Research Article

Quantification and evaluation of garden biomass in municipal solid waste of Nagpur city: A case study

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Abstract

Garden biomass (GB), a potential cellulosic resource for bio energy is commonly found in urban waste. Quantification and characterization of GB would help in disposing this waste properly besides opening avenues to reap energy from it. In this context, the present investigation was carried out in Nagpur, India to quantify and characterize GB in urban waste and to assess its potential as a substrate for bioenergy production. 25 samples were collected from different locations in Nagpur city. Physical and chemical parameters were analyzed in the laboratory. The result showed that the average quantity of GB generation in the urban waste of Nagpur city as 1.68 % with a moisture content of 50.77%. The major (61.17%) portion of garden biomass was fallen leaves followed by cut grasses and small twigs. The characterization of GB samples revealed that it contained 37.33% of cellulose, 26.02% of hemicellulose and 28.39 % of lignin in it. The quantity of biomass in its cellulosic content in the urban waste of Nagpur city warrants its suitability as a promising feedstock for energy generation.
Keywords: Garden biomass, municipal solid waste, energy generation, incineration, biomethanation.

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INTRODUCTION

Rapid urbanization along with increasing rate of population in developing nations like India has created lot of challenges in Municipal Solid Waste (MSW) management. Per capita waste generation in major Indian cities ranges from 0.2 Kg to 0.6 Kg[1]. The calorific value of Indian solid waste is between 600 and 800 kcal/kg and the density is between 330 and 560 kg/m^3 [3, 2]. India is blessed with huge land cover, relatively high population density, and green consciousness. Although not in focus as much as domestic green waste such as foliage, grass, and plant residues are major constituents of solid waste which have potential to be converted into a fuel or value added products[3]. The major ingredients of garden biomass (GB) include foliage, plant residues, decayed and fallen flowers, garden refuse, leaf litter, cut grass, pruned things of trees, weeds and other organic matter discarded from gardens but exclude organic waste of the type obtained from municipal collections. Generally, parks and other recreational centers, home gardens etc. contribute to the increasable quantum of garden biomass in municipal solid waste[4]. Leaves accumulating in the urban and suburban locations such as sidewalks, lawns, and playgrounds are not only an unseemly sight but adds to the overall problem of municipal solid waste disposal[5]. Road sweepings and road side plantations are some areas which generate significant biomass waste[6]. Garden biomass is mostly burnt in open peri-urban (rural – urban) tracts with a view to make treatment and disposal inexpensive[7]. It is burnt either as roadside heaps or at dump sites to reduce waste volume. Open burning of wastes is often reported in developing countries, such burning also increases annual emissions of greenhouse gases[8]. Garden biomass is rich in cellulose and lignin, and

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relatively small amounts of saccharides, amino acids, proteins, aliphatic compounds and carbohydrates[9,10]. As GB is rich in cellulose, there is a scope for its utilization as raw material for bio energy production instead of burning it or dumping in landfills. Considering the scarcity of conventional fuel, and increasing fuel prices energy from waste such as GB can be sustainable and lucrative as well. Although municipalities do aware of green wastes including GB, hardly any inventory available for the quantity and quality of GB generated. However, the quantity and quality are major factors for designing and successful operation of waste to energy systems. City specific inventory for GB generation and their quality assessments would enable municipalities to opt for right type of waste to energy alternatives which is compatible for the city. In this study, we estimated the quantity and quality of GB and assessed the potential of GB for bioenergy production from Nagpur city. Nagpur is located at an elevation of 314.79 m above Mean Sea Level (MSL) and at Latitude 21°8'00" North and Longitude 79°8'00" East[11]. The specific objectives of the present study were: (i) To quantify and characterize GB in the general solid waste stream of Nagpur city. (ii) To evaluate different waste to energy options for GB through theoretical calculations. (iii) To prepare a template for GB management and its utilization for energy production in other Indian cities.

MATERIAL AND METHODS

Sample Collection

MSW samples were collected from 25 different locations from Nagpur City as shown in Figure 1. Approximately 5 kg of MSW then segregated manually into different physical components like paper, plastics, rubber, leather, glass, metals, textiles and polyethylene bags and garden waste. Each of these garden wastes was weighed to determine its fraction in the total solid waste.

Quantification and Characterization of Garden biomass (GB)

GB containing uprooted plants leaves, grass, stems, flowers, creeps, bark etc. were separated from MSW and weighed for wet weight. Moisture content of GB was estimated using standard protocol. Physical characterizations of GB such as various categories components of GB and their percentage are analyzed. Selected samples were sun dried followed by oven drying and ground to powder form for further chemical analysis. The organic carbon content and volatile solids (VS) of GB were estimated by combustion method[12]. The total nitrogen (TN) content of the sample was estimated using LECO Protein-Nitrogen Analyzer (Model FP528). The cellulose concentration of GB was estimated by HNO_3-ethanol method and lignin content of sample was estimated by 72% (v/v) H_2SO_4 method[13].

Theoretical Calculations on Bioenergy Production through Different Options

Theoretical calculations were made taking into consideration the quantity of GB forincineration, biomethanation and cellulosic ethanol. The bench marks for different end products were taken from previous reports[14-16]. However, prediction for next fifteen years was calculated based on population increase according to the data available with urban development, Government of India[17].

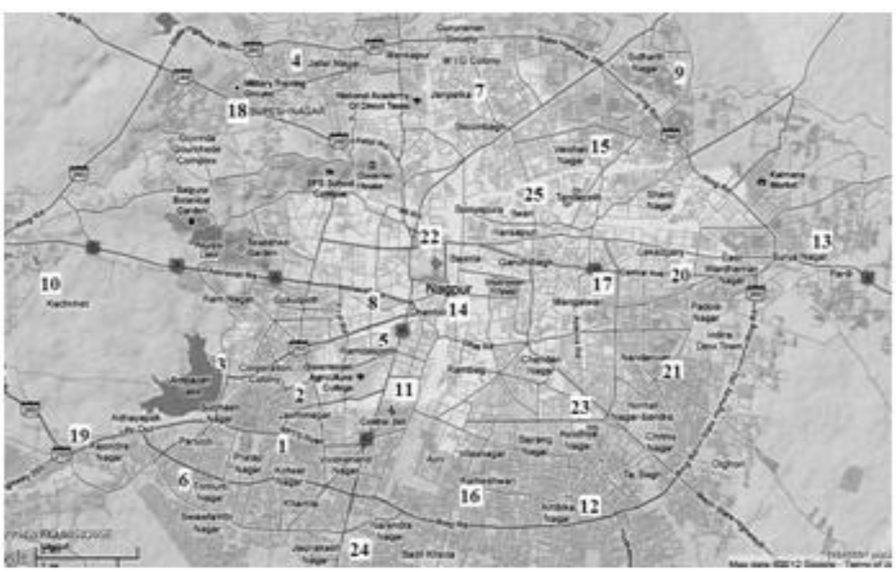

Figure 1: Nagpur city locations map adapted from Google showing different areas for sample collection

RESULTS AND DISCUSSION

High population growth, industrialization, urbanization and economic growth, a trend of significant increase in MSW generation has been recorded worldwide. MSW generation, in terms of kg/capita/day, has shown a positive correlation with economic development at world scale. Due to rapid growth of industries and migration of people from villages to cities, the urban population increases rapidly. Waste generation has been observed to increase annually in proportion to the rise in population and urbanization. The per capita generation of MSW has also increased tremendously with improved life style and social status of the populations in urban areas[18]. India, with a population of over 1.21 billion account for 17.5% of the world population[19]. Nagpur is one of the major cities of central India located in Vidarbha region of Maharashtra state. Nagpur has a population of 24,05,421 as per the 2011 Census of India. Nagpur has 102 gardens spread across the city[20]. Nagpur Municipal Corporation collects five to eight tons of garden biomass per day which may be utilized for bio energy purpose[21]. In the present investigation we found that MSW in Nagpur city contain high quantity of biomass wastes that can be converted into energy fuels by thermo-chemical as well as bio-chemical conversion methods. The MSW collected from metropolitan of Nagpur contained an average of 1.68 % of GB in it although variations found at different localities as shown in Table 1.

Table 1: Percentage of GB and moisture contents in the 25 locations of Nagpur city MSW

Sr. No.	Name of Location	GB (%)	Moisture Content (%)
1	Mate Square	1.13	60.50
2	Laxmi Nagar	1.14	47.00
3	Ambazari	4.80	45.33
4	Jafer Nagar	2.28	72.80
5	Ramdaspeth	2.90	46.68
6	Trimurti Nagar	4.61	42.86
7	Jaripatka	2.12	46.03
8	Dharampeth	1.57	56.52
9	Sidharth Nagar	2.75	43.33
10	Kachimet	1.68	54.30
11	Rahate Colony	2.54	44.09
12	Ambika Nagar	2.00	42.00
13	Surya Nagar	1.78	51.70
14	Dhantoli	1.28	54.70
15	Vaishali Nagar	2.17	36.41
16	Rameshwari	0.60	45.52
17	Mangalwari	0.30	45.90
18	Bhupesh Nagar	1.28	63.16
19	Rajendra Nagar	0.50	44.75
20	C A Road	0.80	61.00
21	Nandanvan	0.70	45.00
22	Sadar	0.70	38.00
23	Ayodhya Nagar	0.92	56.85
24	Jaiprakash Nagar	0.60	63.00
25	Itwari	0.70	62.00
Average Percentage		**1.68**	**50.77**

The average moisture content of GB was found to be 50.77% (Table 1). Physical characterization of GB revealed that it contained high percentage (61.17) of leaves followed by grass cuttings (18.85%) and twigs (14.49%). The quantity of other plant parts such as flowers (3.93%) and roots (1.56%) are low as compared to other components shown in Figure 2.

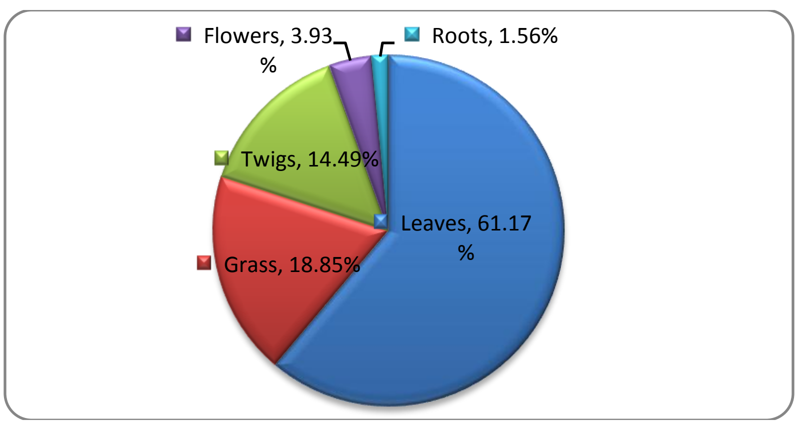

Figure 2: Percentage of different components in GB

Similarly, the average chemical charterization of the GB is depicted in Table 2. It showed that GB contained 92.07% of organic matter and remaining as ash content. Further analysis showed that it contained 49.93 % of organic carbon, 1.65% of nitrogen, 37.33% of cellulose, 28.39% of lignin and 26.02 % of hemicellulose.

Table 2: Chemical characterization of garden biomass

Parameter	Content % (w/w) on dry basis
Total organic matter	92.07
Carbon	49.93
Cellulose	37.33
Hemicellulose	26.02
Lignin	28.39
Nitrogen	1.65

As GB is rich in components like carbon, cellulose, hemicellulose and lignin, it can be converted into cellulosic ethanol, biohydrogen, biomethane (biogas) etc. Unprocessed green wastes can generate potential greenhouse gases upon dumping. Many of the earlier studies reported generation of high amount of greenhouse gases from dumping of un-processed MSW in open dumps which may be the cause for global warming[22]. The ideal way of managing these wastes is to scientifically process them for value added products which includes biofuel.

Assessment of Different Options for Waste to Energy from GB

The large quantity of GB generated every day can be utilized for bioenergy generation leads to effective and efficient waste management; also the energy generated can be utilized for various purposes. In developed countries, environmental concerns rather than energy recovery are the prime motivator for waste-to-energy facilities, which help in treating and disposing of wastes whereas the energy in the form of biogas, heat or power is seen as a bonus, which improves the viability of such projects. Previous report show that green components such as agricultural crops have been used for energy include: sugarcane, corn, sugar beets, grains and many others. There are several factors, which determine whether a crop is suitable for energy use. The main material properties of interest during subsequent processing as an energy source, relate to the moisture content, calorific value, proportions of fixed carbon and volatiles, ash/residue content, alkali metal content, and cellulose/lignin ratio[23]. GB contains recalcitrant or complex compounds such as cellulose and lignin. GB is essentially a composite material constructed from oxygen-containing organic polymers. The plant biomass mainly consist of low molecular weight organic extractives and inorganic minerals (usually 4-10%), and macromolecules like polysaccharides e.g. cellulose and polyoses usually 65-75% and around 18-35% of lignin[24]. Table II indicates the percentage of different macromolecules present in GB. High concentrations of lignocelluloses make GB suitable for thermal and biochemical (anaerobic treatments) degradation processes. Incineration is the high temperature burning (rapid oxidation) of garden waste, usually at 870-1370^{0}C, leftover ashes and unburned combustibles amount to perhaps 25% of original waste[25]. Incineration is a means of disposal, and energy recovery is often a secondary objective. Burning of GB produces smoke, especially if it is damp and smoldering rather than dry and blazing[26]. Although incineration is a means of scientific disposal of organic wastes, its utilization is restricted mostly to hazardous wastes and bio medical wastes at present. Further, the routine supply and quantity of GB are also other issues which may hamper successful operation of incinerator. The higher value of moisture content shows that incineration will be not a proper option for processing of GB as heat must first be supplied to remove moisture. More over the energy production is also not very lucrative as compared to the other options[14]. Anaerobic digestion is a series of processes in which microorganisms break down biodegradable materials in the absence of oxygen. The process produces biogas which is rich in methane and carbon dioxide suitable for the production of energy that can replace fossil fuels. The rate of biogas yield from organic waste ranges from 0.2-0.5 m^3 biogas/kg of volatile solid[27]. A perusal of results shows that the concentration of volatile organic solids in GB is 92%,that will yield approximately 0.18-0.46 m^3 biogas/kg GB after removing moisture. If, considered that the biogas composed about 60% CH_4, then there is a possibility of producing 0.10-0.28 m^3 CH_4 / kg GB. Previous report shows that per day generation of garden biomass in Nagpur city is about 5-8 ton [21].Considering this generation rate, there is a possibility of producing maximum 400 to 1120 m^3 CH_4using the GB collected from MSW in Nagpur. The research on improving ethanol production has been accelerated for both ecological and economical reasons, mainly for its use as an alternative to petroleum based fuels. Utilization of GB will reduce dependency on foreign oil and secondly, this will remove disposal problem of wastes and make environment safe from pollution[28]. The number of gallons of ethanol produced per ton of dry biomass, to improve from 50 gallons per ton to 117 gallons per ton of dry biomass[15]. Considering the theoretical yield of ethanol production as 443 L /ton of dry cellulosic waste, approximately1107 to 1772 liters of ethanol/day can be produced using the GB collected from MSW in Nagpur. Rapid economic growth, increasing population and change in living standards of city causes a high generation rate of MSW and the total solid waste generated in Nagpur Municipality is about 504 tons/day[11]. Our results indicated that average percentage of GB in MSW of Nagpur city was 1.68% i.e. approximately 5-8 tons of GB collection per day. According to report of urban development, Government of India, a rough assessment of the potential of recovery of energy from MSW through different treatment methods can be made from knowledge of its calorific value and organic fraction. Calorific value of dry garden waste is 18.49 MJ/kg i.e. 4417 Kcal/kg[29]. In general, 100 tons of raw MSW with 50-60% organic matter can generate about 1-1.5 Mega Watt power, depending upon the waste characteristics[17,30]. Hence, from the present scenario we can predict for next 15 years (Based on MOEF 2010 and MNRE 2010, Government of India) energy generation with respect to GB from MSW with increasing populations[31,32]. Nagpur city population in the year 2011 around 2405421 and MSW generation was 183960 tons/year, it can produce GB 1825 tons/year based on this energy may generate 198 MW; for next five year in the year 2016 the population of the city may reach 3405421 lakhs and MSW generation will be 283960 tons/year it can produce GB 2817 tons/year and energy may generate 305 MW; moreover, in the year 2021 the population may go on 4405421 lakhs and MSW generation will be 383960 tons/year and can produce GB 3809 tons/year in this context the energy may be generate 413 MW; similarly in the year 2026 the population of the city may become 5405421 lakhs and MSW generation will be reach 483960 tons/year which can be produce GB 4801 tons/year and based on this energy may generate 520 MW. Thus, above prediction has shown that although GB of the city has reasonable resources of renewable energy, it is not so well endowed that its future electricity requirements can be fully met by renewable energy sources. This view is contrary to the popular perception that biomass energy in its direct and indirect forms can supply all of Nagpur city future needs of electricity.

CONCLUSION

The present study indicated that GB is a potential source of bioenergy as it contains considerably high quantities of lignocellulosic substrates in it. It can be processed through different means for energy production. Among all the techniques, biomethanation seem to be the most appropriate process for GB as it yields maximum energy in terms of biogas and the by product of anaerobic digestion, the sludge can be recycled as compost.

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