



Research Article

Seasonal Characterization of Municipal Solid Waste for Selected Wards for Tumakuru City, Karnataka, India

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Abstract

One of the major issues facing in tier-II cities like Tumakuru is the Efficient implementation Of Integrated Municipal Solid Waste Management. In order to choose the best Scientific Waste Treatment Technologies and Management Strategies for Tumakuru city, the amount and Composition of Municipal Solid Waste (MSW) differ considerably over the course of three distinct seasons. In order to ascertain the average per capita waste generation in each of Tumakuru City Corporation's (TCC) thirty-five wards, household data was gathered through a survey. Waste samples from 1050 households in each of the three seasons were recorded in order to calculate the average Household generation for five wards. According to the study's findings, the total amount of waste produced by Tumakuru city's households can be estimated at 110 TPD. And the results show that MSW samples have seasonal variation in Moisture content ranging from 27.52% to 41.2%, with an average of 34.46% which is suitable for composting and Biomethanation. The Calorific value having medium energy recovery potential which is suitable for refuse derived fuel (RDF). The overall results of MSW revealed significant seasonal effects on Moisture content, TOC, and Nutrient Parameters, confirming that climatic conditions strongly influence waste characteristics.

Keywords

Municipal Solid Waste (MSW), Waste Generation Rate, Physical Composition, Tumakuru

1. Introduction

The Management of Municipal Solid Waste (MSW) has become one of the most significant environmental issues facing both developed and developing countries. With rapid urbanization, people growth, industrial expansion, and changing consumption patterns, the quantity and complication of waste produced by households and urban centers have dramatically improved [1, 2]. Understanding the composition, generation rate, and physicochemical properties of MSW is necessary for devising effective management approaches that align with local socio-economic, cultural, and climatic

conditions [3, 4]. Several studies have focused on characterizing MSW to advance planning for collection, recycling, treatment, and disposal. Investigated waste generation models in Abuja, Nigeria, and Tripoli, Libya, respectively, revealing the effect of income levels, urban planning, and waste segregation behaviors [5, 6]. Similarly highlighted the heterogeneity and moisture-rich composition of MSW in Bhopal, while reported on the high Organic content in Sangamner City, indicating the potential for Composting [3, 4]. Quantification and Characterization of MSW are not simply necessary for design-

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ing sustainable waste treatment systems but also for optimizing public health and minimizing ecological risks emphasized the significance of region-specific information on waste generation and composition in Gujranwala, Pakistan, which has consequences for both waste diversion and resource recovery [7, 8]. It was demonstrated how seasonal variations affect the quantity and kind of waste in Jammu, underlining the necessity for flexible and adaptive waste management systems. Seasonal fluctuations are another crucial dimension that influences MSW composition and quantity [9]. Organic and high-moisture waste tends to increase during monsoon months, reducing Calorific value and complicating treatment processes. This has been seen in cities like Jaipur [11], Ujjain [12], and others, where seasonal trends directly affect composting efficiency, landfill leachate generation, and operational logistics [10].

According to the United Nations Human Settlements Programme (2023) carried out independent evaluation of waste generation globally it is estimated about 2.3 billion tons of Municipal Solid Waste. In India, Tier –II cities, which are quickly growing cities but still restricted by inadequate infrastructure, facing a burden on rising waste generation and management practices. According to the Central Pollution Control Board, India generates approximately 1, 70,339 TPD of Municipal Solid Waste is generated, of which 1, 56,449 TPD is collected which translates to overall yield of 92% in the country. A total of 91.511 TPD is scientifically treated, which accounts to 54% of the total waste generation. Karnataka contributes significantly to this volume, about 13,034 TPD of Municipal Solid Waste is generated, of which only 11,655 TPD is collected and less than 45% is scientifically processed [14]. With Tier –II cities emerging as recent hotspots for mismanaged waste streams.

Problem Statement

Cities like Tumakuru, which are growing quickly in Karnataka, are also dealing with a worrying Municipal Solid Waste problem. Tumakuru City Corporation (TCC) has MSW as one of its primary projects. The practice entails collecting waste from all households, Commercial establishments, Bulk generators, and other waste generators using various vehicle types. The waste production rate has been found to increase rapidly due to steady population growth, urbanization, and industrialization over the years, as well as increased patterns of consumption and production. Preliminary studies have revealed that door-to-door collection is only carried out in fifteen out of thirty-five wards, and there is a lack of infrastructure for processing and disposing of MSW. The current aim of the investigation is to describe the ongoing Municipal Solid Waste management practices, identify the challenges, limitations, and determinants influencing waste management, such as population density, urbanization, and industrialization, as well as the pattern of collection and transportation of MSW. It also aims to study the characterization and quantification of waste produced in Tumakuru city, Karnataka, which aids in proper planning, design, and execution of proper scientific

technologies for disposal of waste. Finally, it makes recommendations for an efficient and sustainable method of implementing the waste management method in the city.

2. Materials and Methodology

2.1. Study Area

Located about 70 kilometers northwest of Bangalore, Tumakuru serves as the district's administrative hub. One of Karnataka's fastest-growing tier-II cities, it serves as a significant industrial and educational hub in the Bengaluru-Tumakuru industrial corridor. The corporation's total area is 48 square kilometers, with 35 wards. Tumakuru is a landlocked district that lacks any natural features that would separate it from other parts of the state, such as rivers or mountains. The latitude parallels of 12° 45' to 14° 20' N and the longitudinal meridians of 76° 20' to 77° 31' E were where Tumakuru was situated. 10598 km² was the district's total area. The district's climate is generally pleasant and comparable to Bangalore district's, with the exception of the northernmost section. However, with a slightly hotter Summer, the climate of the northern part of Sira and the Pavagada region is similar to that of the Chitradurga district. Tumakuru City's elevation in the district is about 822 meters above mean sea level, making it relatively flat, and the average annual rainfall is 687.9 mm. The lowest temperature during the cold season can be as low as 9 °C or 10 °C, while the maximum temperature ranges from 35 °C to 41 °C [15].

According to the 2011 census, Tumakuru's population was 302431 lacs, with 152925 males and 149218 females. Over the past ten years, the city's population has grown at a rate of two percent annually. The Indian census for 2021 was postponed due to COVID-19, and Tumakuru's anticipated population growth was estimated to be 3.98 lakhs. Currently, the city has three transfer stations—Akkathangi Kere, Danah Palace, and Kyatsandra Ring Road—to move waste from auto trippers to compactors. The collected waste is then dumped at the Aj-jagondanahalli landfill.

Tumakuru City Corporation (TCC) is in charge of managing the city's Municipal Solid Waste, which is spread across 35 wards. The [Figure 1](#) The city produces roughly 131 TPD of MSW every day. The city's current Municipal Solid Waste management system practices are depicted in [Figure 2](#). The MSW produced by households is collected door-to-door, separated into wet and dry waste, and transported by auto tippers to the nearby processing station in addition to street sweeping. Tippers or tractors are used to collect waste from secondary collection bins and bulk generators, transport it to the processing station, and then use compactors to deliver it to the disposal site. Because only 15 of the 35 wards have door-to-door collection, mixed waste is collected from households due to a lack of infrastructure and awareness regarding MSW. Prior to 2018, all waste was disposed of at the Ajjagondanahalli dumpsite. The Government of India is developing

the city as a Smart city because the existing methods for managing Municipal Solid Waste were unsustainable. For this

study, Tumakuru City Corporation was chosen as the study area.

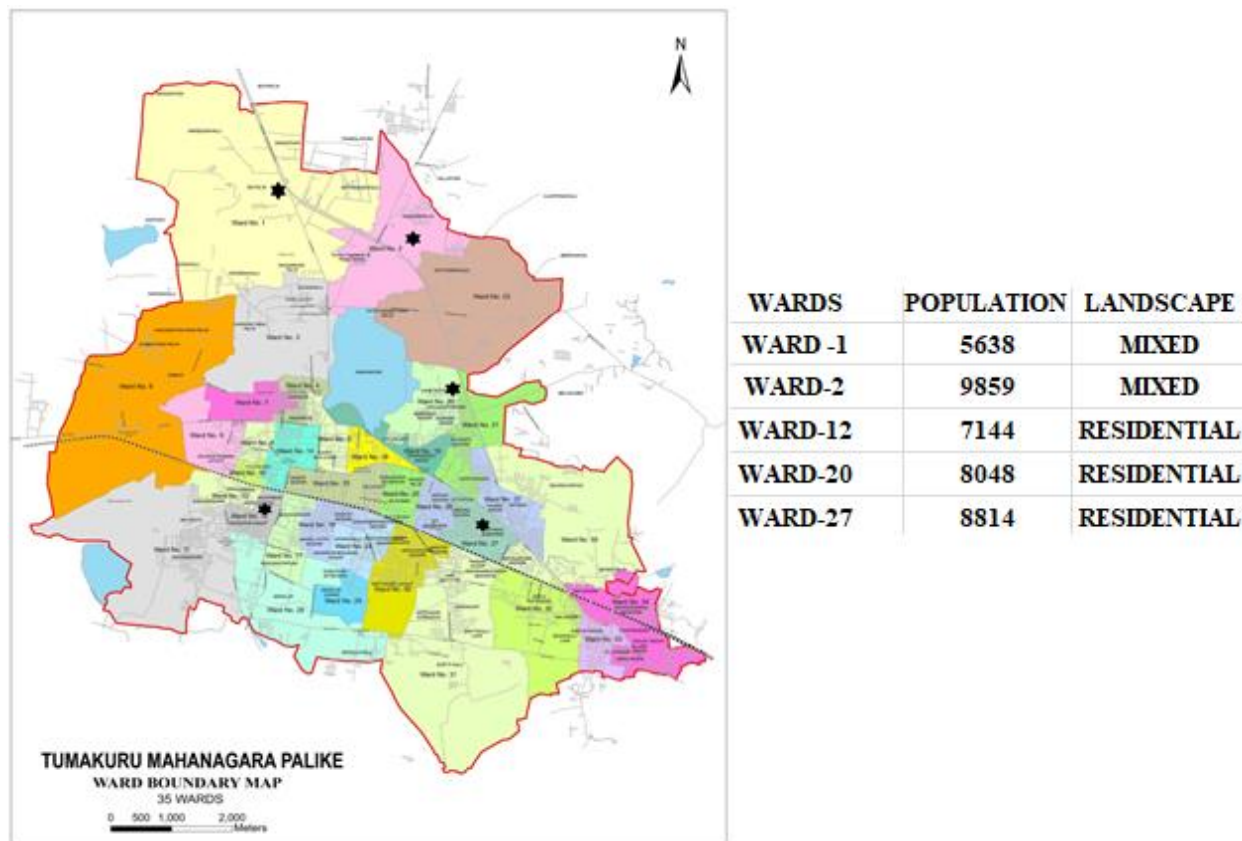


Figure 1. Selected Wards for the Study in Tumakuru City, Karnataka.

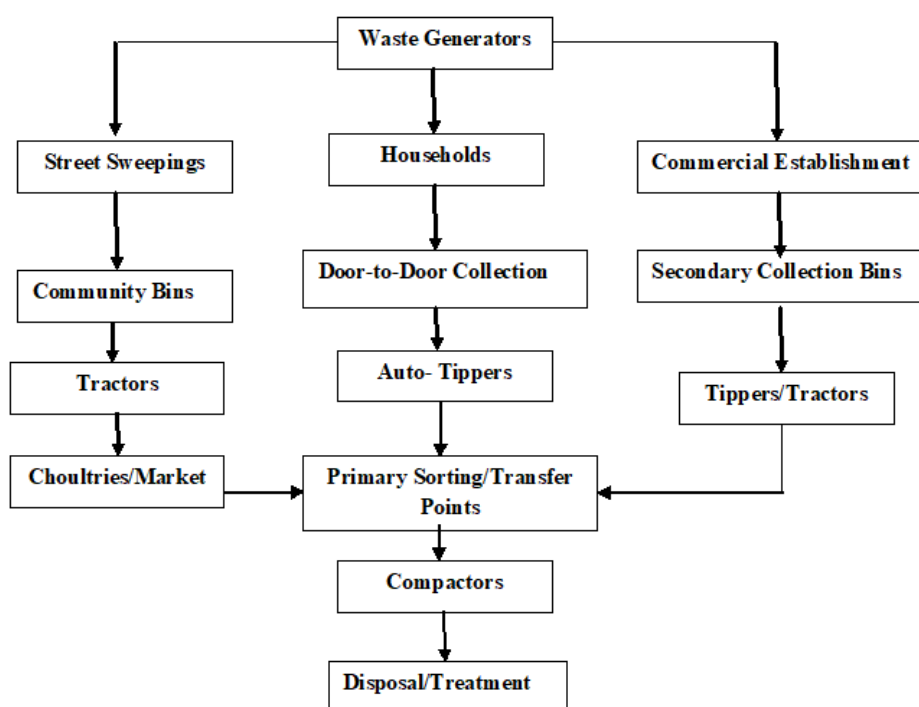


Figure 2. Flow Chart Showing Current Practices for Municipal Solid Waste Management in Tumakuru City.

2.2. Standard Methodology

There are 35 wards in Tumukuru City Corporation, out of which, five wards were selected for the study based on the preliminary survey with the Average Monthly income, Population density and Land scape and other Socio-economic category. Solid waste samples were collected in each household for one week to get representative results in the study. A total of 1050 samples were collected during all the three seasons (Winter, Summer And Rainy) from the five sampling areas. The selected households were informed and provided the collection bags for a week and weighed separately on a calibrated digital scale and recorded in datasheets.

MSW Sample Collection and Preparation

MSW sample Collection and Preparation for each of the five chosen wards was done separately in order to describe and measure the MSW produced in the city. The study used the standard sampling and methodology. Tumakuru City has a total of 35 wards. Five wards were chosen for the study for the Winter (November), Summer (April), And Rainy (August) seasons. The preliminary field survey served as the basis for the study. A total of 1050 samples were taken from five sampling locations over the course of three distinct seasons (December 2023–October 2024). To get representative results in the survey, 10 households were randomly selected from each ward. [13, 15, 46].

2.3. Physical Composition of Collected Samples

For a week, collection bags were given to the chosen household along with information. Based on their physical makeup, household wastes were divided into eight distinct fractions. Organic Waste, Paper, Metal, Plastic, Glass, Wood, Textiles, and so forth. Following the sorting procedure, each fraction is weighed independently on a digital scale that has been calibrated to weigh 10 kg, and the results are entered into data sheets. [13, 15, 46].

2.4. Chemical Composition of Collected Samples

Five wards were sampled for three distinct seasons in order

to characterize the waste's physical and chemical properties using the quartering and coning method. Ten kilograms of household waste are gathered independently from various wards and thoroughly combined with representative samples obtained for sampling using the quarter and cone method. A group of samples was further separated by straight lines that were perpendicular to each other into four equal sections. After discarding the sample's diagonally opposite end, the first half of the sample is mixed and repeated until 1 kg of the desired sample is obtained. The final fraction is thoroughly mixed once more in order to perform the laboratory's Physical and Chemical analysis [13, 15, 46]. The table lists the tests and procedures used for waste Chemical characterization. The feasibility of treatment technologies, such as Composting, Bi-methantion, Recycling and RDF, Gasification, and Incineration, is thoroughly discussed after the Physical composition of the MSW for three distinct seasons has been determined. The study area's results are compared with those of national and international cities based on Composition and Quantification.

3. Result and Discussion

3.1. Physical Composition of MSW

The results of the seasonal variation of the Physical composition of Municipal Solid Waste conducted in Tumakuru city are displayed in Table 2 and graphically depicted in Figure 3 for the Winter, Summer, And Monsoon Seasons. According to the results, Organic waste accounts for the largest percentage weight in the overall MSW in all five wards and seasons (58–64 percent), followed by Plastics, Paper, and Textile waste in the MSW. Metal, Glass, and others accounting for 0.04 percent, 3.71 percent, and 4.05 percent, respectively. Metals made up less than 0.04 percent due to rag pickers manually scavenging large amounts from secondary bins or door-to-door collection. Because Organic waste and recyclables make up a large portion of the study area, recovering recyclables and Organic waste is a cost-effective and environmentally friendly option (Table 2). When examining the seasonal variation in Tumakuru City's MSW composition, Organic, Plastic, and Paper components do not exhibit any discernible variation.

Table 1. Municipal Solid Waste Characteristics and Methods Followed for Chemical Analysis of MSW.

SL. NO.	TEST NAME	METHOD
1	pH	pH meter
2	EC	Conductivity meter
3	Moisture content	Gravimetric method
4	Calorific Value	Bomb calorimeter
5	Total Nitrogen	Kjeldhal method

SL. NO.	TEST NAME	METHOD
6	Total Organic Carbon	Walkey and Black method
7	Potassium	Flame photometric
8	Phosphorous	Vanadomolybdo phosphoric Acid Colorimetric method
9	C/N	C/N ratio is determined from the ratio of total Organic carbon to total nitrogen
10	Organic Matter	OM=TOC X 1.724

The Organic fraction dominated across all seasons, consistent with findings from [9, 10, 32] who reported 50–65% biodegradable content in Indian cities. The slightly higher proportion during Summer (April) may be attributed to increased consumption of fruits and vegetables and faster decomposition at elevated [16, 17]. Similar dominance of Organic waste was observed in tropical climates such as Ghana [14] and Iran [19]. The high Organic content suggests significant potential for Composting and Biomethanation [20, 21]. Paper content (7.5–10.9%) and Plastics (11–15.6%) showed seasonal variability, rising slightly during Winter (November). This may result from higher packaging and household use during festive months [9, 22]. The increase in Plastic waste during Winter was reported that cooler months exhibit more synthetic material use and less Organic degradation [23]. The observed proportions are comparable to those in Manali [24] and Jammu but lower than in metropolitan regions like Delhi [25] due to lower industrial and commercial activities in Tumakuru. Glass and textile fractions showed moderate seasonal variation. The highest Glass percentage (6.22%) occurred in April, linked to increased beverage consumption in Summer, similar to observations by [4, 26]. Textiles ranged between 4.7% and 10.5%, higher in Winter due to clothing turnover and household discards [27, 28]. Metal waste remained insignificant (< 0.3%), reflecting efficient informal recycling by scrap dealers [29]. The “others” category, composed of fine dust, street sweepings, and inert materials, averaged 4.05%. Higher values in the dry season are likely due to accumulation of road dust and construction debris such waste requires separate treatment to avoid contamination of Organic fractions intended for composting [1, 14, 30, 31]. Similar results were reported in [22, 46–48] for Varanasi and [10] in North India, where biodegradable waste peaks in warmer months and inert content increases in Rainy periods due to soil and silt inclusion. The predominance of Organics (60%) suggests that adopting source segregation and decentralized composting could reduce landfill dependency [32, 33]. The seasonal and compositional variability highlights the need for adaptive collection and treatment planning [34, 35, 46, 47]. The observed trends align with national patterns reported by [14] and global findings in developing countries [36, 37].

3.2. Chemical Characterization of MSW

The results of chemical analysis of MSW for Winter, Summer and Rainy season for all five wards are listed in Table 3. The results indicates that MSW samples have seasonal variation in Moisture content ranging from 27.52% to 41.2%, with an average of 34.46% which is suitable for composting and Biomethanation. the calorific value having medium energy recovery potential which is suitable for refuse derived fuel (RDF). The overall results of MSW revealed significant seasonal effects on moisture content, TOC, and nutrient parameters, confirming that climatic conditions strongly influence waste characteristics. Wards did not differ significantly, indicating similar socio-economic profiles and waste generation behaviours across the city—consistent with findings from [27, 38].

Table 2. Seasonal Composition Variation of MSW of Tumakuru City.

Types of Waste	Lowest (%)	Highest (%)	Average (%)
Organics	58.08(AP)	63.82(AP)	61.79
Paper	7.51(AP)	10.87(AP)	8.66
Plastics	11.34(AP)	15.57(N)	13.87
Glass	0.84(N)	6.22(AP)	3.71
Metal	0.09 (AP)	0.28(AP)	0.04
Textile	4.73(N)	10.53(N)	7.82
Wood	0	0	0
Others	1.43(AP)	6.55(AP)	4.05

(On wards level; AP- April, AU-August, N-November)

The pH values of MSW samples ranged between 6.9 and 7.6, with an average of 7.1, indicating near-neutral to slightly alkaline conditions. Higher pH values were recorded during Winter (7.6 in Ward 4), while lower values occurred in Summer (6.8–7.0). The observed pH levels are consistent with findings from [3, 17], who reported neutral to mildly alkaline

waste matrices conducive to microbial activity during composting. The slight increase in pH during Winter may be attributed to reduced Organic acid formation due to lower ambient temperatures [10]. Electrical conductivity varied from 3.06 to 4.2 mS/cm (mean: 3.55 mS/cm). The highest EC was recorded during the Rainy season (Ward 3, 4.2 mS/cm), possibly due to leaching of soluble salts from Organic waste [40]. Similar trends were observed by [19, 39] in monsoonal regions where increased rainfall enhances ionic mobility within

decomposing Organic matter. Moisture content ranged between 27.52% (Summer) and 41.2% (Rainy), with an average of 34.46%. The Rainy season recorded significantly higher moisture, attributed to higher humidity and precipitation enhancing microbial decomposition [26]. Lower moisture during Summer corresponds to drier conditions and higher evaporation rates [9, 10] the observed seasonal variability agrees with studies from [16, 23].

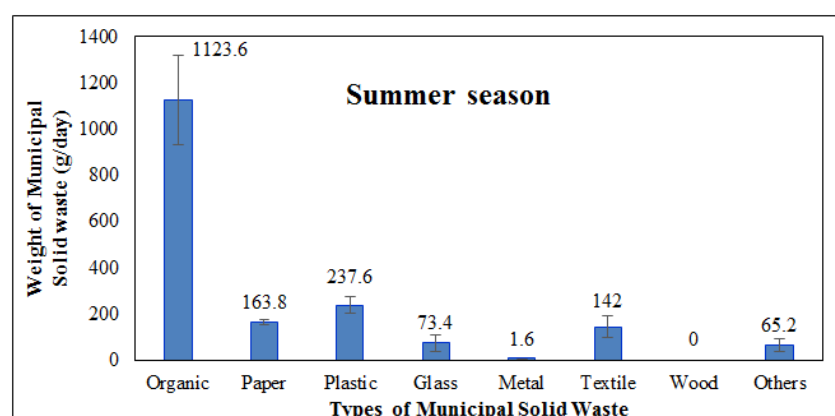
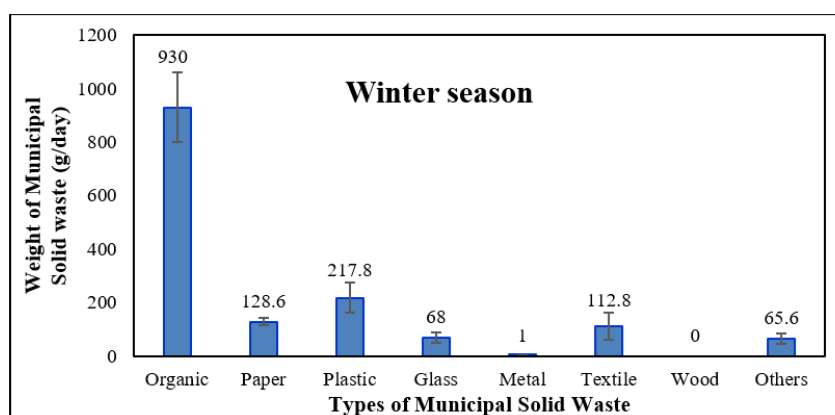
Table 3. Seasonal Variation of Physical Composition of MSW for Different Wards of the City.

WARDS		1	2	3	4	5	AVG.
ORGANIC	NOV	60.95	62.03	60.45	58.98	62.29	60.94
	APRIL	63.31	62.11	63.82	58.08	62.64	61.99
	AUG	62.25	61.66	61.07	65.9	61.32	62.44
	AVG.	62.17	61.93	61.78	60.98	62.08	61.79
PAPER	NOV	8.1	7.94	9.34	8.57	8.13	8.41
	APRIL	9.48	8.39	8.51	10.22	9.11	9.14
	AUG	7.54	7.58	7.51	10.87	8.62	8.42
	AVG.	8.37	7.97	8.45	9.88	8.62	8.66
PLASTIC	NOV	12.4	14.19	15.57	15.29	13.87	14.26
	APRIL	13.16	11.34	13.85	14.43	13.22	13.2
	AUG	13.66	14.67	15.54	11.67	15.27	14.16
	AVG.	13.07	13.4	14.98	13.79	14.12	13.87
GLASS	NOV	5.77	5.88	0.84	4.53	5.81	4.56
	APRIL	4.61	4.69	0.88	4.54	6.22	4.18
	AUG	2.87	2.79	1.27	1.14	3.91	2.39
	AVG.	4.41	4.45	0.99	3.40	5.31	3.71
METAL	NOV	0.35	0	0	0	0	0.07
	APRIL	0	0.09	0.28	0	0	0.074
	AUG	0	0	0	0	0	0
	AVG.	0.11	0.03	0.09	0	0	0.04
TEXTILE	NOV	7.11	4.73	10.53	6.79	7.42	7.31
	APRIL	7.98	9.29	9.21	6.14	5.94	7.71
	AUG	9.4	9.83	9.77	5.3	7.88	8.43
	AVG.	8.16	7.95	9.83	6.07	7.08	7.82
WOOD	NOV	0	0	0	0	0	0
	APRIL	0	0	0	0	0	0
	AUG	0	0	0	0	0	0
	AVG.	0	0	0	0	0	0
OTHERS	NOV	5.28	5.21	3.22	5.82	2.45	4.39

WARDS	1	2	3	4	5	AVG.
APRIL	1.43	4.04	3.41	6.55	2.83	3.65
AUG	4.25	3.44	4.81	5.1	2.97	4.11
AVG.	3.65	4.23	3.81	5.82	2.75	4.05

Calorific values ranged from 759 kcal/kg (Rainy) to 1036 kcal/kg (Summer), averaging 857 kcal/kg. The higher energy potential in Summer samples may be due to a larger proportion of dry and combustible fractions (plastic, paper, textiles) and reduced moisture. Similar Calorific ranges were reported for Indian municipal waste [24, 41]. Seasonal reduction during the Monsoon was also observed in studies due to increased biodegradation of Organic matter [28]. TN content varied between 0.51% (Summer) and 0.97% (Rainy), with an average of 0.71%. Elevated TN during monsoon is linked to enhanced microbial decomposition and nitrogen mineralization. These results correspond with the findings to emphasize the importance of nitrogen availability for composting efficiency [17, 42]. TOC ranged from 16.02% (Summer) to 32.54% (Rainy), averaging 23.36%. Higher TOC in the Rainy season suggests a greater presence of Organic fractions, while the lowest values in Summer indicate more oxidation and decomposition of Organic matter. The obtained results are comparable to those

[31, 43]. Potassium content varied between 0.39% and 0.98%, averaging 0.62%, while phosphorus ranged from 0.34% to 0.67% (average 0.49%). Both nutrients were found in higher concentrations during the Rainy season, attributed to enhanced microbial and leachate-mediated mobilization but Similar nutrient levels were reported by [20, 21, 42] supporting the composting potential of MSW. The C/N ratio ranged between 29.48 and 35.61, with an average of 32.53. The optimum range for compostable material (25–35%) was maintained across all seasons, indicating balanced biodegradability. Slightly higher C/N during the Rainy season may be due to a higher proportion of lignocellulosic waste [26]. OM content ranged from 27.28% to 52.81%, averaging 40.27%, showing a direct relation with TOC. Maximum OM was recorded during the Rainy season, consistent with increased Organic inputs and moisture retention. Similar findings were reported by highlighting seasonal fluctuations in Organic fractions within urban MSW [18, 44].



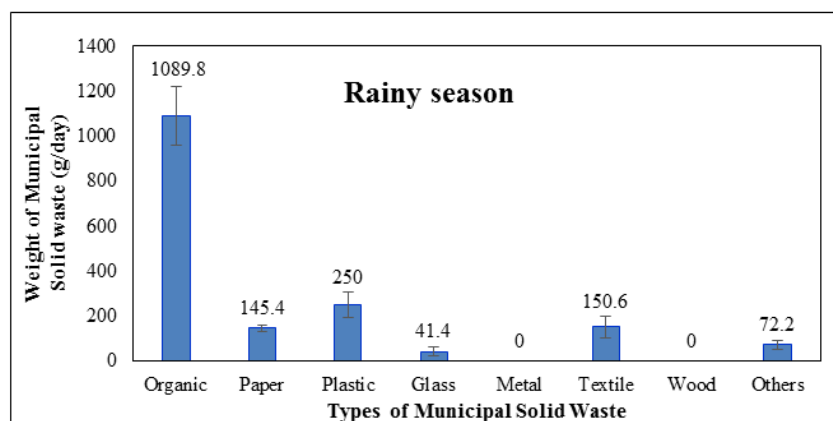


Figure 3. Seasonal Composition Variation of MSW During (a) Winter (b) Summer (c) Rainy Season (Mean $\pm$ SD).

3.3. Comparison of MSW Composition of Tumakuru City with Other City

Moisture and Organic matter content were similar to those in Varanasi [26] and Mangalore [45]. C/N ratio and nutrient composition were comparable to compostable fractions in Bhopal [3,

23]. Organic fractions are suitable for composting and Bio-methanation. The calorific value was within the range reported for Indian Class I cities, and the higher content of plastic, paper, and textiles in comparison to other Indian cities indicates a high potential for recycling waste [12, 31], verifying 856.66 kcal/kg of energy recovery potential, it might be sufficient for RDF generation or incineration with appropriate segregation.

Table 4. Chemical Analysis of MSW for Different Wards with Seasons.

WARDS		1	2	3	4	5	AVG.
pH	NOV	7	7.4	7.1	7.6	6.9	7.2
	APRIL	6.8	7.4	7.5	7.2	6.6	7.1
	AUG	6.9	7	6.6	6.8	7.2	6.9
	AVG.	6.9	7.26	7.06	7.2	6.9	7.0
EC (mho/cm)	NOV	3.15	3.95	3.9	3.06	3.69	3.55
	APRIL	3.74	3.89	3.83	3.16	3.48	3.62
	AUG	3.21	3.38	4.2	3.2	3.46	3.49
	AVG.	3.36	3.74	3.97	3.14	3.54	3.55
Moisture content (%)	NOV	34.1	39.5	40.9	33.58	35.92	36.8
	APRIL	27.52	28.88	28.32	28.42	27.86	28.2
	AUG	37.2	39.6	41.2	38.8	35.2	38.4
	AVG.	32.94	35.99	36.80	33.6	32.99	34.46
Calorific Value (kcal/kg)	NOV	764	952	988	790	796	858
	APRIL	917	948	814	885	1036	920
	AUG	759	798	768	781	854	792
	AVG.	813.33	899.33	856.66	818.66	895.33	856.66
Total Nitrogen (%)	NOV	0.68	0.76	0.87	0.62	0.67	0.72
	APRIL	0.51	0.55	0.53	0.52	0.54	0.53
	AUG	0.86	0.92	0.97	0.87	0.83	0.89

WARDS		1	2	3	4	5	AVG.
Total Organic Carbon (%)	AVG.	0.68	0.74	0.79	0.67	0.68	0.71
	NOV	24.32	25.14	25.48	22.39	24.42	24.35
	APRIL	16.02	16.48	16.32	16.29	16.14	16.25
	AUG	30.25	28.71	32.54	28.96	26.94	29.48
	AVG.	23.53	23.44	24.78	22.54	22.5	23.36
Potassium (%)	NOV	0.39	0.48	0.49	0.43	0.46	0.45
	APRIL	0.44	0.54	0.49	0.47	0.51	0.49
	AUG	0.95	0.91	0.98	0.93	0.88	0.93
	AVG.	0.59	0.64	0.65	0.61	0.61	0.62
Phosphorous (%)	NOV	0.37	0.47	0.47	0.34	0.45	0.42
	APRIL	0.39	0.47	0.45	0.43	0.41	0.43
	AUG	0.63	0.58	0.67	0.61	0.56	0.61
	AVG.	0.46	0.50	0.53	0.46	0.47	0.48
C/N (%)	NOV	32.78	34.74	34.58	32.3	34.65	33.81
	APRIL	29.56	31.76	29.48	30.12	32.38	30.66
	AUG	33.21	35.61	30.78	32.44	33.56	33.12
	AVG.	31.85	34.03	31.61	31.62	33.53	32.53
Organic Matter (%)	NOV	39.65	45.1	44.85	37.72	42.53	41.97
	APRIL	27.28	28.76	27.8	27.65	28.61	28.02
	AUG	51.86	49.78	52.81	50.96	48.69	50.82
	AVG.	39.5967	41.2133	41.82	38.7767	39.9433	40.27

Table 5. Seasonal Variation in Chemical Analysis of MSW in Tumakuru City.

Sl. No	Contents	Lowest (%)	Highest (%)	Average (%)
1	pH	6.9(AP)	7.6(N)	7.1
2	EC	3.06(N)	4.2(AU)	3.55
3	Moisture content (%)	27.52(AP)	41.2(AU)	34.46
4	Calorific Value (kcal/kg)	759(AU)	1036(AP)	857
5	Total Nitrogen (%)	0.51(AP)	0.97(AU)	0.71
6	Total Organic Carbon (%)	16.02(AP)	32.54(AU)	23.36
7	Potassium (%)	0.39(AP)	0.98(AU)	0.62
8	Phosphorous (%)	0.34(N)	0.67(AU)	0.49
9	C/N (%)	29.48(AP)	35.61(AU)	32.53
10	Organic Matter (%)	27.28(AP)	52.81(AU)	40.27

(On wards level; AP- April, AU-August, N-November)

This study shows that climatic condition is greatly influencing the waste characteristics as observed by the seasonal fluctuations in most parameters in the Households in the five

wards. Wards did not differ significantly, indicating similar socio-economic profiles and waste generation behaviors across the city, consistent with findings from [27, 38, 46-48].

Table 6. Seasonal Variation in Moisture Content, TOC, Nutrients and Calorific Value of MSW in Tumakuru City.

Sl. No	Parameters	Winter	Summer	Rainy
1	Moisture Content (%)	36.8	28.2	38.4
2	Total Organic Carbon (%)	0.72	0.53	0.89
3	Total Nitrogen (%)	0.42	0.43	0.61
4	Phosphorous (%)	0.45	0.49	0.93
5	Potassium (%)	24.35	16.25	29.48
6	Calorific Value (kcal/kg)	858	920	792

4. Conclusion and Recommendations

The Efficiency of the Municipal Solid Waste is not satisfactory in many urban cities due to the lack of suitable infrastructure for collection, transportation, processing and disposal of solid waste scientifically. Organic waste management should focus on composting and biogas units, especially during Summer when moisture and biodegradability are high. Recycling of plastic and paper can be enhanced during Winter to offset increased synthetic waste. The study identifies the calorific value and other nutrients and are useful for further benefits. There is need to bring public awareness on segregation, recycle and reuse and minimize inert solid waste disposal. The current study can be continued for further investigations for enhancing the management of solid waste.

Abbreviations

AP	April
AU	August
N	November
EC	Electrical Conductivity
C/N	Carbon Nitrogen Ratio
MSW	Municipal Solid Waste
TOC	Total Organic Carbon
RDF	Refused Derived Fuel
TPD	Tonnes per Day

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Author Contributions

Kariyanna Harisha: Conceptualization, Data curation, Formal analysis, Investigation, Writing – original draft

Jambhava Samavedamuni Chandrashekar: Supervision, Validation, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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