Asian Jr. of Microbiol. Biotech. Env. Sc. Vol. 26, No. (2) : 2024 : 269-279

ISSN-0972-3005

DOI No.: http://doi.org/10.53550/AJMBES.2024.v26i02.016

ASSESSMENT OF SOLID WASTE GENERATION IN BISWANATH CHARIALI MUNICIPAL AREA: A COMPREHENSIVE APPROACH TO SUSTAINABLE AND ENVIRONMENT-FRIENDLY WASTE MANAGEMENT STRATEGIES

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(Received 9 November, 2023; Accepted 5 January, 2024)

Key words: *Waste Dynamics, Color-Coded Paradigm, Technological Interventions, Organic Resource Potential, Municipal Aesthetics, Sustainable Solutions*

Abstract – In a comprehensive examination of solid waste generation within the Biswanath Chariali municipal area, Assam, India our study delves into representative 180 households and 15 hotels, meticulously scrutinizing the intricate dynamics of waste disposal. Over a month, we methodically documented the waste generation patterns, revealing a vivid tapestry of disposal practices and habits. The introduction of colour-coded waste bins, strategically positioned in both households and hotels, has heralded a noticeable shift in waste disposal behaviours. The projected data were calculated from the sampled data for the entire household and hotels present in the municipal area. The data reveals that the total waste from the Biswanath Chariali municipal area is 280.77 mt/month out of which 201.62 mt organic waste, 49.74 mt plastic waste and 33.71 mt other waste (Glass, plastic etc.) Notably, Ward number 6 emerged as a focal point of heightened waste production (52.06 mt of total waste generated/month). Out of 66.12 mt of total hotel waste generated in the municipal area, 51.06 mt is organic waste, 9.44 mt is Plastic waste and 5.63 mt is other waste. A paradigm shift is envisaged through the exploration of technological interventions, encompassing composting, biochar production, and the conversion of organic waste into electricity. A noteworthy revelation underscores that over 70% of the waste predicament can be alleviated by harnessing the potential of organic waste, thereby transforming it into a valuable resource. However, a pivotal aspect to consider lies in the necessity for large-scale receptacles, essential for realizing a visibly cleaner municipal landscape. As we conclude, our contemplation extends towards the implementation of recycling centres and waste-to-energy facilities as transformative solutions for a sustainable and aesthetically pleasing Biswanath Chariali.

INTRODUCTION

Bio-waste management is a real challenge for developing countries like India. It is estimated that urban areas of our country generate solid wastes between 1.3 x 10^5 to 1.5 x 10^5 metric tonnes (mt) every day. It is about 0. 33- 0.55 kg of solid waste per urban resident in a single day. Year after year, we find ourselves grappling with an overwhelming volume of waste – currently standing at about 50 million metric tons. If we don't change our current trajectory, this figure is poised to skyrocket to an astonishing 125 million metric tons each year by 2031. What's particularly troubling isn't just the sheer increase in quantity, but the waste's very nature is shifting. We're witnessing a transition from a predominant presence of biodegradable waste to a concerning surge in non-biodegradable waste (Biswas *et al.,* 2021). In India, the municipal waste management rules were initially put into action in the year 2000. Since then, various waste management rules have been revised and introduced in 2016, focusing on the 5R concept – Reduce, Reuse, Recycle, Remanufacture, and

Recover, of which 3R is a subset(Municipal Solid Waste Rules, 2000,Solid Waste Management Rules, 2016 and Biomedical Waste Management Rules 2016). The technology aspect predominantly explores the collection, segregation, recycling, Mechanical and Biological Treatment (MBT) of waste, incineration, and land filling. However, In India, Solid Waste Management (SWM) is distressing due to the underutilization of the most effective waste management methods. There's a shortage of training in SWM, and the pool of qualified waste management professionals is limited. Accountability is also lacking in the existing SWM systems across India. Municipal authorities bear the responsibility of managing Municipal Solid Waste (MSW) but struggle with budgets that fall short of covering the necessary expenses for establishing proper waste collection, storage, treatment, and disposal infrastructure. The absence of strategic MSW plans, deficiencies in waste collection and segregation, and the lack of a regulatory framework for government finance pose significant obstacles to achieving effective SWM in India (Kumar *et al*., 2017). Environmental awareness is also limited, hindering innovation and the adoption of new technologies that could revolutionize waste management practices. The presence of pathogenic microorganisms in bio-waste poses risks to human health, underscoring the need for strategic planning to convert biodegradable wastes into productive materials like compost and vermicompost through bio-transformation processes (Debrah *et al*., 2021). Public attitudes toward waste also present a substantial barrier to improving SWM in India (Kumar *et al*., 2017). Nevertheless, it is essential to assess the various kinds of wastes generated in a particular municipal area to prepare scientific plans for proper waste management. Building upon the successes and lessons learned from waste management practices embracing the 3R approach (Jibril *et al*., 2012), the present study aims to formulate a strategy for bio-waste management in the Biswanath Chariali municipal area. Considering the importance of public awareness, this project involved 180 households (4% of the total) and 15 selected hotels, trained them to segregate inorganics and organics at-source and data were collected from the trained respondents regularly for a month to address the following objectives:

1. To analyze the waste generation status of the Biswanath Chariali Municipality area.
2. To evaluate the technology options available for safe treatment and disposal of MSW generated in the Biswanath Chariali municipality area.

MATERIALS AND METHODS

The Municipal area of Biswanath Chariali town comprises 12 wards with 4454 households covering a population of 19145 as per the 2011 census. The current estimated population of Biswanath Chariali Town Committee in 2023 is approximately 26,200. The scheduled census of 2021 for Biswanath Chariali city is postponed due to COVID-19 **(Biswanath Charilai Population Census, 2011).** A huge quantity of city waste is generated by the households creating a serious problem of solid waste management. Therefore, a survey has been conducted covering 4% of randomly selected households (180) considering the population of each ward and the size of the household. Additionally, 15 restaurants/hotels (8% of the total) were selected from the Biswanath municipality area covering small, medium and large category hotels to estimate the nature and quantity of organic and inorganic waste generated in the township and to find out the probable means of managing and recycling them with the best possible ways of scientific interventions. Projected waste generation of the entire Biswanath area was calculated from the survey data. The study area map is presented in Fig. 1. Tentative ward boundaries are presented in Fig. 2. The names of the respondents from individual households were not mentioned here considering their privacy. However, hotels' names have been mentioned in this paper for proper strategic points of view by the municipal authority.

Waste categorization: The waste generated was categorized into two main groups *viz*. biodegradable and non-biodegradable waste (Fig 3). Accordingly, two waste bins of different colours were provided to each household and each hotel to collect bio-degradable and non-biodegradable waste. This also helped to create awareness of waste segregation at source among the participants.

We measured the weight of both types of waste daily for one month and converted it to monthly projections for all households and hotels in the area. Plans based on the projected data have been prepared.

RESULTS AND DISCUSSION

Projected overall waste generation from the

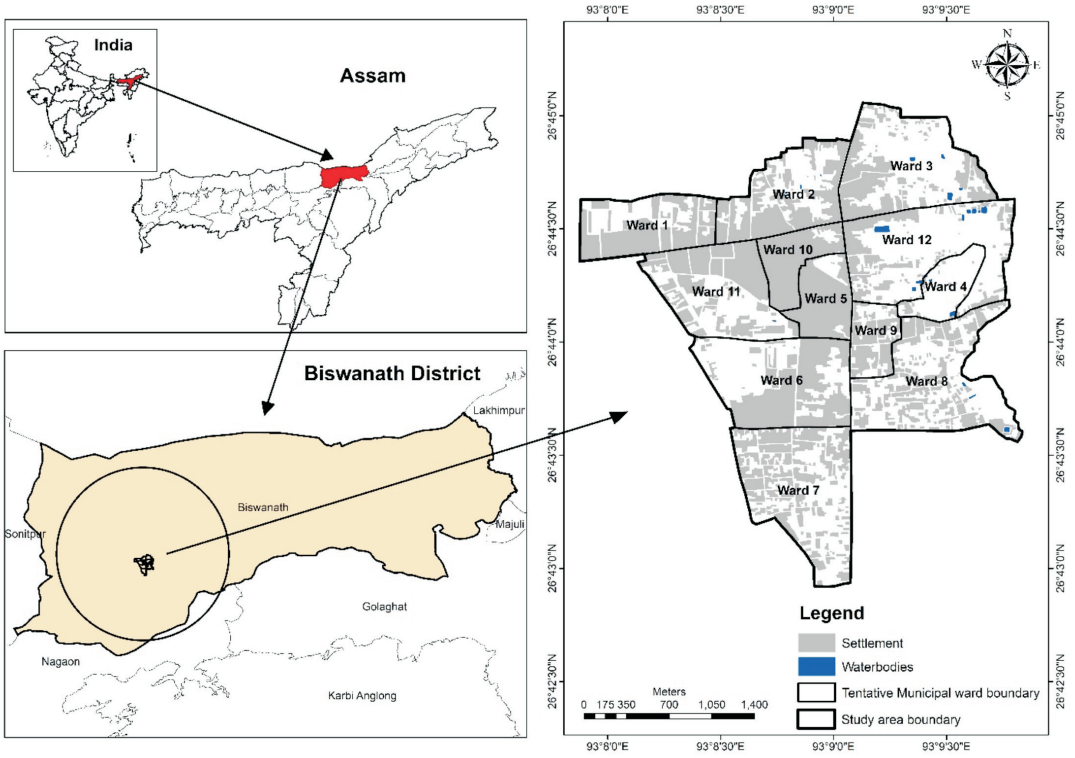

Fig. 1. Study area map

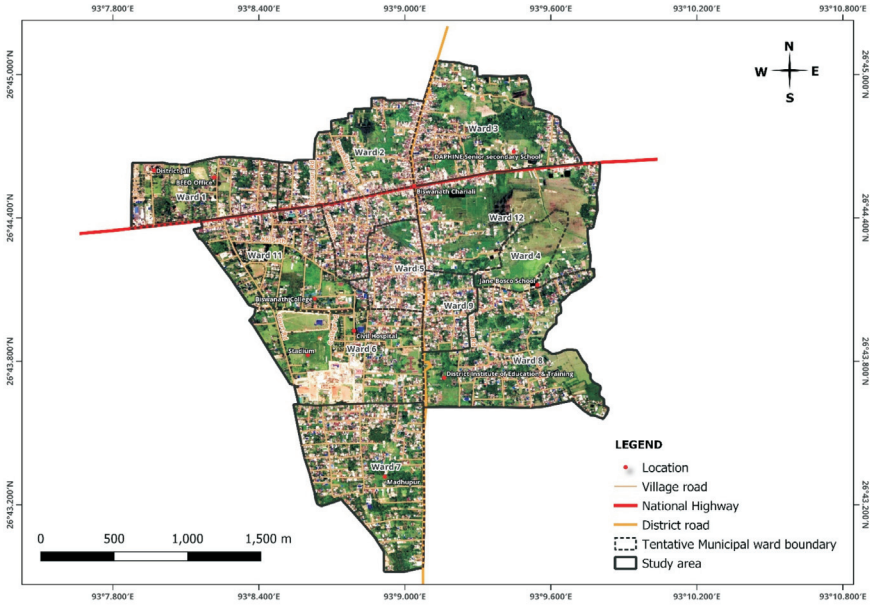

Fig. 2. Tentative municipal ward boundaries of Biswanath municipal area

households of all the municipal wards in Biwanath chariali (mt/month) is presented in Table 1. The data reveals that the total waste generated from the Biswanath Chariali municipal area is 280.77 mt/month out of which 201.62 mt organic waste with an average of 16.80 mt/ward, 49.74 mt plastic waste with an average of 4.15 mt/ward and 33.71 mt other waste (Glass, metaland rubber) with an average of 2.81 mt/ward. The projected data were calculated from the surveyed data of 180 households. Table 1 describes the fractional distribution of organic, inorganic and other wastes in metric tons per month

Table 1. Projected range, mean and standard deviation of waste factions from the household of Biswanath municipal area per month (mt/month)

Parameters	Organic waste	Plastic waste	Other waste (Glass, metal and rubber)	Total waste
Grand Total	201.62	49.74	33.71	280.77
Average/ward	16.80	4.15	2.81	23.40
Max/ward	40.84	9.67	6.75	52.06
Min/ward	8.49	1.22	0.27	10.65
stdv	7.89	2.34	1.89	9.82

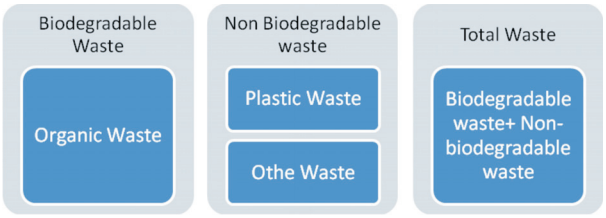

Fig. 3. Type of waste

with range, mean and standard deviation. A graphical representation of the same has been made in Fig. 4.

Ward-wise projected monthly waste generation from the households in Biswanath municipal (mt/month) is presented in Table 2 and a graphical representation is made in Fig. 5. A perusal of the data reveals that the highest total, organic and plastic waste was generated in Ward 6 (52.06 mt/month) and the lowest was in Ward 4 (10.65 mt/month). However, the highest other waste (glass, metal and rubber) was generated in ward 2 (6.75 mt/month) and the lowest was inward1 (0.27 mt/month). Wardwise fractionation of waste is presented in Fig 6. Ward-wise waste dot representation of different fractions of waste is made in Fig. 7. Pie diagram of waste fractions from the households in the Biswanath municipal area is presented in Fig. 8.

Waste generation from 15 sample hotels per month in the Biswanath municipal area is presented in Table 3. A perusal of data from Table 3 reveals that the highest waste was generated in the small category restaurant *viz.* Mira Hotel(1252.55 kg/month) and the lowest was in medium category bakery viz. Mahamaya Bakery (21.94 kg/month). Among the fractions, the maximum organic waste (1008.85 kg/month) was also generated in Mira Hotel and the lowest was in Mahamaya Bakery. Similarly highest plastic waste was also generated in Mira Hotel (185.6 kg/month), followed by medium category restaurant *viz.* Yammi Kitchen (142.58 kg/month) and the lowest was in small category

Table 2. Ward-wise projected monthly waste generation from the households in Biswanath municipal area (mt/month)

Ward Number	Organic waste	Plastic waste	Other waste (Glass, metal etc)	Total waste
1	18.39	7.32	0.27	25.72
2	14.72	1.83	6.75	22.78
3	16.54	5.13	2.92	24.39
4	8.49	1.22	1.16	10.65
5	13.55	4.99	1.76	19.81
6	40.84	9.67	2.43	52.06
7	16.30	4.63	5.46	26.33
8	16.30	2.76	4.57	23.53
9	11.66	1.69	0.93	14.06
10	19.31	3.06	1.14	22.99
11	15.61	3.96	3.55	22.63
12	9.90	3.46	2.77	15.82

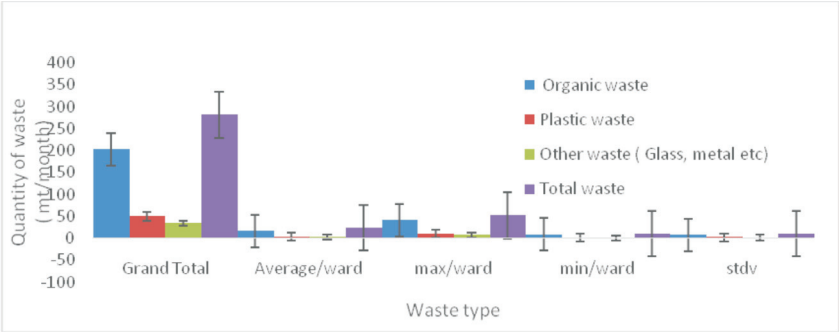

Fig. 4. Projected monthly waste generation from the households in Biswanath Chariali (mt/month)

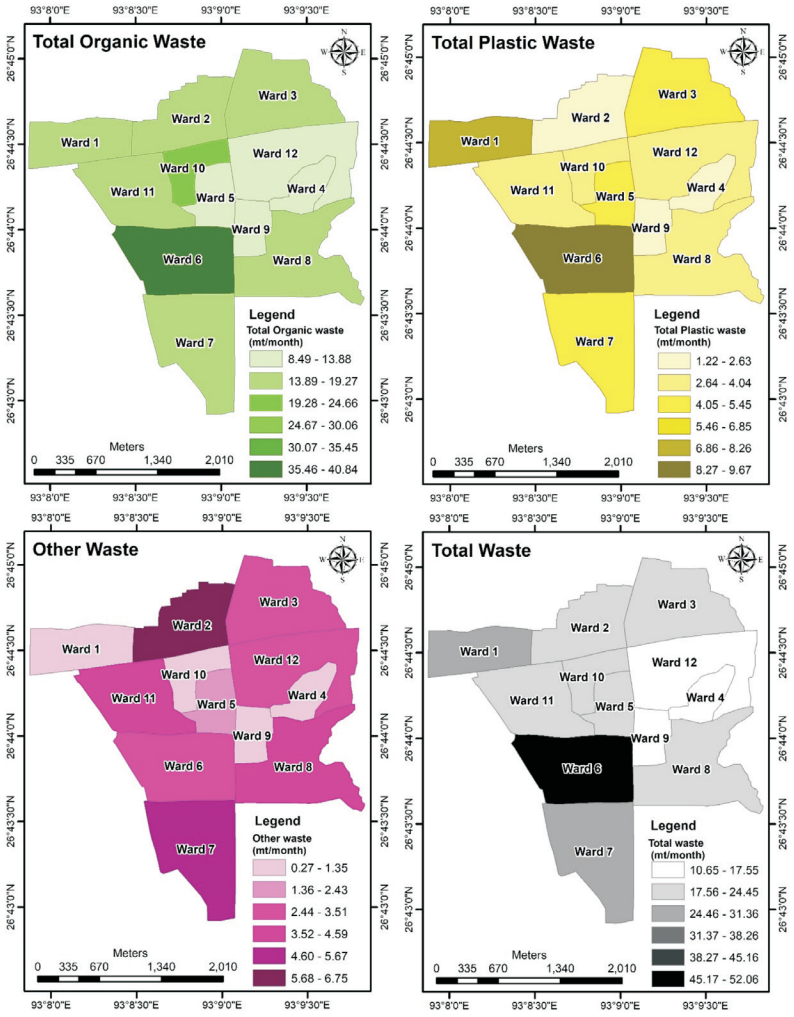

Fig. 5. Ward-wise projected monthly waste generation from the households in Biswanath Chariali (mt/month)

Table 3. Waste generation (kg) from 15 sample hotels per month in Biswanath Municipality area

Sl No.	Name of the Hotel	Category	Total Organic Waste	Total Plastic waste	Other waste (metal, glass, etc.)	Total Waste
1	Hotel Royal palace	Large	445	38	1	484
2	Hotel Pradyut	Large	180.6	34	20	234.6
3	Baideo hotel	Lrage	111.35	33.5	17.5	162.35
4	Yammy Kitchen	Medium	315	142.58	70	527.575
5	Green Chilly	Medium	122.5	42.45	60	224.95
6	Rain Drop Restaurants	Medium	187.5	47.2	50	284.7
7	Spring Velly	Medium	416.175	76.8	26.05	519.025
8	Mira hotel	Small	1009.85	185.6	57.1	1252.55
9	Parik Mistan Bhandar	Small	121	8.75	10	139.75
10	C.L.P. Police point	Small	174.935	11.95	20	206.88
11	B.L.P. Police point	Small	47.5	10	5	62.5
12	Hotel Paradise	Large	588.625	78.64	55	722.265
13	Kasturi Palace Restaurant	Medium	161.525	17.075	56.35	234.95
14	Hotel Jokaichuk	Medium	395	45.5	22.5	463
15	Mahamaya Bakery	Medium	2	18.94	1	21.94

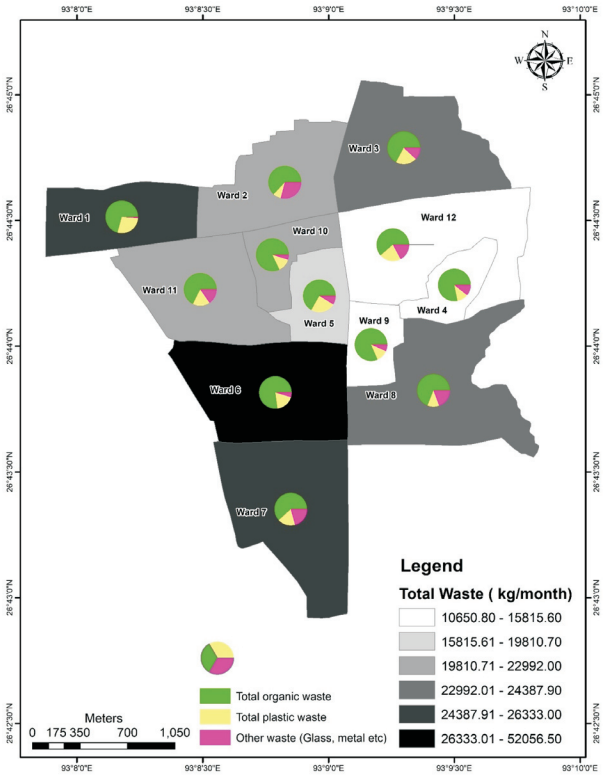

Fig. 6. Ward-wise fractional distribution of waste (projected) in Biswanath Municipal area (kg/month)

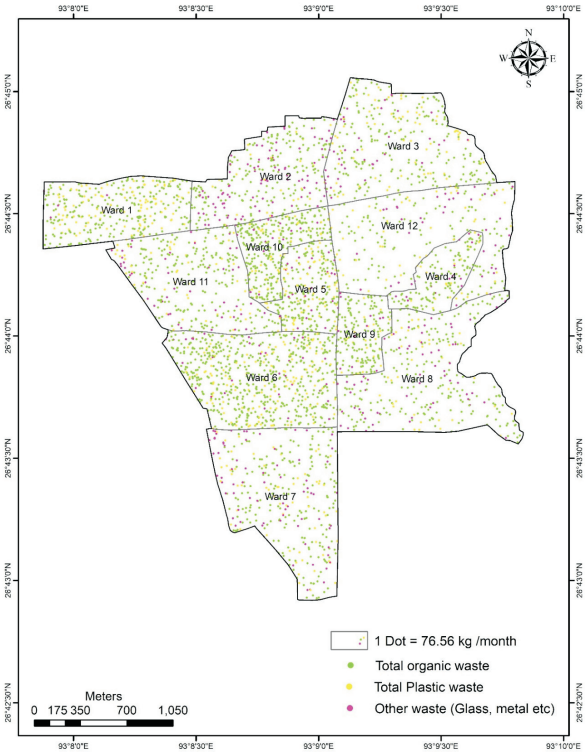

Fig. 7. Ward-wise waste dot representation of different fractions of waste

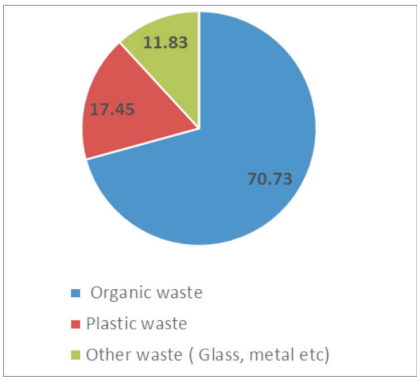

Fig. 8. Fractionation of different wastes (%) in the entire Biswanath Municipal area (household)

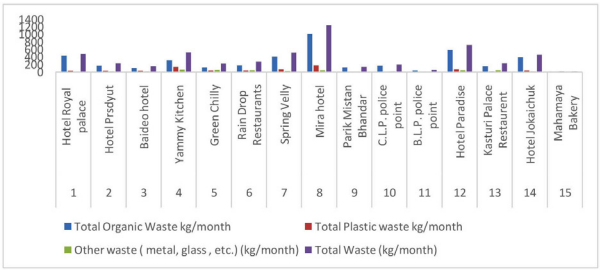

Fig. 9. Fractional distribution of waste (kg) generated from 15 sample hotels per month in Biswanath Municipality area

restaurant *viz.* Parik Mistan Bhandar (8.75 kg/month). The highest other waste was generated in Yammi Kitchen (70 kg/month) followed by medium category restaurant *viz.* Green Chilli (60 kg/month) and the lowest was in large category hotel *viz.* Hotel Royal Palace and Mahamaya Bakery (1kg/month). Irrespective of categories the data indicates the organic fraction of the waste occupies majority portion of total waste followed by plastic waste and other waste. Graphical representation is made in Fig 9 and Fig 10. Pie diagrams showing the per cent share of different fractions of waste within the hotels are presented in Fig 11.

The range, mean and standard deviation of different waste fractions of waste generated per month in 15 sampled hotels in the Biswanath Municipal area are presented in Table 4. A perusal of data reveals that the mean organic waste generated from the sampled hotels is 285.24 kg/month with a range of 1009.85 kg/month having a standard deviation of 250.48 kg/month. Mean Plastic waste is 52.73 kg/month with a range of 8.75-185.60 kg/month (standard deviation 48.95 kg/month). Other waste ranges from 1 to 70 kg/month (standard deviation 23.18 kg/month) with a mean value of

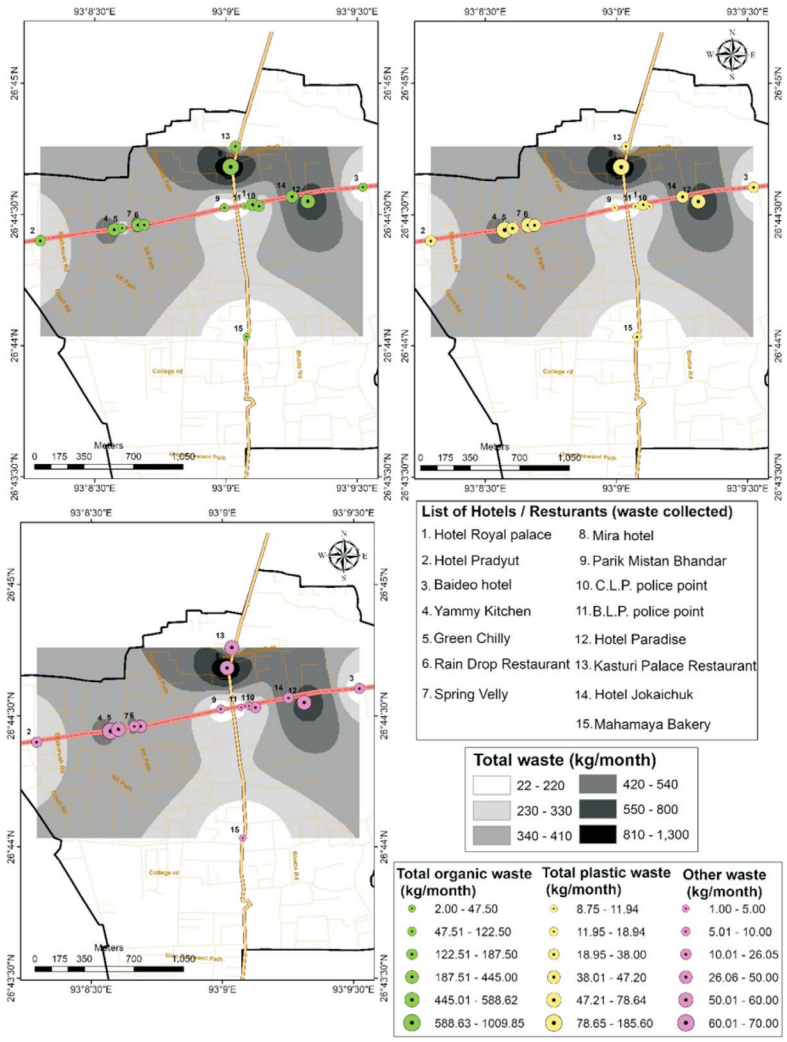

Fig. 10. Different fractions of waste distribution (kg/month) from 15 sample hotels per month in Biswanath Municipality area

Table 4. Range, mean and standard deviation of waste generated per month in 15 sampled Hotels of Biswanath Municipal Area (in Kg)

	Organic Waste	Plastic waste	Other waste (metal, glass, etc.)	Total Waste
Mean	285.24	52.73	31.43	369.40
Maximum	1009.85	185.60	70	1252.55
Min	2	8.75	1	21.94
Stdv	250.48	48.95	23.18	302.76

31.43 kg/month. The range, mean and standard deviation of different fractions of waste generated per month in 15 sampled Hotels of Biswanath Municipal Area (kg/month) is illustrated in Fig 12. Per Cent share of different fractions of waste generated from 15 sampled hotels of the Biswanath municipal area is presented in the piediagram (Fig 13). The highest per cent share of hotel waste is from

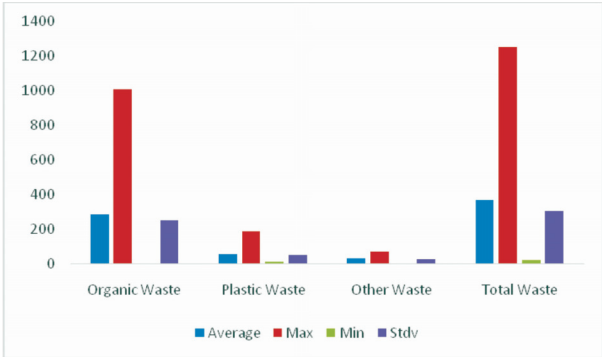

Fig. 12. Range, Mean and Standard Deviation of Waste Generated per month in 15 sampled Hotels of Biswanath Municipal Area (Kg/month)

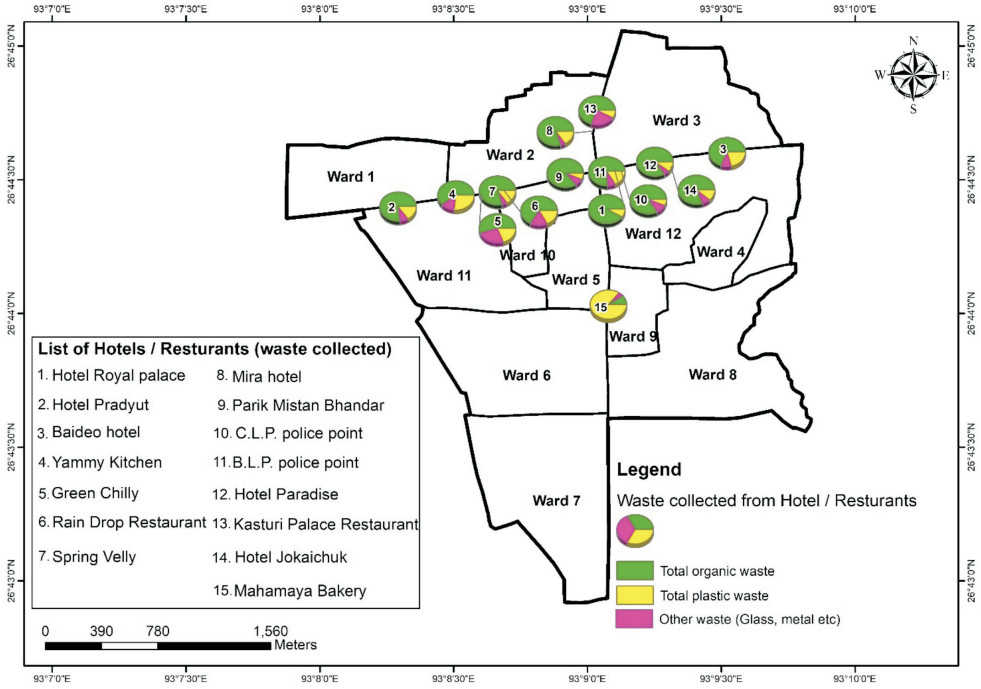

Fig. 11. Pie diagram of per cent fractions of water in each selected hotel in Biswanath municipal area

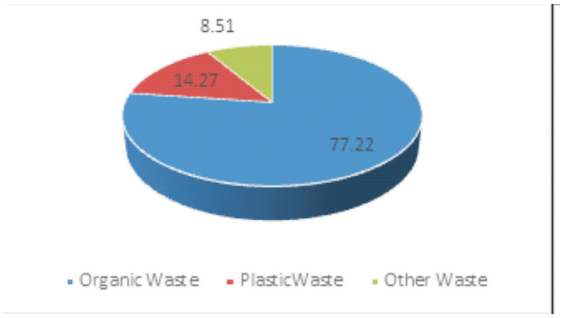

Fig. 13. Per Cent Share of different types of wastes Generated from 15 sampled hotels of Biswanath Municipal area

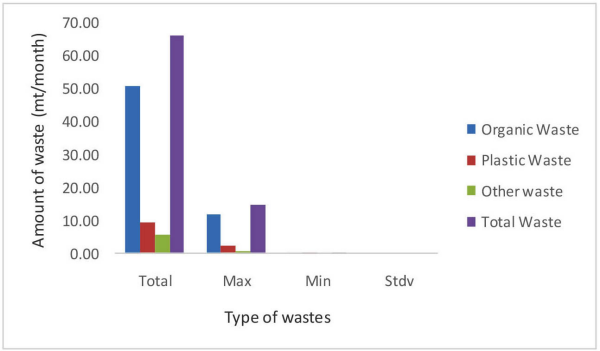

Fig. 13. Projected waste generation (mt) per month from all the hotels in Biswanath Municipal area

the organic fraction (77.22 %) followed by plastic waste (14.27%) and the lowest was other waste (8.51%).

Biswanath Chariali municipal area has 179 hotels. Accordingly, projected waste generation data has been calculated from the surveyed data for all the hotels and presented in Table 5. A graphical representation of the same has been made in Fig. 13. The pie diagram depicting the projected per capita share of waste fractions is presented in Fig. 14. A perusal of the data reveals that a total of 66.12 mt total waste is projected per month with a range of 0.26-14.95 mt (standard deviation 3.61 mt/month) from all the hotels in Biswanath Municipal area. Out of 66.12 mt of total waste, 51.06 mt is organic waste, 9.44 mt is Plastic waste and 5.63 mt is other waste. The projected per capita waste fraction is organic

Table 5. Projected waste generation (mt) per month from all the hotels in Biswanath Municipal area

	Organic Waste	Plastic Waste	Other waste	Total Waste
Total	51.06	9.44	5.63	66.12
Max	12.05	2.21	0.84	14.95
Min	0.02	0.10	0.01	0.26
Stdv	2.99	0.58	0.28	3.61

waste @ 0.29 mt/month, plastic waste@ 0.05 mt/month and other waste at 0.03 mt/month (Fig. 14).

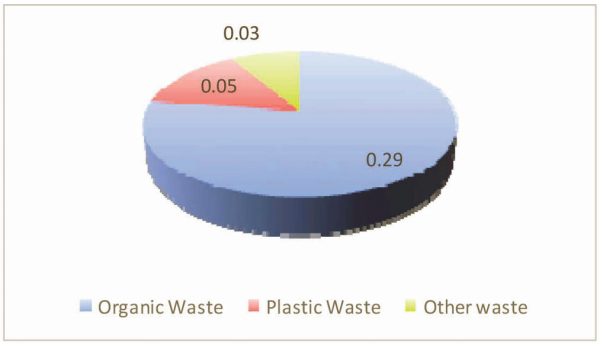

Fig. 14. Projected per capita waste generation from the Hotels/Month (mt)

Dustbin distribution of the Biswanath Municipal area: Presently no official big-size dustbin is located in the Biswanath municipal area probably because of the nuisance created by monkeys in the dustbin sites. Moreover, some people also throw waste here and there near the dustbin sites making the area messy. However, some small dustbins are still present in some wads supplied by an NGO. Dustbin locations are illustrated in Fig. 15.

Technology options available for safe treatment and disposal of MSW generated in the Biswanath Chariali municipality area

Total organic waste generation from the households

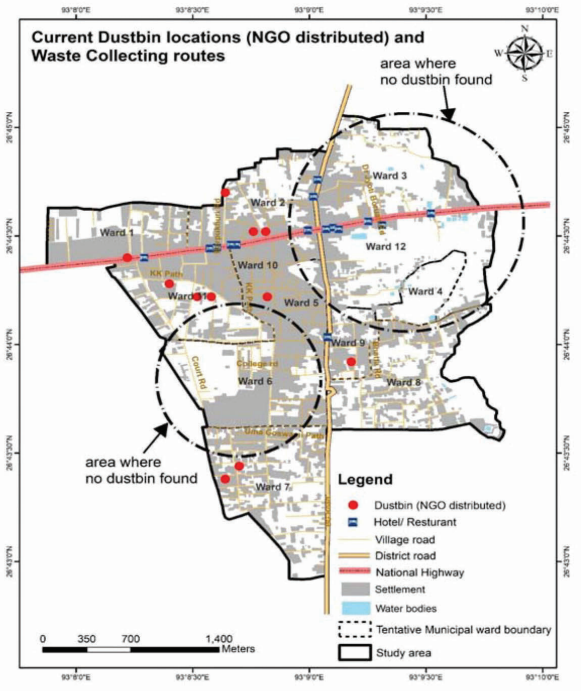

Fig. 15. Dustbin location in Biswanath municipal area

in Biswanath Municipal area is 201.62 mt/month ie. 2419.44 mt/year. Depending on the composting process and other factors, approximately 725.83 to 967.77 metric tons of compost can be produced from 2419.44 metric tons of organic waste. Similarly, 483.88 mt to 725.83 mt of biochar for soil amendment can be produced from 2419.44 mt of organic waste. Biochar is the carbon-rich product when biomass is subjected to Pyrolysis with little or no oxygen(Lehmann and Joseph, 2009).Equally, about, 604860 m^3 to 1209720 m^3 of biogas can also be produced from the household organic wastes of the Biswanth municipal area and 603584 to 1506960 kWh of electricity can be generated from 2419.44 mt of organic waste using a biogas generator assuming 35 % conversion efficiency.

Total organic waste generation from all the hotels of the Biswanath municipal area is 51.06 mt/month, ie. 612.72 mt/year. Depending on the composting process and other factors, approximately 183.82 - 245.10 metric tons of compost can be produced from 612.72 mt of organic waste. Similarly, 122.54 mt to 183.82 mt of biochar can be produced from 612.72 mt of organic waste and roughly, 153180 m^3 to 306360 m^3 of biogas can be produced from the organic wastes of hotels in the Biswanth municipal area. Again, 160839 to 536130 kWh of electricity can be generated from 612.72 mt of organic waste using a biogas generator with a conversion efficiency of 35%. Projected total possibilities of compost/ vermicompost, biochar, biogas and electricity generation in the Biswanath municipal area illustrated from Fig 16 Fig. 18.

Minimum potential compost production = (Amount of organic waste in kg x Minimum composting efficiency (0.4))

Minimum potential compost production =

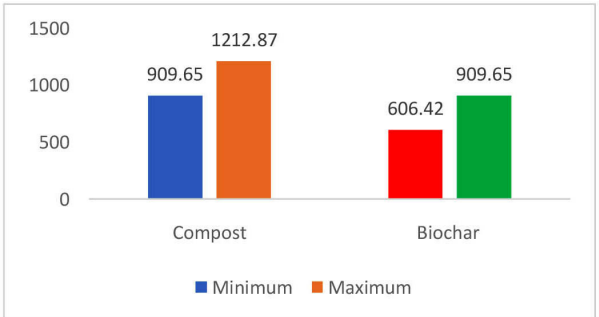

Fig. 16. The projected possibility of compost/ vermicompost and biochar production (mt) per year from the organic waste produced in the Biswanath Municipal area.

(Amount of organic waste in kg x Minimum composting efficiency (0.3))

Potential biochar production = (Amount of organic waste in kg x Biochar yield per kg of organic waste)

The biochar yield per kg of organic waste depends on the type of organic waste and the pyrolysis process used, but a typical range is between 20-30% of the original weight of the organic waste.

Assuming a biogas yield range of 0.25-0.5 m^3 per kg of organic waste,

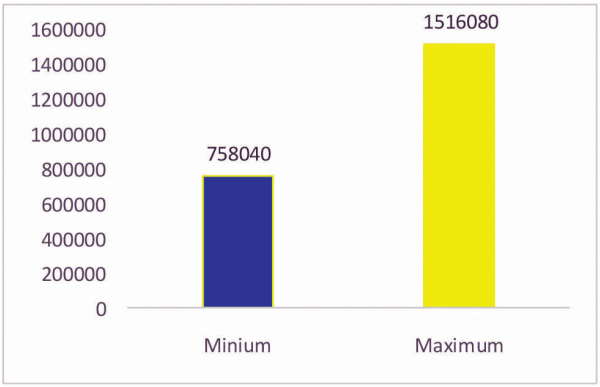

Fig. 17. Projected possibilities of biogas production (m^3) per year from organic waste produced in Biswanath municipal area.

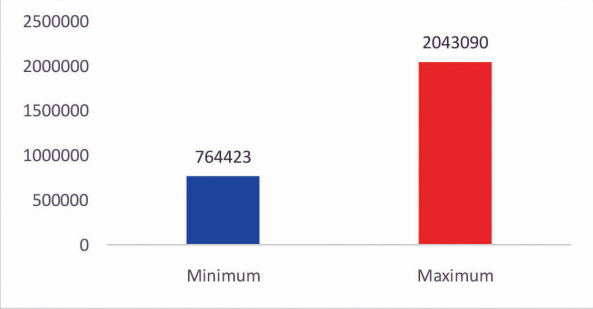

Fig. 18. Projected possibilities of electricity generation (kWh) per year from organic waste produced in Biswanath municipal area

Minimum potential electricity production = (Amount of organic waste in kg x Minimum biogas yield x Minimum electricity yield x Conversation efficiency)

Assumptions

Biogas yield	Electricity yield	Conversion efficiency
Minimum 0.25 m^3/kg	Minimum 3 kWh/m^3	0.35
Maximum 0.5 m^3/kg	Maximum 5 kWh/m^3	0.35

Maximum potential electricity production = (Amount of organic waste in kg x Maximum biogas yield x Maximum electricity yield x Conversation efficiency)

CONCLUSION

In the realm of waste management, towns can explore eco-friendly avenues like composting, anaerobic digestion, and recycling. Each approach entails specific logistical aspects, covering collection systems and processing infrastructures.When dealing with materials such as plastic, the adoption of recycling, coupled with contemplation of waste-to-energy methodologies and materials reuse, emerges as prudent. The judicious selection of a strategy should be contingent upon the distinctive needs of the municipality. Pondering the establishment of a recycling facility near Biswanath Chariali presents an enticing prospect for elevating the town's environmental allure and sustainability. About 70 per cent of the problem can be solved by managing the organic wastes in a scientific manner.

ACKNOWLEDGEMENTS

1. Biswanath District Administration, Govt. of Assam, India for sponsoring the project
2. HDFC Bank, Biswanath Chariali, Assam, India for partly sponsoring the project under CSR Head
3. Directorate of Research (Agri), Assam Agricultural University for providing research facilities.

Conflict of Interest

None

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