. The equipment used in the sites was a manual separator, musk, hand gloves, electric balance, and van and trucks. The solid waste in the Patuakhali city was disposed of in mixed conditions. The separation was necessary to quantify each type of waste disposed of in the collection points. The manual separator was used for the separation of different types of wastes, such as food waste, plastics, paper, wood/trimming, and hospital waste. The electric balance was used for weighting the separated waste in order to estimate the composition of the waste. The truck weighing was used for measuring the total waste generated in the city. Truck weighing system scale was economical and user-friendly weigh station. This system provided full and reliable results when the truck passes through the electric weighing terminal. Musk/hand gloves were used to protect workers from germ infection. Safety musk/hand gloves were also used during waste handling and recycling to prevent odor and other poisonous elements and to ensure safety. The van was used to transfer waste from the collection points to transfer stations. Finally, the trucks were engaged for the disposal of accumulated waste in several sites like open dumping.

Estimation of Population

The municipal solid waste generation is generally related to the population reside in the municipality. The generation of waste also depends on population density. Waste is commonly generated in the residential and commercial area in such type of small municipality. The utmost importance is to estimate the future population of the community, at least for the design life-cycle period in order to calculate the quantity of MSW produced, source of renewable energy, area of required landfill area for sanitary disposal of solid waste. In order to estimate the waste generation for the design life, population estimation is a necessary part of waste management. The design population can be estimated mathematically by using an annual compounding formula, as shown in Equation 1.

$$P_f = P_0(1+r)^n \tag{1}$$

Where,

P_f : future population

P_0 : present population

n : landfill design life from 2016 to 2050

r : annual population growth rate in percent.

Solid Waste Estimation

The total amount of waste produced in the study location was measured by electric balance. Therefore, the per capita production of Municipal Solid Waste (MSW) was estimated by dividing the total waste by covered population according to the Equation 2. The per capita production is used for future estimation of waste. The coverage of the total population was 65% in the Patuakhali municipality. The significant challenges during estimation of generated waste were appeared as odor and nuisance problem, separation of different wastes and the negligence of local people to express their opinion about contemporarywaste management practice, activities of waste management authority.

$$W_{ppc} = \frac{W_T}{P_T} \tag{2}$$

Where,

W_{ppc} : production per capita per day (kg/cap/day)

W_T : total Municipal Waste production per day (kg/day)

P_T : total population (base population 80000)

Estimation of Required Landfilling Area of Solid Waste

The landfilling is one of the widely accepted ways of final disposal of solid waste. For the design of a landfill site, the population, waste generation and volume of waste is required for to be estimated. This investigation was intended to design the landfill site only for hospital waste and wood/trimming waste which produces small amount of biogas might be uneconomical in terms of cost-benefit analysis. The volume and area of the landfill were estimated. The density of the compacted MSW for landfilling was used from the research paper [3]. From field data the mass of waste was known and the waste volume was estimated using Equation 3 that was also used for estimating volume and area of landfill.

$$V_{daily} = \frac{W_T}{D_{msw}} \tag{3a}$$

$$W_T = W_{ppc} * P_f * Cov \tag{3b}$$

$$V_{annual} = V_{daily} \times 365 \tag{3c}$$

$$c.m = V_{annual} \times 0.25 \tag{3d}$$

$$V_{SL} = V_{annual} + c.m \tag{3e}$$

$$V_{SL1} = \sum_{i=1}^{n} V_{SL} \tag{3f}$$

$$A_{SL} = \frac{V_{SL}}{h_{LS}} \tag{3g}$$

$$A_T = F \times A_{SL} \tag{3h}$$

Where,

Cov : Coverage of service of population, (65% of total population).

V_{daily} : Volume of Municipality solid waste to be disposed of in one day (m^3/day)

V_{annual} : Volume of Municipality solid waste to be disposed of in one year (m^3/year)

D_{msw} : Density of the recently compacted MSW and of the stabilized landfill

$c.m$: cover material equivalent to 20 or 25% of the volume of the recently compacted waste

V_{SL} : Volume of the sanitary landfill (m^3/year)

$\sum_{i=1}^{n} V_{SL}$: Volume of the sanitary landfill during its useful life (m^3)

n : Numbers of years

A_{SL} : Area to be filled successively (m^2)

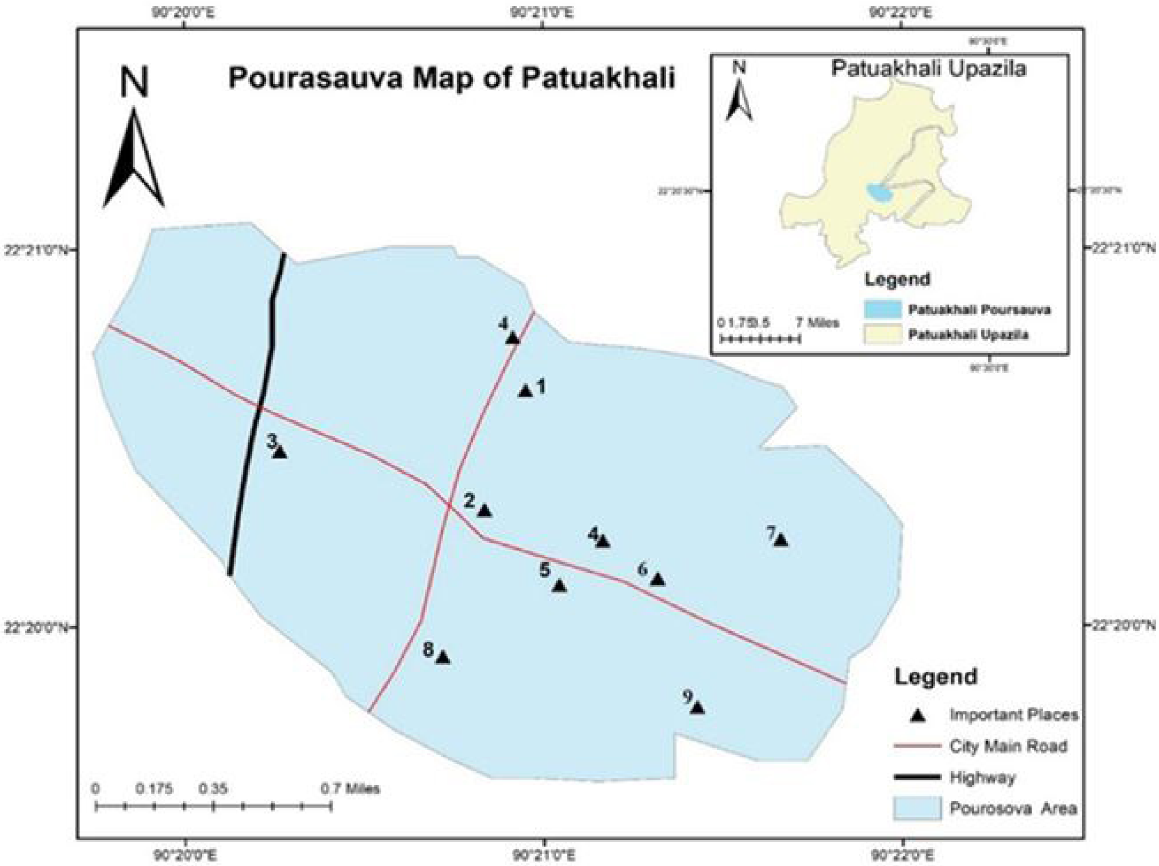
h_{LS} : Mean height or depth of the sanitary landfill (m)

A_T : Total area required (m^2)

F : Factor of increase in the additional area required for penetration road, border setback areas, control building and sanitary facilities, maneuvering yard, etc. This is 30% of the area to be filled for this study.

Results and Discussion

Patuakhali Municipality is established under the Patuakhali district of Barisal division in the southern coastal belt of Bangladesh. Patuakhali Municipality was established in 1st April 1892. Its population was about 80,000 covering an area of 27.03 sq. Km. It is known as a first-class municipality, but the waste management system is not developed at all. Waste management only depends on waste collection and disposal. In Patuakhali Municipality, mainly solid waste produced from households, clinics, markets, and commercial institutions. Among them, household food waste is prominent for biogas production. Other types of waste can be reused, disposed for landfilling, and hazardous waste can be managed through burning, and deep well dumping depending on financial supply. The following table and map indicate the location from where municipal solid waste was collected. Location of solid waste collection points/dustbin in Patuakhali municipality Figure 1.



(1) Beside Jubilie school, (2) Battala road, chalkbazar, (3) Titas cinema more, beside boudho bihar, (4) In front of Himi clinic, (5) West side of DC office, (6) Beside fire service station, (7) South side of jubo samsad, kalatola more, (8)Patuakhali clinic, (9) Patuakhali polytechnic institute
Figure 1: Study area indicating waste collection points

Current Waste Management Scenario in Study Area

In Patuakhali Municipality, waste was collected from the road, drain, household, clinic, market, hotels, restaurants, dustbin, and gathered and transferred. The waste cleaner took off the waste, clean the drain, and keep the waste on the road beside the drain. The drain waste was transferred by collection van and hand trolley for storing in a fixed place. Finally, the truck collected it from sorting point to the dumping station. Open dumping threatened public health and the clean environment. Road wastes are collected through 126 personnel. Every person had responsibility for cleaning the 500m length of the road. However, they started their work at 4-5 am cleaned the road and gathered the wastes in different places. Then these wastes were collected by hand trolley to store in the pre-defined location to be collected in disposal sites for final dumping. There were six existing markets in the municipality area. The cleaning personnel collected market waste after 7 pm and stored in a fixed place by hand trolley and van. Waste collection truck then collected the waste and disposed of it in the dumping site. Dustbin waste directly collected through the truck and disposed of in the final dumping sites.

The municipal authority did not maintain the systematic way of managing the waste. They did not consider odor problems, the health status of workforces, and the effects of open dumping on the topsoil and groundwater contamination. In maximum case, open dumping of solid waste without proper sorting degrade soil production capacity and the groundwater quality. In this case, sanitary landfilling could contribute to reducing the haphazard waste management. The household and clinical waste was collected by van and hand trolley to the sorting point of storage. These wastes were stored in that place for a short time and carried out to a final dumping site using the truck. The overall scenario is shown in Figure 2.

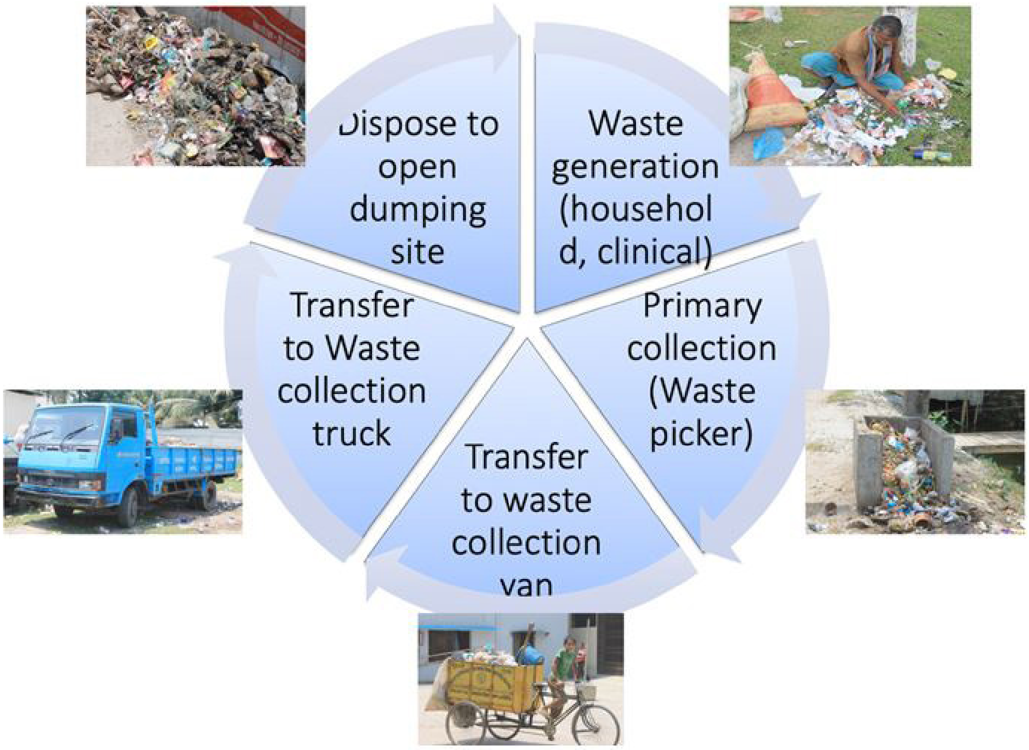


Figure 2: Overall waste collection and disposal Process in Patuakhali Municipality

Daily Waste Generation

The main focus of this study was on the characterization of solid waste. The solid waste types were food waste, polybags, plastic, paper, tin-can and steel, wood/ trimming, and hospital waste (operation theater waste, sharp, needles, blade, glass waste), as shown in Figure 3 & 4. The authors separated waste and measured quantity for each day of the study period from the same tank in the sites. The ratio of the waste was derived from field measurement. The time period, six days, was chosen to represent weekdays and weekends, focusing variation in waste generation. The total waste was 14 tons, which is equivalent to 14000 kg. The generated food waste was 53.39%, equivalent to 7474.6 kg. Figure 3 shows generated waste share in percentage and Figure 4 shows equivalent waste in a kilogram of total waste generated every day. There was 53.39% (equivalent to 7474.6 kg) food waste, 20.92% (2928.8kg) of polybag/plastic, 13.23% (1852.2 kg) of paper waste, 1.83% (256.2 kg) tin-can and steel, 2.65% (370.4 kg) wood/trimming waste, and hospital waste was 7.90% (1106 kg) every day.

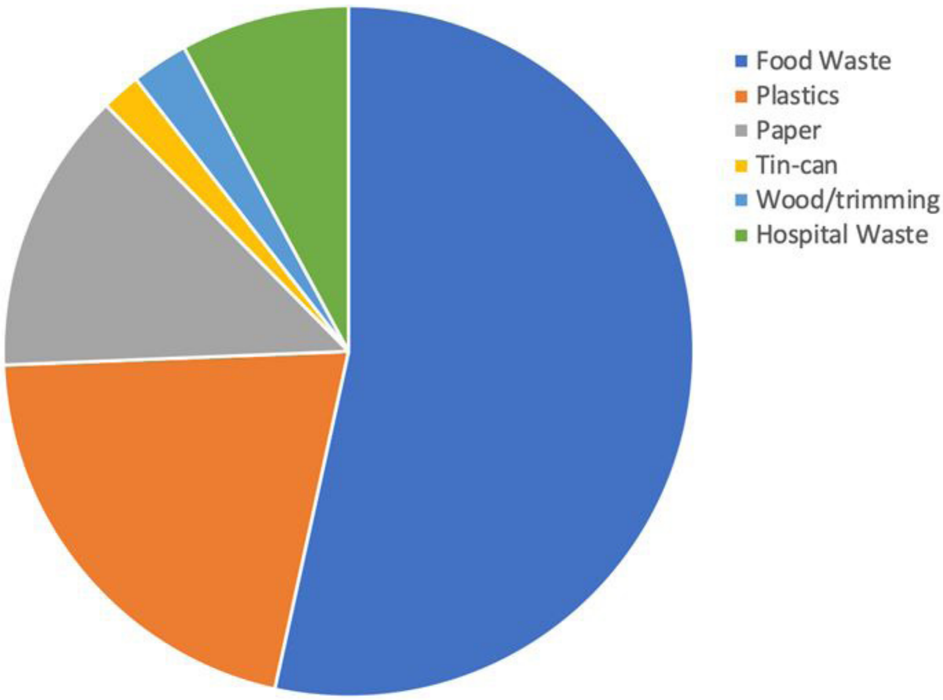


Figure 3: Percentage share of generated waste in Patuakhali Municipality

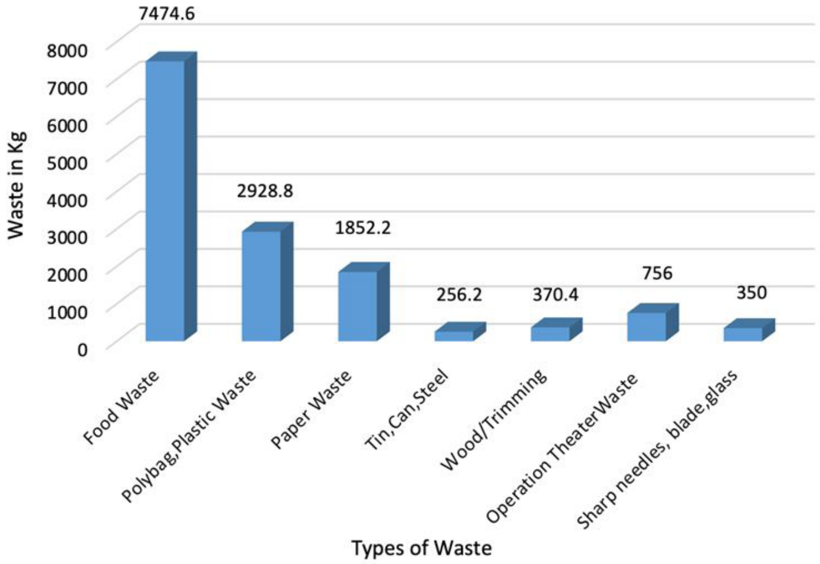


Figure 4: Calculation of daily total generated municipal waste in Kilogram

However, the waste management system in the Patuakhali municipality was not environmental friendly at all. The municipal authority recruited employees to collect the waste from different locations and to dump it in an open place. This situation creates odor problems, soil contamination as well as underground water pollution. In this study, the author proposed integrated solid waste management emphasizing on energy recovery and landfilling. The proposed method was to recover energy at a low cost in the study area.

Food Waste: The production of food waste in the Patuakhali Municipality was dominant. According to the Food and Agriculture Organization (FAO) estimated about 1.3 billion tons of food is wasted globally each year, which is one-third of all food produced for human consumption. The cost of food lost is about 2.6 trillion USD annually, which is more than enough to feed four times, about 815 million hungry people in the world. FAO also estimates that the carbon footprint of food waste is 3.3 billion tons of CO_2 equivalents per year. When food is dumped in an open place, it eventually makes its way to landfills and odor pollution. Food waste becomes harmful when decomposes in a landfill without oxygen, creates an anaerobic sequence that produces methane, and is approximately 20 times more harmful to the atmosphere than carbon dioxide. This results in the destruction of the ozone layer that ultimately increases the temperatures around the globe. Dumping of food waste creates air pollution that has been linked to respiratory diseases and even types of cancer [13].

So, this study identified that 7474.6 kg of food waste produced daily in the municipality area. This food waste can be used for biogas production instead of open dumping that ensures eco-friendly waste management. According to [14], each ton of food waste can produce 367 m^3 of biogas, which results in 65% methane production with an energy content of 6.25 kWh/m^3 yielding 894 TWh annually. Here 7474.6 kg of food waste equals 7.5 tons of waste, which are equivalent to 2743.19 m3 of biogas as well as 65% methane equivalent to 1783.07 m^3 methane gas. The combination of food waste and paper waste by two-stage thermophilic anaerobic co-digestion (coAD) helps to produce biogas [15]. By dumping food waste, the total amount of 2743.19 m^3 of biogas production is lost every day. This process also produces fertilizer as residue. Figure 5 shows yearly food waste production (kg) from 2016 to 2050 and in contrast, the amount of yearly renewable energy losses. So this research suggests producing biogas instead of dumping food waste using modern technology for cooking, lighting, and other purposes.

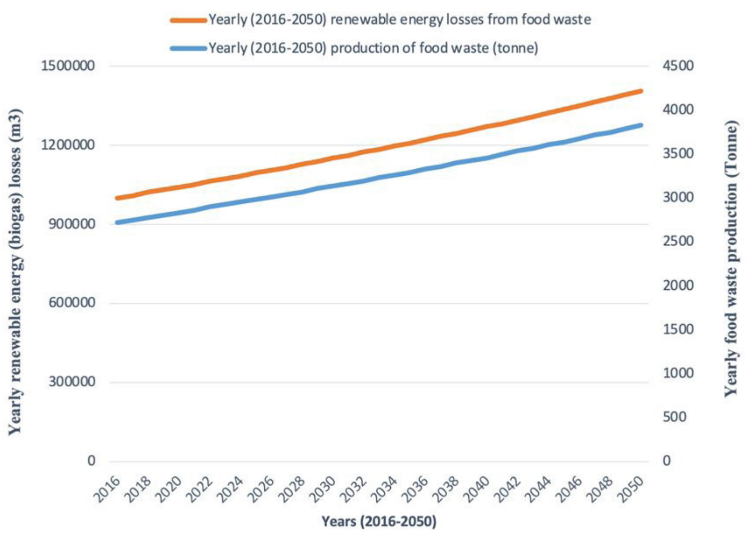


Figure 5: Estimated biofuel from food waste

Polybag/Plastic Waste: The use of plastics has been introduced in the 1970's and gained popularity in the market as it is cheap. Approximately 500 billion plastic bags are used every year worldwide that is harmful to a living organism because it is not readily biodegradable [16]. Accumulation of plastic bags blocks drainage systems that can result in flooding [17]. However, among all plastics, PVC is the most environmentally damaging plastic throughout its lifecycle (production, use, and disposal) [18]. This study found 2.90 tons of polybag and plastic waste generated every day in the Patuakhali municipality that is disposed to here and there. This investigation proposes alternative applications of waste plastics, e.g., admixture with bitumen, fuel extraction, reuse, and recycling instead of open disposal. The waste polyethylene and waste PVC increase compressive strength, binding capacity, temperature susceptibility, and reduce bleeding and stripping in summer [6,7]. Plastic waste can be used as a compacted binder for enhancing the bituminous strength or viscoelastic behavior of the bitumen in road construction [19]. The use of High-density polyethylene (HDPE) and Polypropylene (PP) with unmodified bitumen at a temperature range of 160 ˚C-170 ˚C showed slight linear increment in the viscosity, softening, and penetration values of bitumen. This plastic binder can be taken as a non-traditional, modified binder for increasing the softening characteristics of unmodified bitumen.

The polybags/plastic can be a reliable alternative source of low-cost fuel production. "**Fuel from Plastic**" is a theme of producing fuel, including petrol, diesel, and kerosene in Jamalpur district and Dhaka division of Bangladesh [8]. Plastic is burned at a high pressure to change the carbon form and convert to fuel in a 2:1 ratio. That means 100 kg of plastic produces approximately 50 liters of fuel. The cost of production is also very low; the raw material of 24BDT can produce fuel of 87BDT. Burning at 1200C to 1500C produces petrol, 1500C to 2000C produce diesel and above 2000C produce kerosene through condenser [8]. Every day, the Patuakhali municipality can produce 1.45 tons of fuel that are 50% of waste plastic generation. So polybag and plastic waste can be used as a resource that can bring economic profitability and environmental protection.

Paper Waste: Paper has negative impacts on the environment throughout its life cycle from the production to the disposal known as paper pollution. This study found 1.85 tons of waste paper waste produced per day in the Patuakhali municipality that can be reused or recycled instead of dumping. New tissue paper can be produced from original virgin pulp (virgin fiber) or waste paper pulp (recycled fiber) [20], although both types of production have environmental impacts during its life cycle, which can be assessed through life cycle assessment method. But the tissue paper production using recycled waste paper is strongly recommended because of its lower material and energy requirements in the entire life cycle. According to [21], paper waste can be used in plastering mortars or the manufacture of building materials. Paper production results in deforestation, which has risen by 400% in the past 40 years with 35% of harvested trees being used for paper manufacturing in the world. Paper production from waste paper is more environmentally friendly than virgin paper as it helps in forest preserving, conserves resources, and generates less pollution during manufacturing because the fibers have already been processed once. It also reduces solid waste because it diverts usable paper from the waste stream.

Every ton of recycled fiber results in reduction of 100% wood, 27% total energy consumption, 33% wastewater, 28% air particulate emissions and 54% solid waste than virgin fiber [22]. Energy savings can be realized from the recycling of paper products indicate that energy savings of 7 to 57 percent are possible for paper products such as newsprint, printing paper, packaging paper, and tissue paper, where paper, being an organic material, has a relatively high energy value [23]. Besides by protecting our natural environment with every ton of recycled fiber saves an average of 17 trees, it saves landfill space and reduces air pollution from incineration. Approximately every ton of recycled paper saves 3 yard3 landfill space, 95% less air pollution at least 30,000 L of water, 3000-4000 kWh of electricity. Waste paper recycling can reduce the amount of methane release in the environment during landfilling as it is also part of organic matter [22].

Approximately 40% of paper waste can be used for mortar production, which accompanying non-polluting technology, minimal embodied energy, and with good thermal insulation properties. This type of mortar can be fire-resistant because paper fibers are saturated with cement, and oxygen cannot penetrate the mass of the material to support burning. During a fire, the mortar will slowly black but will not burn faster like most traditional materials. This type of mortar has good thermal insulation because each grain of sand is surrounded by paper fibers that increase the heat transfer duration that can improve the energy performance of buildings. Paper waste acts as a phenol absorber, which is a harmful organic compound byproduct of the environment [12]. He concluded that the highest phenol removal efficiency is 86% by maintaining the requirement. Paper waste also can be used for biogas production.

Tin-Can and Steel Waste: Approximately 0.256 tons of tin-can and steel waste are produced in the Patuakhali municipality every day, which is safe to be disposed into the sanitary landfill. These materials are toxic in nature when it is oxidized and exposed to the atmosphere. It should be reused rather than recycling because the recycling process requires more energy, leave greenhouse gases and toxic gases. Besides, open dumping of beverage can litter wastes is a serious logging problem of major waterways. In this sense, this research recommended that reuse can be a better option for tin, can, steel waste. [24] derived a stabilizer from the intimate mixture of steel waste (powder electric arc furnace oxidizing slag - PES) and fly ash. The stabilizer increases the mechanical strength of soil for the application in urban paving. This mixture of target meets the relevant technical requirements for conventional methods of designing layers of flexible pavement structures, mainly to meet the paving demands of urban roads and besides makes the economical use of steel and tin-can waste.

Wood/Trimming Waste: Though wood waste is less environmental polluter than steel and concrete waste where steel emits

15% more greenhouse gases (GHG) than wood and concrete emits 29% GHG more than wood. The wood is less harmful to the water than steel and concrete [25]. Although the wood waste produces biogas, the biogas production rate is smaller than food waste and costlier. Wood waste can be used as a replace material of coal for electricity or steam generation. The use of the wood waste as a replacement of high sulfur bituminous coal can reduce 80% sulfur emission. An alternative application of wood waste reduce the burden on landfilling, reduces CO_2 emissions from processing virgin material, contributes to carbon sequestering, and sustainable use of natural resources [26]. In this study, authors suggested wood waste to dump in the landfilling because of its less biogas productive capacity.

Hospital (Hazardous) Waste: Landfilling can be taken as a suitable option for hazardous waste management. The Patuakhali municipality produced approximately 1.106 tons of hospital (hazardous) waste every day. The authority was not concerned about the special care of hospital waste. Hospital waste was also dumped in the open space together with other residential and commercial waste. Several studies focused on the landfilling as an ultimate disposal of hazardous waste management. Incineration, which produces inert material, was suggested as a method of hazardous waste management [27]. It causes detoxify of combustible carcinogens and pathological waste as well as reduces the volume of it. Different types of kilns, i.e., rotary kiln, cement kiln, can be used for incineration. The inert material after incineration is suitable for landfilling. Incineration creates heat energy, which can be used for warming the community in winter and boiler of industries.

Although the incineration recovers energy, it produces flue gases causing air pollution need special consideration. Besides the different physical, chemical, and biological treatment processes landfills, surface impoundments, waste piles, injection wells, salt domes, land treatment, underground disposal, underground injection, ocean dumping, ocean incineration can be taken as a hazardous waste management method. But all these techniques require special consideration in maintenance, and some are costly. So, we should choose the techniques based on our financial ability and maintenance opportunity [28]. The International body suggested that hazardous waste should be collected, minimized, prevented, and treated appropriately following the waste hierarchy from "cradle-to-cradle."

Estimation of Population

The total population of the municipality area was 80,000 in 2016. The future population from 2017 to 2050 has been projected based on the current population with a 1% growth rate using Equation 1, and in 2050 the approximate population will be 1,15000 (Figure 6). The population growth rate was collected from the website of the Bangladesh Bureau of Statistics.

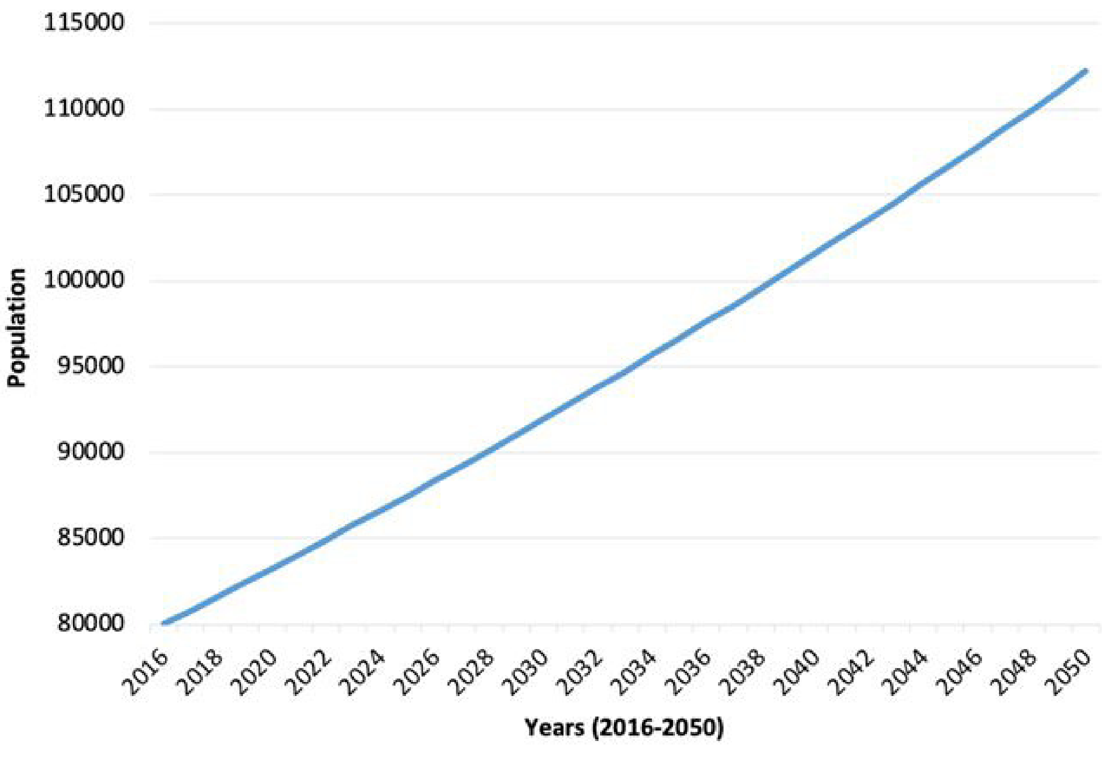


Figure 6: Population projection for the design life of the landfill

Estimation of Landfill Site

The authors derived methods of solid waste management and disposal from the existing literature and methods. The study relies on strong evidence from the pieces of literature. The wood/trimming waste could be mixed up with food waste for biogas production, but it may reduce the production rate and cost of processing, for example, extra cost for grinding of wood. Therefore, the authors suggest depositing tin-can, wood/trimming, and inert, hazardous materials into landfill. This investigation focused on the reduced volume of waste after reuse and biogas production. The food waste for biogas, paper for recycling, plastic/polybags for fuel production, and tin-can, wood/trimming, and inert, hazardous materials are suggested for dumping into landfilling. All types of waste can be reused through the recycling process, where operation and maintenance costs can be a barrier. The reuse and recycling reduce the volume of solid waste to be disposed into the landfill. This study emphasized on environmental friendly reuse, recycling, and energy extraction from the waste. Therefore, the authors suggest wood/trimming waste producing small biogas, tin-can, and hazardous materials to deposit into the landfill. If the volume of waste is reduced through reusing, then the life-span of the landfill will be increased, and less space will be required for landfilling, Table 2. Table 2 shows the required landfilling area for selected waste for 34 years. Reuse, recycling, and energy extraction maximize the life of the landfill and reduce the area required for landfill.

Table 2: Volume and area required for sanitary landfill for tin-can, wood/trimming and hospitalwaste

Year	Population (lackhs)	Wppc Kg/cap/ day	Quantity of solid waste		Volume (m^3)				Accumulated Volume, ΣV_{SL}, (m^3)
			Daily (kg/day)	Annual (ton/year)	Compacted solid wastes: Daily (m^3)	Compacted solid wastes: Annual (m^3)	Cover material(m^3) Annual	Volume of Sanitary landfill (V_{SL})(m^3)	
1	2	3	4	5	6	7	8	9	10
2016	80,000	.021657	1732.6	632399	3.46	1262.9	315.72	1578.62	
2017	80,800	.021657	1749.9	638713.5	3.49	1273.85	318.46	1592.31	
2018	81,608	.021657	1767.4	645101	3.53	1288.45	322.11	1610.56	
2019	82,424	.021657	1785.06	651546.9	3.57	1303.05	325.76	1628.81	
2020	83,248	.021657	1802.90	658058.5	3.61	1317.65	329.41	1647.06	
2021	84,080	.021657	1820.92	664635.8	3.64	1328.6	332.15	1660.75	
2022	84,920	.021657	1839.11	671275.15	3.68	1343.2	335.8	1679	
2023	85,769	.021657	1857.50	677987.5	3.71	1354.15	338.54	1692.69	
2024	86,626	.021657	1876.06	684761.9	3.75	1368.75	342.19	1710.94	
2025	87,492	.021657	1894.81	691605.65	3.79	1383.35	345.84	1729.19	
2026	88,366	.021657	1913.74	698515.1	3.83	1397.95	349.49	1747.44	
2027	89,249	.021657	1932.86	705493.9	3.86	1408.9	352.22	1761.12	
2028	90,141	.021657	1952.18	712545.7	3.90	1423.5	355.87	1779.37	
2029	91,042	.021657	1971.70	719670.5	3.94	1438.1	359.52	1797.62	
2030	91,952	.021657	1991.40	726861	3.98	1452.7	363.17	1815.87	
2031	92,871	.021657	2011.31	734128.15	4.02	1467.3	366.82	1834.12	
2032	93,799	.021657	2031.40	741461	4.06	1481.9	370.47	1852.37	
2033	94,736	.021657	2051.70	748870.5	4.10	1496.5	374.12	1870.62	65828.19
2034	95,683	.021657	2072.21	756356.65	4.14	1511.1	377.77	1888.87	
2035	96,639	.021657	2092.91	763912.15	4.18	1525.7	381.42	1907.12	
2036	97,605	.021657	2113.83	771547.95	4.23	1543.95	385.99	1929.94	
2037	98,541	.021657	2134.10	778946.5	4.27	1558.55	389.64	1948.19	
2038	99,566	.021657	2156.30	787049.5	4.31	1573.15	393.29	1966.44	
2039	100,561	.021657	2177.85	794915.25	4.35	1587.75	396.94	1984.19	
2040	101,566	.021657	2199.61	802857.65	4.40	1606	401.5	2007.5	
2041	102,581	.021657	2221.60	810884	4.44	1620.6	405.15	2025.75	
2042	103,606	.021657	2243.79	818983.35	4.49	1638.85	409.71	2048.56	
2043	104,642	.021657	2266.23	827173.95	4.53	1653.45	413.36	2066.81	
2044	105,688	.021657	2288.88	835441.2	4.58	1671.7	417.92	2089.62	
2045	106,744	.021657	2311.75	843788.75	4.62	1686.3	421.57	2107.87	
2046	107,811	.021657	2334.86	852223.9	4.67	1704.55	426.14	2130.69	
2047	108,899	.021657	2358.42	860823.3	4.72	1722.8	430.7	2153.5	
2048	109,977	.021657	2381.77	869346.05	4.76	1737.4	434.35	2171.75	
2049	111,076	.021657	2405.57	878033.05	4.81	1755.65	438.91	2195.56	
2050	112,186	.021657	2429.61	886807.65	4.86	1773.9	443.47	2217.37	

Figure 7 shows the share of waste for landfilling and recycling, reuse, and energy recovery. The same landfill site can serve for an eight times longer period if the waste is treated properly. It is easier to handle a reduced amount of waste in the landfill site. It requires less manpower, equipment, mitigation of environmental pollution and GHGs, and low cost of operation.

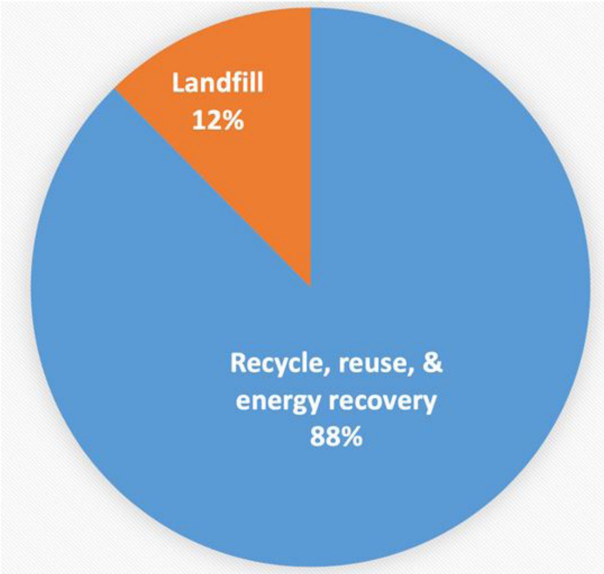


Figure 7: Share of waste for landfilling and recycling, reuse, and energy recovery

Conclusion

Patuakhali municipality collects all types of waste in the same bin and dumps in the open space without treatment causing environmental threats. The municipal authority gives direction to the employer to collect the waste and then open dumping without proper segregation, treatment, and recycling. This process hikes the cost of waste collection and disposal, but energy recovery might compensate for the cost. Each type of waste was measured at six pre-selected locations for six days, including weekends and weekdays, to represent the variation of waste generation. The ratio of waste composition was estimated from field measurement. The municipality generates 14 tons (14000kg) of solid waste everyday which is composed of 53.39% (7474.6 kg) food waste, 20.92% (2928.8kg) polybag/plastic, 13.23% (1852.2 kg) paper, 1.83% (256.2 kg) tin-can and steel, 2.65% (370.4 kg) wood/trimming waste, and 7.90% (1106 kg) hospital waste.

The authors explored the waste to recovery energy (biofuel/fuel), fertilizer, and to dispose into landfill. Based on the evidence from literature, this study suggests food waste for biogas (biofuel) and fertilizer (as residue) production, paper for recycling as tissue and paper, and polybags/plastics for petrol, diesel and kerosene production. Food waste can produce approximately 2743.19 m^3 biogas and polybags/plastic can contribute 1464 liter of fuel every day in the study area at low cost (Innovation Lab, BD). Polybag/plastic waste can be applied for the production of high strength of bituminous mixes, and flood resilient bituminous pavement construction in disaster prone areas. Tin-can, wood/trimming, and hospital waste after burning could be deposited into the landfill. The design life of the landfill was 34 years targeting 2050. Volume of required landfilling was 2250 m^3 for tin-can, wood/trimming, and hospital waste. The hazardous waste is recommended to burn in incinerator before depositing into landfill. Deep sea injection may not be economically viable hence waste pile could be constructed for hazardous waste.

Acknowledgement

The author acknowledged to Dr. S.M. Ekramul Nahid, Head of the Department, Waste Collection and Management, Patuakhali Municipality for his kind cooperation and valuable suggestions during primary and secondary data collection. This work was financially supported by the Research and Training Centre (RTC), of Patuakhali Science and Technology University.

References

1. SM Reazul Ahsan, AKM Islam, Shahriar Shams (2009) Municipal Waste Management Mechanism for Khulna City: A Practice for Better Environment. pp. 101-8.

2. A Ahsan, M Alamgir, MM El Sergany, S Shams, MK Rowshon, et al. (2014) Assessment of Municipal Solid Waste Management System in a Developing Country. Chinese J Eng pp. 1-11.

3. Muttalib A, Alam O, Mohammed Mozaffar H (2016) Quantification and Physical Composition of Household Municipal Solid Waste and People's Attitudes towards its Final Disposal – Chuadanga Municipality, Khulna. Glob J Res Eng J Gen Eng 16: 1-13.

4. P Adhikary, IM Hamidul, Muna, SH Saha, M Emon M (2016) Solid Waste Management System at PSTU Campus.

5. E Marañón, L Castrillón, G Quiroga, Y Fernández Nava, L Gómez, et al. (2012) Co-digestion of cattle manure with food waste and sludge to increase biogas production. Waste Manag 32: 1821-5.

6. M Shahin (2015) Effect of Water on the Compressive Strength of Bituminous Mixes. LAP LAMBERT Academic Publishing, Germany.

7. MN Rahman, M Shahin, MA Sobhan, TU Ahmed (2013) Experimental Behavior of Waste Polyethylene and PVC on the Compressive Strength of Bituminous Mixes. pp. 248-51.

8. The Daily Sun (2018) Bangladeshi youth invents fuel from plastic waste, The Daily Sun.

9. MN Parvez, MN Bari, M Shahin (2015) Design of Integrated Solid Waste Management System of Kakonhat Municipality. pp. 1-10.

10. TM Chowdhury, NS Haque, S Kabir (2015) Solid Waste Management in Chittagong City. pp. 87-92.

11. M Mian, A Paul, M Alam, M Rasheduzzaman, A Saifullah (2013) Solid Waste Management Practice in Mymensingh Municipal Area, Bangladesh. J Environ Sci Nat Resour 5: 193-8.

12. M Sarker, M Rahman (2018) Assessment of Solid Waste Management Process in Rangpur City Corporation Area. J Geogr Environ Earth Sci Int 16: 1-10.

13. NM, Somashekar RK, Verma R (2014) Potential of biogas production from food waste in a uniquely designed reactor under lab conditions. Int J Geol Agric Environ Sci 2: 1-7.

14. N Curry, P Pillay (2012) Biogas prediction and design of a food waste to energy system for the urban environment. Renew Energy 41: 200-9.

15. B Xiao, W Zhang, H Yi, Y Qin, J Wu, et al. (2019) Biogas production by two-stage thermophilic anaerobic co-digestion of food waste and paper waste: Effect of paper waste ratio. Renew Energy 132: 1301-9.

16. GI Staff (2018) How Do Plastic Bags Affect Our Environment?. Greener Ideal.

17. S Madaan (2019) 15 Serious Effects of Plastic Bags Causing Environmental Pollution. Earth Eclipse.

18. Greenpeace (2003) PVC: The Poison Plastic.

19. JK Appiah, VN Berko Boateng, TA Tagbor (2017) Use of waste plastic materials for road construction in Ghana. Case Stud Constr Mater 6: 1-7.

20. A Masternak Janus, M Rybaczewska Błażejowska (2015) Life Cycle Analysis of Tissue Paper Manufacturing From Virgin Pulp or Recycled Waste Paper. Manag Prod Eng Rev 6: 47-54.

21. C Aciu, DAI Varvara, N Cobirzan, A Balog (2014) Recycling of Paper Waste in the Composition of Plastering Mortars. Procedia Technol 12: 295-300.

22. P Bajpai (2014) Recycling and Deinking of Recovered Paper.

23. Jain R, Lloyd V Urban, Harold E Balbach, Matthew D Webb (2012) Handbook of Environmental Engineering Assessment.

24. TO da Silva, HN Pitanga, AL Dos Santos, DC de Lima, ACB Silva (2019) Use of steel waste for the application in urban paving. Acta Sci Technol 41: 37596.

25. S Adhikari, B Ozarska (2018) Minimizing environmental impacts of timber products through the production process "From Sawmill to Final Products". Environ Syst Res 7: 6.

26. Solid Waste Association of North America (2002) Successful approaches to recycling urban wood waste.

27. A Akkoyunlu, Y Avşar, GO Erguven (2017) Hazardous Waste Management in Turkey. J Hazardous Toxic Radioact Waste 21: 04017018.

28. WC Blackman Jr (2001) Basic Hazardous Waste Management, 3rd ed. Lewis Publishers, Boca Raton London New York Washington DC.