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Keywords: Municipal household solid waste; Gravimetry composition; Statistics analysis; Anova

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Statistical Analysis of Gravimetric Composition of Municipal Solid Household Waste in the City of Belém-Pará-Brazil: A Systematic Study for Decision Making and Public Policies

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Abstract: This article aimed to evaluate, using statistical tools, the generation and composition of urban solid waste (MSW) in the city of Belém, Pará, from nine urban collection sectors in the municipality, and the average nominal income of the population. Approximately 900kg of urban solid waste were collected from the municipality in the period from 2021 to 2022. Statistical tests were carried out on hypotheses with 5% significance in comparative evaluations, and their respective average nominal incomes. The results indicated that the organic fraction corresponds to 55.57% of the waste generated in the municipality, 14.26% is inert waste (potentially contaminating) and 0.67% is miscellaneous waste. It was observed that the waste generated by families with high purchasing power tends to contain higher percentages of recyclables, while in families with lower purchasing power the highest percentages tend to be organic. Knowledge of the generation of MSW is fundamental for the choice and dimensioning of operations and processes involved in the management chain at the municipal level. The decentralization of services offered based on solid waste management would enable greater success in serving the population.

Keywords: urban solid waste; statistics; gravimetry

1. Introduction

The generation of urban solid waste (MSW) is a significant environmental problem on a global scale. The amount of solid waste (RS) produced can vary according to factors such as population size, level of industrialization and consumption patterns. Globally, around 1.3 to 1.9 billion tons of solid waste are generated annually [4]. Properly managing solid waste, based on non-generation, reduction, reuse, recycling and adequate treatment, guarantees lower carbon and greenhouse gas emissions into the environment, contributing to the achievement of Sustainable Development Goals. When pollutants related to MSW combustion are inappropriately released into the atmosphere, they cause serious damage to human health and the environment. [52].

In Brazil in 2022, a total of 81.8 million tons of MSW were generated, corresponding to 224 thousand tons per day, that is, each Brazilian produced, on average, 1.043 kg of waste per day. The

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region with the highest waste generation continues to be the Southeast, with around 111 thousand tons per day (approximately 50% of the country's generation) e an average of 450 kg/habitant/year, while the North region represents 7.4% of the total generated, with around 6 million tons/year and 328 kg/habitant/year, the lowest among the regions [2].

The city council of Belém in the State of Pará, Brazil, the city that will host the 30th UN Conference on Climate Change (COP-30), in November 2025, allocates practically all of its MSW to landfills [5]. Only around 1.3% of waste is recycled in the municipality of Belém, unlike what occurs in developed countries where we find much higher recycling and composting percentages [6].

Currently, waste management can be of four types: landfills, recycling, thermal and biological treatment. Most of the global scenario addresses MSW management in the form of landfills. Statistics reveal that only 15% of the total waste collected is sent for recycling and the remaining waste is sent to landfills or is simply dumped in open spaces, inviting high risk factors [11].

This amount is estimated to increase to around 3.5 billion tonnes by 2050, overwhelming existing management systems [12,13]. In the current scenario of total waste collection, only around 11% is converted into energy, 19% is recycled and around 70% is dumped in landfills, causing many health and environmental problems [4].

Furthermore, common MSW management practices such as incineration and landfilling pose numerous dangerous risks while increasing greenhouse gas (GHG) emissions, contributing to climate change, MSW causes a substantial socioeconomic burden, and its management cost is estimated to increase by 675.5 billion dollars by 2025 [14].

In Brazil, to minimize such problems, the National Solid Waste Policy, Brazilian legislation on solid waste, regulated by Decree No. 7,404/2010, which brings together a set of principles, objectives, guidelines, instruments, goals and actions for integrated management and the environmentally correct management of urban solid waste, aiming to offer alternatives for waste management, it proposes the implementation of energy recovery as an environmentally appropriate treatment and destination, in addition to determining the development of RS management plans at state, municipal and regional levels, as well as the National Solid Waste Plan; the establishment of goals for the eradication of landfills; provides for the preparation of RS management plans by companies; in addition to the implementation of selective collection and reverse logistics [15,16].

In this sense, research focused on this topic has attracted the attention of researchers in recent years. According to [17], the insertion of statistical techniques has proven to be relevant to assist the municipality in the planning and management of solid waste. Multivariate techniques stand out for enabling the simultaneous analysis of several indicators and pointing out possible management strategies for public managers [7–9].

Accurate and reliable data on the composition of waste are fundamental both for the planning and environmental assessment of waste management and for improving resource recovery in society. To develop the waste system and improve technologies, detailed data on the material characteristics of the waste involved are needed. Characterization of waste composition typically consists of three phases: first sampling the waste itself, then sorting the waste into the desired number of material fractions (e.g., paper, plastic, organics, etc.) and finally handling, the interpretation and application of the data obtained. Sampling and sorting activities themselves are fundamental to obtaining adequate data on waste composition. The absence of international standards for solid waste characterization has led to a variety of sampling and screening approaches, making it challenging to compare results across studies [18].

Determining the composition and quantity of waste allows greater knowledge of the reality of the generating source, enabling more efficient management proposals [20]. Furthermore, gravimetric characterization supports the development of any program or project related to MS, therefore being an important integrated management instrument for the municipality [19].

In view of the above, the present work aimed to statistically analyze the gravimetric composition of urban solid waste (MSW) in the city of Belém, Pará, based on the nine urban sectors of the municipality and the household income of the population.

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2. Materials and Methods

In this work, the methodology for achieving the proposed objectives in the current research is presented, detailing the study area, methodological design, specific data collection procedures, data analysis, and the statistical techniques used. The methodology was divided into four stages, with the development of the experimental research taking place in the year 2021. Figure 1 depicts the flowchart of the stages developed in the research.

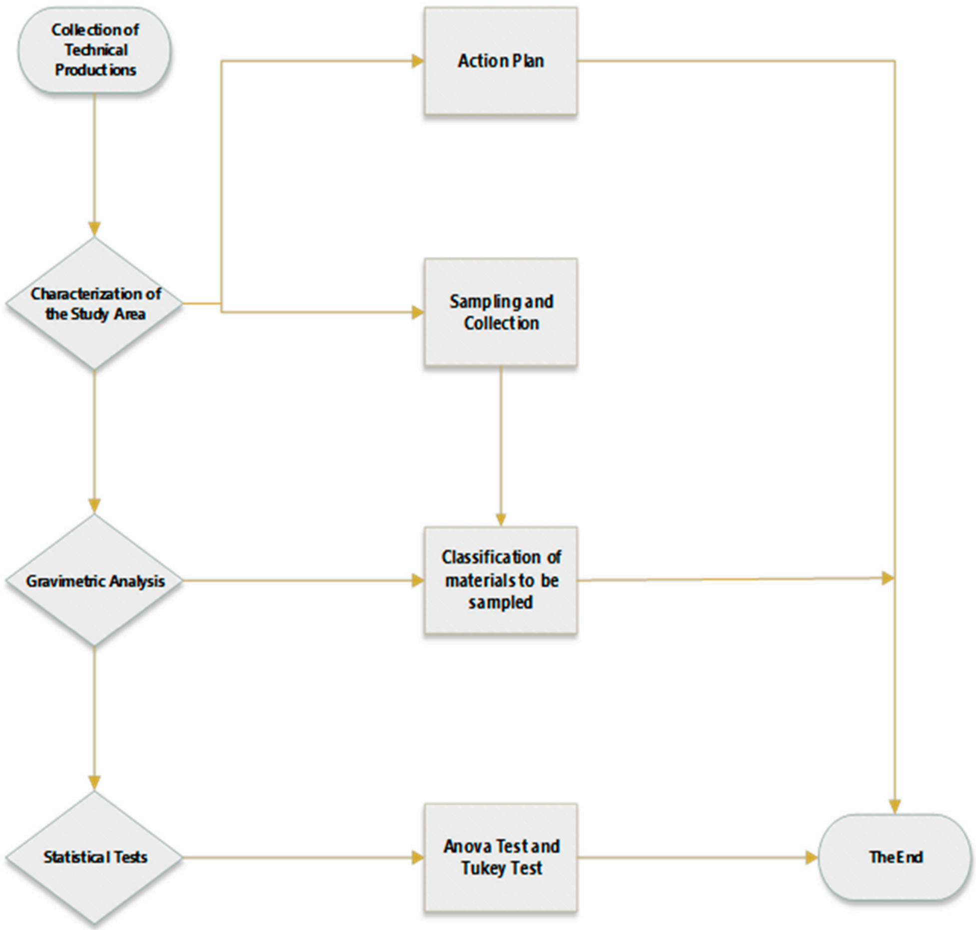

Figure 1. Flowchart of the steps developed in the research.

2.1. Collection of Technical Productions

The first stage sought to understand the management context, including the generation and composition of MSW to formulate the problem and thus move on to the second stage of identifying the objectives, that is, it was defined within the reality of MSW collected by the company TERRAPLENA LTDA within the municipality of Belém/PA which specific sector was intended to work, directing the work.

At this stage, research was carried out in academic and technical publications to collect reference data on the gravimetric composition of MSW adopted in other countries, in Brazil and in the city of Belém/PA, which served as a basis for adopting the type of collection and gravimetric composition adopted in the research. To achieve this, several sources were consulted, including: [10,21–27].

2.2. Characterization of the Study Area

The study area is, therefore, the urban area of Belém served by TERRAPLENA LTDA belonging to Lot 1, according to the division presented in the Municipal Basic Sanitation Plan of Belém [35], which includes 21 neighborhoods in the urban area of Belém (Figure 2), totaling 37 itineraries (routes).

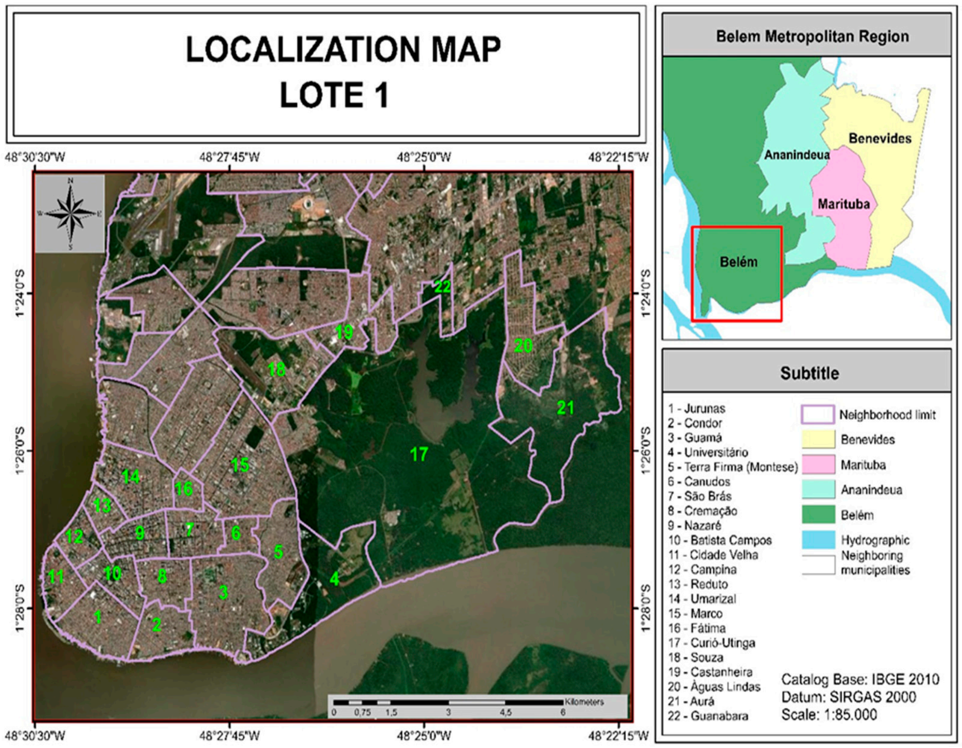

Figure 2. Neighborhoods served by the company Terraplena in the municipality of Belém/PA.

With the objective of carrying out the quantitative characterization of urban solid waste (MSW) in the twenty-one (21) neighborhoods in which the Company TERRAPLENA LTDA provides collection and transportation services, it was necessary to prepare and execute a work plan viable and appropriate. The plan included activities related to on-site knowledge of the waste flow of collection routes, definition of the volume to be collected, sampling of newly deposited waste, transportation of waste to the location where the gravimetric composition was determined that have already been described in Assunção et al. [27].

The neighborhoods were classified according to family income, which was established by adapting the methodology recommended by the IBGE (2010) [29]. According to this methodology, the Brazilian population is divided into five classes (A, B, C, D and E) according to family income, based on the minimum wage. It is noteworthy that, for the municipality of Belém, there are no neighborhoods that fit into class A and B, and that most of its neighborhoods, approximately 61%, are characterized as class E. It can be inferred that the absence of neighborhoods in classes A and B suggests a scenario where the population in Belém does not reach the highest income levels, directly impacting consumption patterns and, consequently, waste generation. With approximately 61% of neighborhoods classified as Class E, there is a significant characterization of areas with lower purchasing power.

By grouping the 21 neighborhoods into 9 sectors (Figure 3), it was possible to establish the formation of regions, which correspond to larger areas, which were considered as a unit for sampling solid waste for statistical analyses.

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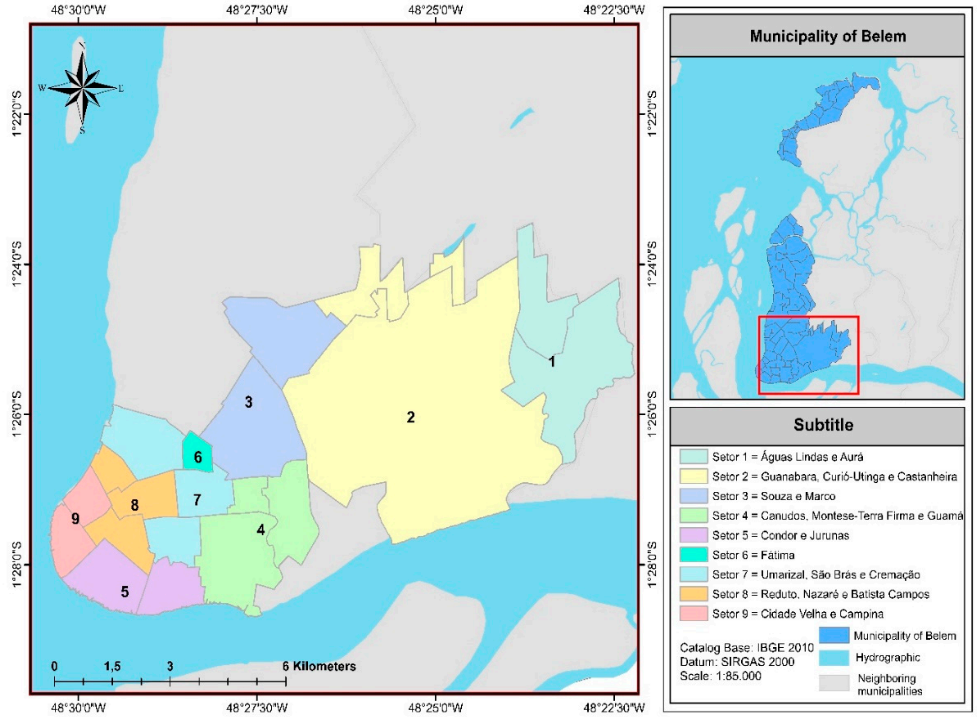

Figure 3. Map of sectorization of the neighborhoods of Belém/PA belonging to Lot 1.

Therefore, the composition of three regions was determined, as shown in Table 1. The grouping into sectors and regions aimed to facilitate the planning of collections, gravimetric composition and all packaging and transformation processes carried out on waste, considering the objectives of the research carried out.

Table 1. Determination of the grouping of sectors into regions.

Region	Class	Sectors	Neighborhoods
1	E	1, 2 e 3	Aurá, Águas Lindas, Curió-Utinga, Guanabara, Castanheira, Souza e Marco.
2	D	4, 5 e 6	Canudos, Terra Firme, Guamá, Condor, Jurunas e Fátima.
3	C	7, 8 e 9	Umarizal, São Brás, Cremação, Batista Campos, Nazaré, Reduto, Campina e Cidade Velha.

2.3. Gravimetric Analysis

The methodology used in the research for collecting and preparing the samples, as well as determining the gravimetric analysis, has already been previously described by Assunção et al. [27] and Pereira et al. [31]. In a summary, statistical sampling was initially carried out using the STATDISK 13.0 software sampling tool (Statsoft, 2021). The tool was applied to determine the amount of waste that must be collected for the sample to be statistically representative. Therefore, with a reliability index of 95%, significance of 5% and margin of error of 10%, a mass of waste of approximately 100 kg was obtained to compose the sample in each collection carried out, from a total of 15.000 kg. which can be collected in a 15m³ collection truck, when considering the specific weight of water at 1 atm and 25ºC. The gravimetric analysis was carried out considering the separation of solid waste into the following fractions: *Paper, Cardboard, Tetra Pak, Rigid Plastic, Malleable Plastic, Glass, Metal, Organic Matter, Fabrics, Sanitary Waste and Rejects/Others*. Before carrying out the gravimetric characterization, the total mass of waste was measured, to guide the gravimetric process, with the correct proportion of waste characterized by Assunção et al. [27] and Pereira et al. [31].

2.4. Statistical Tests

2.4.1. Descriptive and Analytical Statistics

Using the R Statistics software (R Core Team, 2023), descriptive analysis of the data was carried out to understand the population and apply statistical tests [32,33], a statistical analysis of the data obtained in the field was carried out, considering a significance level of 5% when carrying out the tests. To characterize the sampling distribution of the data set, measures of central tendency and dispersion were used. Measures of central tendency, or position measures, signal the middle of the data distribution (such as the mean, median and mode) or other important points of the distribution (such as quartiles). Dispersion measures, on the other hand, point out the variability of the data (such as variance and standard deviation) [32,33].

Initially, the test was selected to check whether the sample values are compatible with the population it represents, thus having a normal distribution [3]. In this test, the distribution of sample data for each variable under study was evaluated, and it was verified whether the data for each fraction of urban solid waste from the collected sectors are parametric (have normal distribution) or non-parametric (do not have normal distribution).

The test selected was the Shapiro-Wilk (W test), as it calculates samples: $2 < n < 50$. The test result is obtained by dividing the square of the appropriate linear combination of the sample's ordered values by the estimated symmetric variance [3]. The test was performed, along with a probability distribution analysis (Q-Q plot), in addition to descriptive statistics of the data set.

After verifying the normality of both fractions, the parametric simple classification analysis of variance test (One-way ANOVA) was carried out, as well as the verification of the following hypotheses:

I. H_0: the averages of the materials are the same.
II. H_1: the averages of the materials are different.

This test compared the averages of organic and inert waste fractions from different sectors, evaluating the presence of statistically significant differences between them, with a confidence level of 95%. To conduct these tests, a critical analysis was carried out in which a limit of two standard deviations was established to identify and remove outliers, which are frequently found in environmental data sets. To deepen the understanding of the discrepancies observed between two specific means, the Tukey multiple comparison method was used. This involved defining several significance levels (α) to evaluate the most significant contrasts.

3. Results

3.1. Analysis by Descriptive Statistics of Gravimetric Analysis

The composition of MSW is directly affected by a variety of factors: socioeconomic status, cultural conditions, eating habits, season, geographic location, etc. In Table 2, the results of the gravimetric analysis of MSW for the nine urban sectors of the municipality of Belém are illustrated, corresponding to the neighborhoods that were grouped according to socioeconomic classification and in Table 3, several statistical variables were calculated, such as mean, median, minimum, maximum, coefficient of variation and standard deviation of the collected masses, which have already been described by Pereira et al. [31].

Table 2. Results of the gravimetric characterization for the nine sectors in relation to the percentage of the collected mass of waste, collected in the municipalities of Belém, state of Pará, between 4 November 2021 to 13 May 2022 Pereira et al. [31].

Class of MHSW	Sectors								
	S1 (%)	S2 (%)	S3 (%)	S4 (%)	S5 (%)	S6 (%)	S7 (%)	S8 (%)	S9 (%)
Paper	1.24	2.30	6.38	6.13	5.01	1.67	4.70	6.45	11.95
Cardboard	2.26	3.11	1.87	2.63	4.82	2.66	5.39	3.17	2.90

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Tetra Pak	0.31	0.68	0.48	0.34	0.63	0.99	0.92	0.87	3.25
Hard plastic	3.72	3.29	3.98	2.25	4.10	3.25	4.53	3.37	3.70
Soft plastic	7.96	11.69	9.50	10.15	8.44	8.17	10.66	15.25	7.90
Metal	2.03	2.39	1.39	1.68	3.09	2.35	2.58	1.20	1.25
Organic matter	61.12	54.15	60.43	49.45	53.71	57.61	54.33	54.79	54.55
Glass	2.87	4.29	0.53	0.00	0.43	2.93	0.63	1.39	3.65
Sanitary waste	16.67	13.00	15.44	20.34	12.78	18.78	12.72	10.34	8.25
Fabrics	1.81	5.10	-	1.87	6.17	1.58	3.55	3.17	2.60
Rejects/Others	-	-	-	5.17	0.82	-	-	-	-
Total	100	100	100	100	100	100	100	100	100

Table 3. Mean, standard deviation, median, variance, maximum and minimum values of percentages of waste fractions collected in collection campaigns and gravimetric characterization results Pereira et al. [31].

Class of MHSW	Mean ± SD	Weighted Averade	Median	Variance	Maximum	Minimum
Paper	5.09 ± 3.28	5.35	5.01	10.76	11.95	1.24
Cardboard	3.20 ± 1.16	3.40	2.90	1.35	5.39	1.87
Tetra Pak	0.94 ± 0.90	0.64	0.68	0.81	3.25	0.31
Hard plastic	3.58 ± 0.65	3.43	3.70	0.42	4.53	2.25
Soft plastic	9.97 ± 2.38	10.17	9.50	5.68	15.25	7.90
Metal	2.00 ± 0.66	2.06	2.03	0.43	3.09	1.20
Organic matter	55.57 ± 3.62	53.94	54.55	13.09	61.12	49.45
Glass	1.86 ± 1.59	0.92	1.39	2.53	4.29	0.00
Sanitary waste	14.26 ± 3.91	15.38	13.00	15.29	20.34	8.25
Fabrics	3.23 ± 1.66	3.01	2.89	2.75	6.17	1.58
Rejects/Others	3.00 ± 3.08	1.69	3.00	9.46	5.17	0.82

Analyzing the results obtained in the characterization, it was found in Table 2 that the fractions that presented the highest percentage in all nine sectors, that is, the most representative, were the organic ones, composed of food and pruning remains, ranging from 61, 12% to 49.45% and sanitary waste consisting of (toilet paper, disposable diapers, surgical masks, etc.), varying between 20.34% and 8.25%. Following these fractions, with the highest percentage we have the recyclable fraction, such as paper ranging (11.95% to 1.24%), cardboard (5.89% to 1.87%), rigid plastic (4.53 % to 2.25%) and malleable plastic (11.69% to 7.90%).

In relation to the results in Table 3, a greater deviation can be seen in the values referring to the fractions of paper ± 3.28, malleable plastic ± 2.38, organic matter ± 3.62 and sanitary waste ± 3.91. Lower values were found for the fractions of rigid plastic ± 0.65, metal ± 0.66, tetra Pak ± 0.90 and cardboard ± 1.16. The heterogeneity of waste fractions across sectors makes statistical data very sensitive to changes and the presence of outliers.

In general, it is possible to verify the proximity between the mean and median values (no difference above 3 units), which represents a good distribution of data within their minimum and maximum values. It is possible to verify, however, a proximity between the average values and the values of each composition, given that, except for the "other" composition, the standard deviation value is always lower than the average value, which is an indicator of homogeneity of the collected samples.

It can be seen in Figure 4 that the fractions organic matter, sanitary waste, malleable plastic and paper are the materials that make up an average of 85% of urban solid waste in the sectors of the municipality of Belém/PA (S1-S9). While Figure 5 represents a more detailed analysis of the composition of solid waste by sector on an individual basis.

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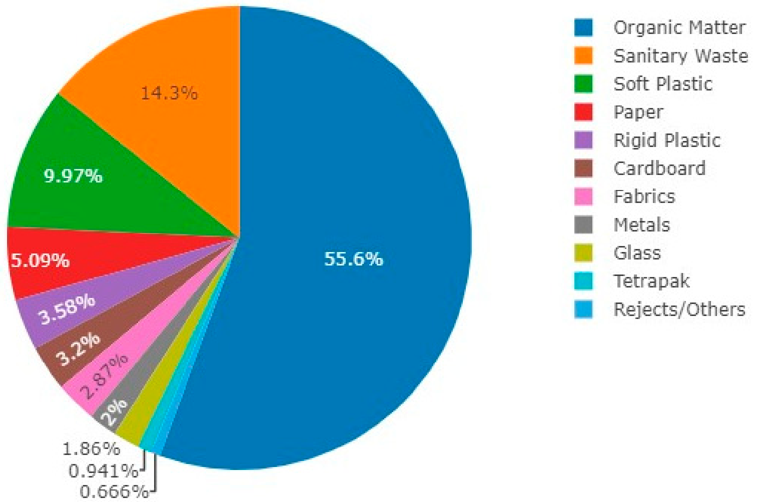

Figure 4. Distribution of urban solid waste by sectors in the municipality of Belém/PA.

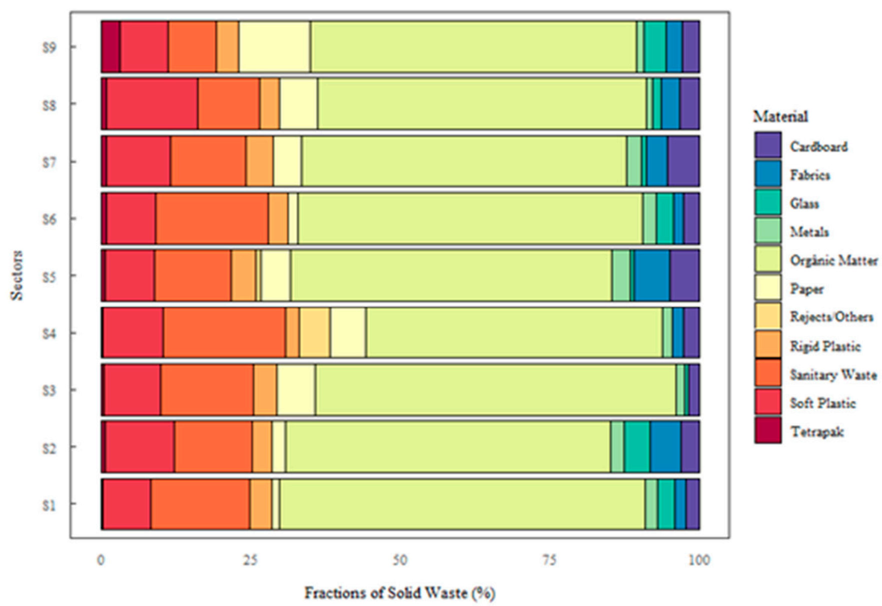

Figure 5. Detailed analysis of solid waste fractions in the municipality of Belém/PA.

Comparing the results found in tables 2 and 3, for the different MSW fractions, with data reported by the Basic Sanitation Plan of the municipalities of Belém [25,30,35,36] it can be observed that the variation in the mass percentages of the different fractions is in line with those found in this study. When comparing the average data on the organic fraction obtained in this study, with data from the Basic Sanitation Plan of the municipality of Belém [35], which are in the order of 51.34% and from the research by [25] who, during the period from 2018 to 2022, developed a study of the per capita generation and gravimetric composition of urban solid waste in the municipalities that make up the Metropolitan Region of Belém, in the state of Pará, the proximity between such values can be seen, which were 51.2% for the municipality of Belém, demonstrating that waste is still a common practice [30].

Several researchers like Suthar and [24,37,39] also reported similar results, that is, food/kitchen waste is the main constituent of household waste generated. For UNEP [40], food waste in Brazil has still proven to be a common practice, with a rate of around 12 tons/year wasted and disposed of in landfills and/or dumps. Oliveira et al., [41] and Campos [42] highlight that the aspect with the greatest influence on the per capita generation and composition of urban solid waste is the economic aspect,

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which is directly associated with the level of development of the region, since, developed countries have greater amounts of recyclables and developing countries have greater amounts of organic matter.

In developing countries, most urban and rural populations still cook their daily meals in domestic kitchens and, generally, food waste (kitchen waste; organic fraction) is the main component of MSW. According to Gupta et al. [43], the composition of solid waste in urban centers depends on a wide range of factors, such as housing, culture, lifestyle, climate and income, etc. According to a report published by [44], the bio-degradable fraction is the largest fraction of urban waste (38.6%), followed by inert materials (stones, bricks, ash, etc.: 34.7%), not biodegradable (leather, rubber, bones, and synthetic material (13.9%), plastic (6%), paper (5.6%) and glass (1.0%). The relative percentage of organic waste in MSW is generally linked to socioeconomic level; thus, low-income families generate more organic waste than high-income families.

It is important to highlight that the comparative analysis of the gravimetric composition between some works can be quite questionable due to the use of different methodologies, covering areas with peculiar social, economic, and cultural characteristics or even due to the great variability in the classification adopted.

Making comparisons with the bibliography researched, by adding up the averages of materials destined for recycling and/or reverse logistics such as paper, cardboard, tetra Pak, metals, aluminum, fabrics and glass in the order of 29.87%, an approximation to the reference values of Menezes et al., [30] was found, who in their studies statistically analyzed the gravimetric composition of domestic solid waste in Juiz de Fora, Minas Gerais, depending on the seven urban regions of the municipality and household income of the population and found values of 31.74% for recyclables. In relation to the fraction of contaminants such as inert materials (sanitary waste) and rejects, the sum of the averages of these values are 17.26% for this research and are in line with the values found by Belém [35], Da Silva et al., [25] and Menezes et al., [30] which were 13.39%, 12.5% and 14.36%, respectively.

According to ACIESP [45], a contaminant is any substance added to the environment that causes a deviation in its average geochemical composition, becoming a pollutant from the moment it causes an adverse effect on the environment. Still, more broadly, Resolution No. 420/09 of the National Environmental Council (CONAMA) [46] defines contaminants as substances introduced into the environment through human activities, whose concentrations restrict the use of the natural resource for current uses or predicted.

3.2. Analysis by Analytical Statistics (ANOVA and TUKEY Test)

Table 4 presents the result of the ANOVA applied to the percentage data of the types of materials in the gravimetric composition in relation to the total mass of the sample from the different socioeconomic groups (Regions 1, 2 and 3).

Table 4. ANOVA of gravimetric composition data from Regions 1, 2 and 3.

		GL	**SQ (Aj.)**	**QM (Aj.)**	**F-Value**	**P-Value**	**F-Critical**
R1	Factor	10	8663.8	866.28	236.92	0.000	2.297
(E)	Error	22	80.4	3.66			
	Total	32	8744.2				
		GL	**SQ (Aj.)**	**QM (Aj.)**	**F-Value**	**P-Value**	**F-Critical**
R2	Factor	10	7209.2	720.92	134.42	0.000	2.297
(D)	Error	22	118.0	5.36			
	Total	32	7327.2				
		GL	**SQ (Aj.)**	**QM (Aj.)**	**F-Value**	**P-Value**	**F-Critical**
R3	Factor	10	7232.7	723.27	196.28	0.000	2.297
(C)	Error	22	81.1	3.68			
	Total	32	7313.8				

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In the Table 4, GL represents the degree of freedom and QM means the mean square. In both regions, the calculated F value was greater than the critical F, rejecting the null hypothesis that the percentage averages of the materials are equal at a significance level of 5%. The analysis of variance indicated that at least one of the materials has a different mean than the others. As a 95% confidence level was used in the analysis, the fact that the P-Value is less than 0.05 demonstrates that the type of material is significant, that is, influence on the percentage values of these materials in relation to the total mass of the samples.

Furthermore, the value of the coefficient of determination (R^2) was 99.08%, 98.39% and 98.89% for regions 1,2 and 3 respectively, indicating that the percentage values in relation to the total mass of the sample are strongly explained by the variable "type of material". The results of the statistical test demonstrate that the sample collected represents a normal distribution (p-value > 0,05) in all cases in which the test was performed. The ANOVA analysis of variance showed no significant difference between the means of the fractions at 5% significance. Figures 6,7 and 8 illustrate the histogram graphs and the quantile for the three regions.

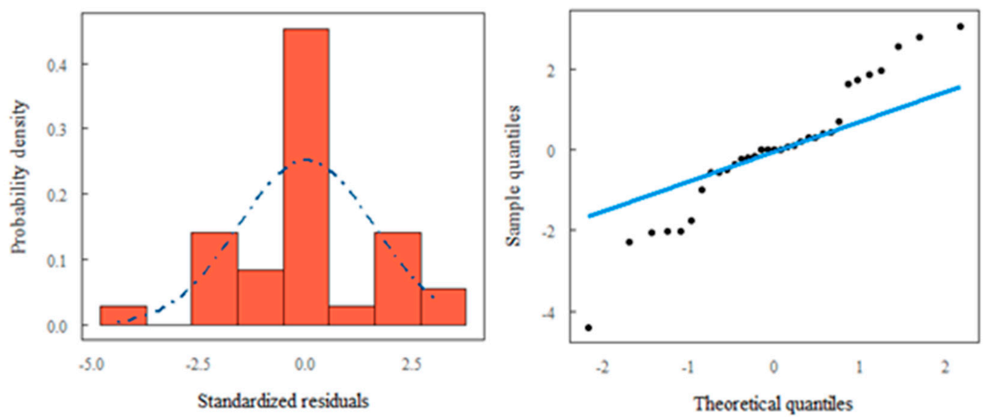

Figure 6. Shapiro-Wilk and quantile-quantile (Q-Q) test for Region 1.

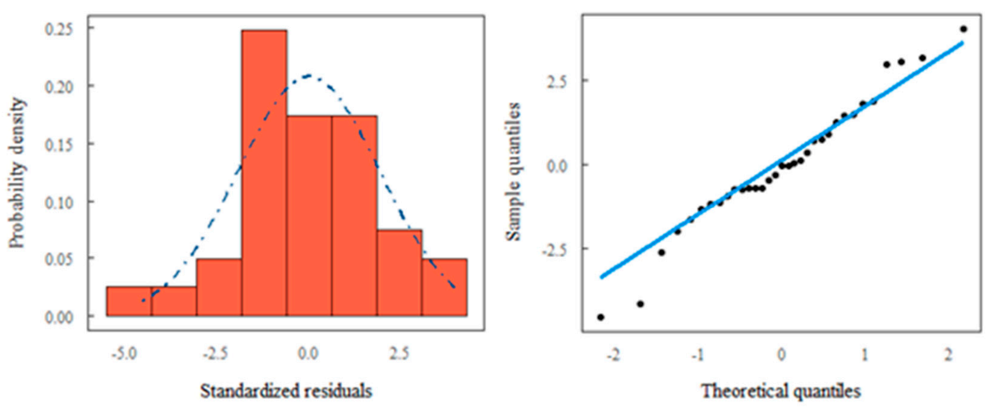

Figure 7. Shapiro-Wilk and quantile-quantile (Q-Q) test for Region 2.

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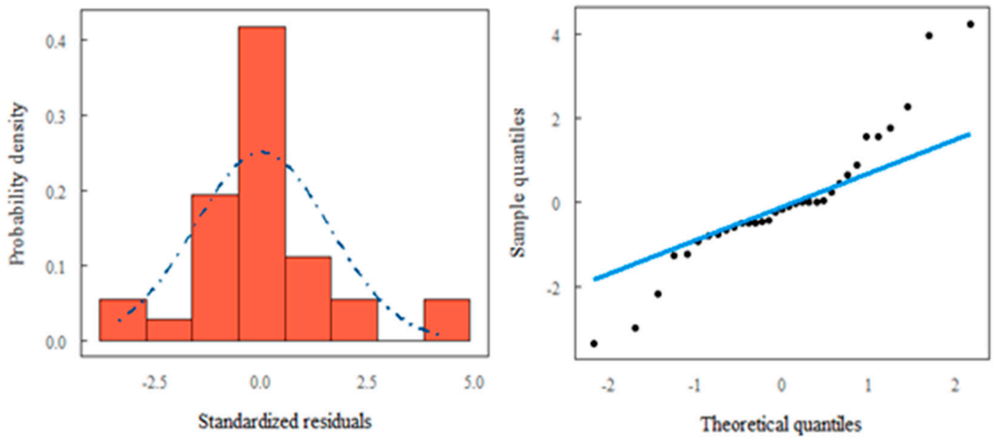

Figure 8. Shapiro-Wilk and quantile-quantile (Q-Q) test for Region 3.

It can be observed in both graphs that the residuals behave relatively like a normal bell-shaped curve and in the quantile graphs the residual values fall along an approximately straight line, which contributes to the statement that the residuals are normally distributed.

Some studies used GenStat as a computational tool to apply the ANOVA technique, aiming to find statistically significant relationships between waste produced by households in Wales and variables such as location, season, etc. [47]. This study found a maximum value for recyclable and compostable fractions of 65% and contained 62% biodegradable material. In Mexico, Gómez et al., [48] found fractions for organic waste of approximately 45% of all MSW generated and used the ANOVA technique to validate that there was no significant difference between the three socioeconomic levels. In the studies by Menezes et al., [30] who carried out the gravimetric composition for seven regions that were classified according to socioeconomic stratification, the analysis of variance also did not indicate a significant difference between the means of the fractions at 5% significance.

Luizari [49] used the statistical test (ANOVA) to assess whether there was a significant difference between the density values of the household solid waste (MSW) categories in the four condominiums investigated and it can be concluded that there was no significant difference of the MSW density of the condominiums surveyed, statistically it can be concluded that there was no variation between the waste generated by the residents of the condominiums, based on the twelve samples analyzed.

To identify these differences in means between materials, the Tukey test was applied for multiple comparisons for each region. In Figure 9, for region 1, the test identified 3 different groupings, one group formed only by organic matter (a) which had the highest average percentage value (58.57%), another group formed by inert materials (15.04 %) and soft plastic (b) (9.72%). While Group C is made up of materials with the lowest percentage representation in relation to the total mass of samples (hard plastics, fabric, glass, metal, paper, cardboard, and tetra Pak and others), which ranged from 0.49% to 3.66%. Figures 9,10 and 11 illustrate the variation in percentage values of different materials within a 95% confidence interval.

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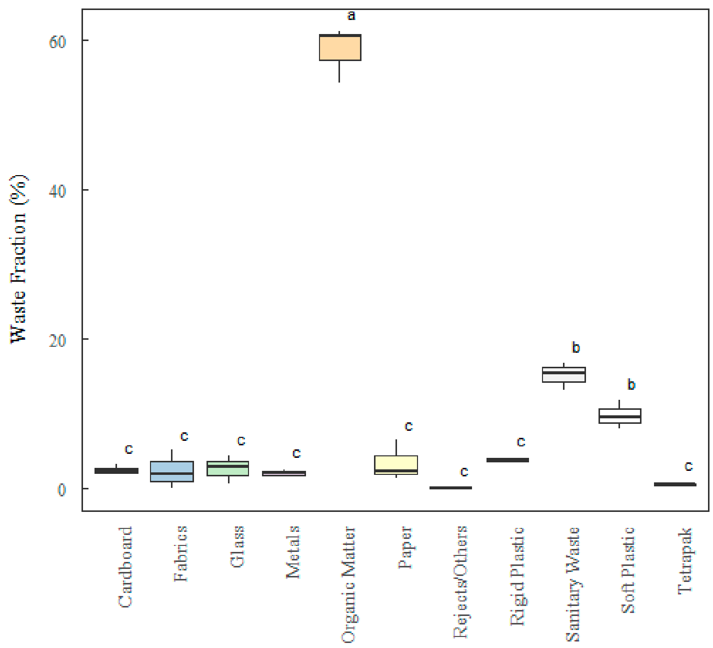

Figure 9. Variation in percentage values of materials in relation to the sample mass for Region 1.

In Figures 10 and 11, regions 2 and 3 formed 5 clusters, noting that organic matter showed less variability in Region 3.

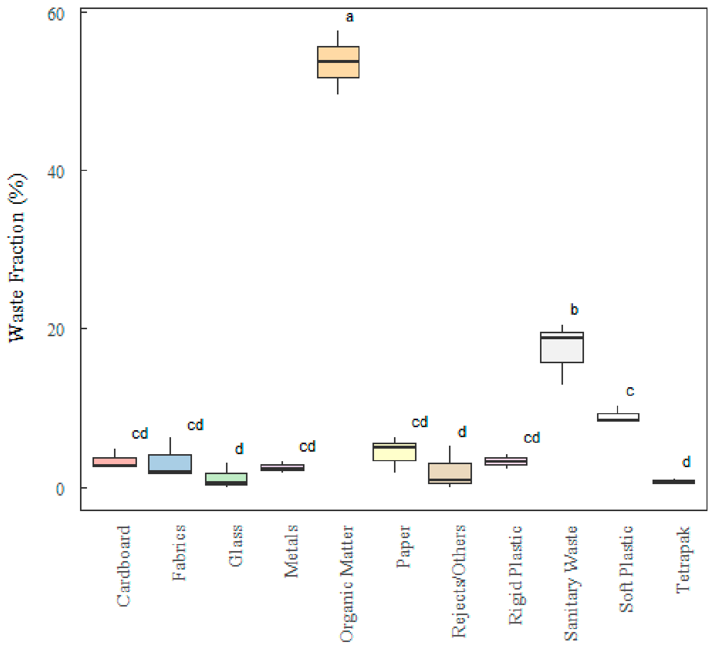

Figure 10. Variation in percentage values of materials in relation to the sample mass for Region 2.

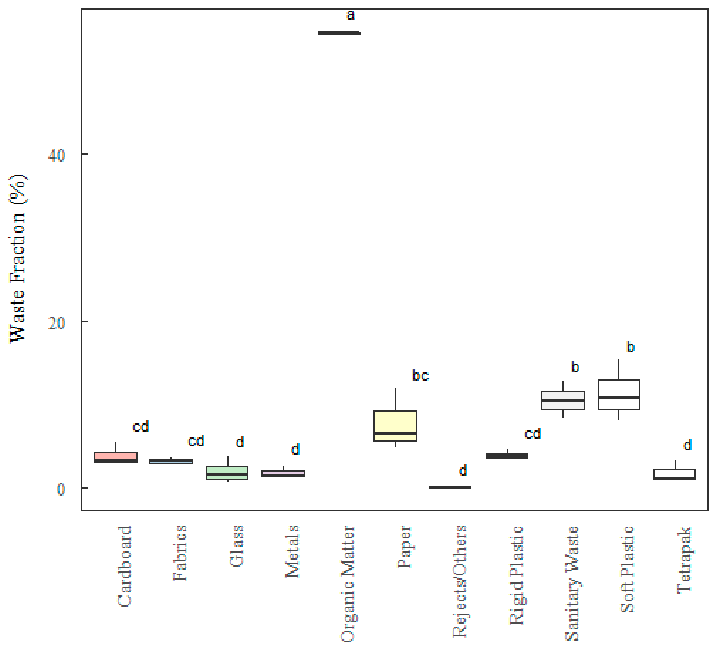

Figure 11. Variation in percentage values of materials in relation to the sample mass for Region 3.

The test identified 5 different groupings (Figure 10), one group formed only by organic matter (a) which had the highest average percentage value (58.6%), another group formed by inert materials (b) (17.3%), group (c) formed by malleable plastic (8.92%), and (cd) which varied from 2.37% to 4.27%. While group (d) is composed of materials with the lowest percentage representation in relation to the total mass of samples (waste, glass, and tetra Pak), which ranged from 0.65% to 2.00%.

The same occurred for the values found in Figure 11, in which the test also identified 5 different groupings, one group being formed only by organic matter (a) which had the highest average percentage value (54.6%), another grouping made of malleable plastic and inert materials (b) (11.3%) and (10.4%), respectively. Another group formed was (bc) composed solely of paper (7.7%), while (cd) formed by hard plastic, cardboard and fabrics ranged from 3.11% to 3.87%. Finally, group (d) comprised the materials with the lowest percentage representation in relation to the total mass of the samples (metal, waste, glass and tetra Pak), which ranged from 1.68% to 1.89%.

3.3. Analysis Based on Household Income

Due to the economic diversity between neighborhoods in the same region, it was decided to carry out an analysis based exclusively on this factor, considering the organic matter fraction, which stood out significantly among the fractions of urban solid waste collected. In Figure 12, the result of household income in the neighborhoods of the city of Belém/PA is graphically represented compared with the average nominal income* from data from (IBGE, 2010) [29] and the fractions of organics collected from regions 1, 2 and 3, classes E, D and C, respectively. In general, higher incomes may be associated with greater waste generation. However, sectors with higher incomes had lower organic fraction generation and smaller population. It was observed that in region 1, income was less than R$1000, however, the fraction of organic matter did not grow with the increase in population. While in region 2, where income was less than R$1500, the fraction of organic matter varied between 10% and 50%. In region 3, income varied between R$1000 and R$3000, with a smaller number of inhabitants and smaller fractions of organic material, showing a slight tendency to reduce the fraction of organic matter with increasing income and population.

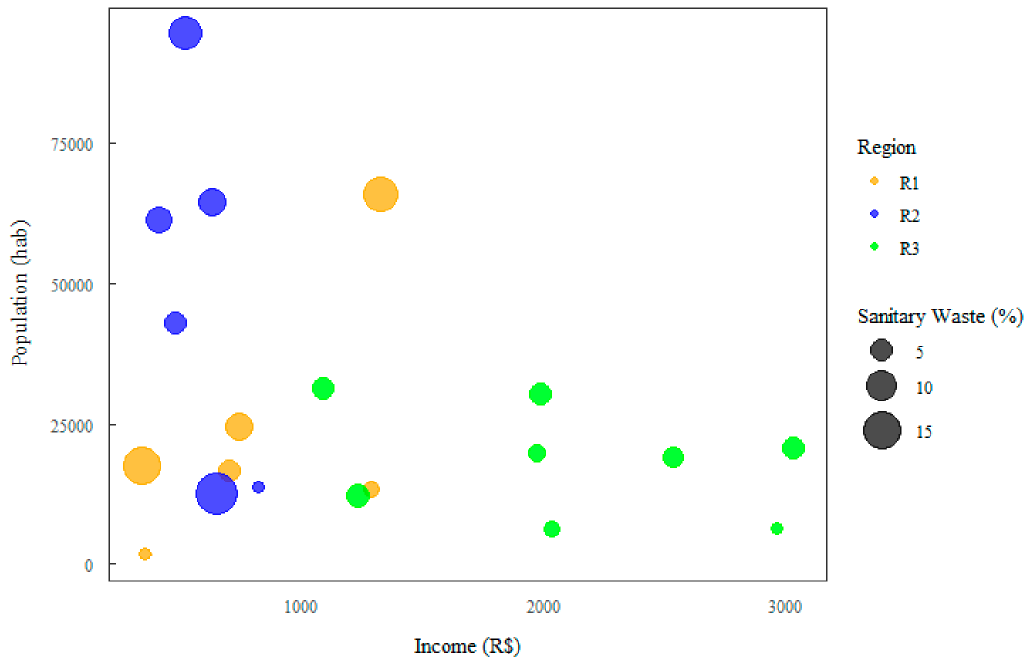

Figure 12. Generation of organic matter from income and number of inhabitants.

The finding that the higher the income, the lower the organic fraction suggests that there is an association between people's purchasing power and waste disposal patterns. People with higher incomes may have different consumption behaviors, such as purchasing processed foods, which may generate less organic waste. This result may also be because families with greater purchasing power normally do not eat their meals at home. Families with lower purchasing power typically have their meals cooked at home, justifying the high percentages of organics found in their waste [50].

This relationship can guide waste management strategies that consider the socioeconomic characteristics of the population. For example, in higher income areas, emphasis may be placed on selective collection of recyclable materials. The consistency of these results with previous studies, such as Costa [51], provides additional validation of the observed relationship. This strengthens confidence in the identified patterns.

Based on the results, environmental awareness campaigns can be targeted at higher income classes to promote sustainable waste management practices. It is important to consider that the relationships between income and waste composition may vary regionally and culturally. Therefore, personalized approaches may be necessary. Longitudinal studies over time can provide a more dynamic understanding of changes in disposal patterns in response to socioeconomic factors. By integrating these observations into future waste management research and practices, it is possible to develop more accurate and effective strategies for dealing with variations in waste composition across different social strata. This contributes to the promotion of more sustainable practices that are aligned with the specific characteristics of the community in question.

The evaluation of the results of the characterization of urban solid waste revealed that the main average fractions of waste were organic and sanitary waste, representing, respectively, 55.6% and 14.4% of the total waste analyzed. Region 1 had the highest percentage of organic (58.6%) and inert (15%) (Figure 13). The comparison of the means of the main fractions between the materials, through statistical analyses, revealed significant differences for each region. Based on statistical analysis of the data, it is possible to infer that region with greater purchasing power and fewer inhabitants tend to generate fewer organic materials. On the other hand, in areas with low-income families and more inhabitants, a greater presence of organic matter is observed. The high percentages of organic and

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inert waste indicate the potential for waste generation in the city, highlighting the disparity in the composition of waste in different areas, implying that waste management strategies must be adapted to the specific characteristics of each region. These inferences are valuable for guiding public policies, waste management practices and awareness initiatives in the city. Understanding the relationships between socioeconomic and demographic characteristics and the composition of waste is fundamental to the development of sustainable and effective strategies.

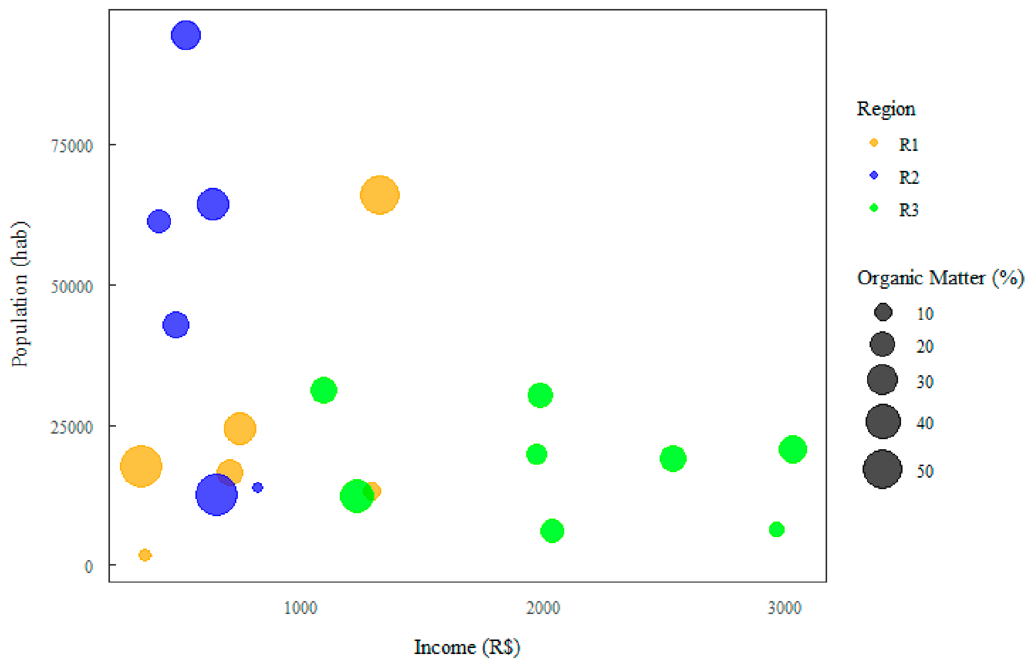

Figure 13. Generation of sanitary waste based on income and number of inhabitants.

4. Conclusions

The analysis of the results of the characterization of urban solid waste from the urban area of Belém served by TERRAPLENA LTDA belonging to Lot 1, allowed us to verify that the majority fractions of waste in the city of Belém/PA were organic and inert, representing maximum values of 61.12% and 49.45% and minimums of 20.34% and 8.25%, respectively, of the sectors collected.

On average, 5.46% ± 1.86% of MSW generated in the sectors of the urban area of Belém served by TERRAPLENA LTDA consists of material with the potential to be recycled and/or enter a reverse logistics route. While 14.26% ± 3.91% refer to inert materials (waste and/or low economic potential for recycling).

Based on the statistical analysis of the data, it can be concluded that the class C (R3) region with greater purchasing power and instructional level indicates a greater tendency in the generation of recyclable materials. On the other hand, in regions where families have low household income and educational level classes D (Region 2) and E (Region 1), there is a higher incidence of organic matter in MSW.

No significant differences were found in the means of the majority fractions between the regions analyzed. This suggests that, statistically, the waste compositions in different regions of the municipality are similar, allowing the presentation of unique trend values for the entire municipality. No significant differences were also identified between the averages of these fractions in the analysis between social classes C, D and E, indicating that, at least at a statistical level, the waste compositions in these social classes are comparable. In summary, the results of the statistical analyzes suggest homogeneity in waste compositions between different regions and social classes in the municipality. However, the focus on the high presence of organic, inert and recyclable materials highlights the urgency of efficient management to deal with these specific fractions, aiming at environmental sustainability and reducing the impact of waste in the municipality.

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References

1. Associação Brasileira de Empresas de Limpeza Pública E Resíduos Especiais—ABRELPE. *Panorama 2022*; ABRELPE: São Paulo, Brazil, 2023.
2. Brasil Ministério do Desenvolvimento Regional. *Diagnóstico Temático do Manejo de Resíduos Sólidos Urbanos*; SNIS: São Paulo, Brazil, 2022.
3. AYRES, M. Elementos de Bioestatística 2.ed. Belém: Supercores. 2012.
4. Mutz, D., Hengevoss, D., Hugi, C.M. and Gross, T. (2017) Waste-to-Energy Options in Municipal Solid Waste Management. A Guide for Decision Makers in Developing and Emerging Countries. Eschborn.
5. Legado da COP-30 para Belém vai transformar a vida da população e beneficiar a cidade. Agência Belém, 2023. Disponível em: Agência Belém (agenciabelem.com.br). Acesso em: 24, novembro de 2023.
6. BRASIL. Sistema Nacional de Informação sobre Saneamento. Diagnóstico dos Serviços de Água e Esgoto - 201 Brasília: SNIS, 2021.
7. Chang, Y.F., Lin, C.J., Chyan, J.M., Chen, I.M., Chang, J.E., 2007. Multiple regression models for the lower heating value of municipal solid waste in Taiwan. J. Environ. Manage. 85 (4), 891–899;
8. Lin, C.J., Chyan, J.M., Chen, I.M., Wang, Y.T., 2013. Swift model for a lower heating value prediction based on wet-based physical components of municipal solid waste. Waste Manage. 33 (2), 268–276.
9. Ryu, C., Shin, D., 2013. Combined heat and power from municipal solid waste: status and issues in South Korea. Energies 6 (1), 45–57
10. Zhou C, Gong Z, Hu J, Cao A, Liang H. A cost-benefit analysis of landfill mining and material recycling in China. Waste Management. 2015;35:191–198. doi: 10.1016/j.wasman.2014.09.029;
11. Rajendran, N., Gurunathan, B., Han, J., Krishna, S., Ananth, A., Venugopal, K., Sherly Priyanka, R.B. Recent advances in valorization of organic municipal waste into energy using biorefinery approach, environment and economic analysis. *Bioresource Technology*.**2021**, *337*, 125498, 0960-8524. https://doi.org/10.1016/j.biortech.2021.125498.
12. Scarlat, N., Motola, V., Dallemand, J.F., Monforti-Ferrario, F., Linus Mofor. Evaluation of energy potential of Municipal Solid Waste from African urban areas. *Renewable and Sustainable Energy Reviews*.**2015**, *50*, 1269-1286, 1364-0321, https://doi.org/10.1016/j.rser.2015.05.067.
13. Kaza, S. et al. (2018). What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050. Washington DC: The World Bank.
14. Wang, N., Chen, D., Arena, U., He, P. Hot char-catalytic reforming of volatiles from MSW pyrolysis. Appl. *Energy*, (2017), 191, 111-124, 10.1016/j.apenergy.2017.01.05
15. BRASIL, 2010. Lei Federal N° 12.305, de 2 de agosto de 2010. Institui a Política Nacional de Resíduos Sólidos que altera a Lei n° 9605, de 12 de fevereiro de 1998; e outros arranjos, Brasil.

 doi:10.20944/preprints202401.1155.v2

16. GOUVEIA, N. (2012) Resíduos sólidos urbanos: impactos socioambientais e perspectiva de manejo sustentável com inclusão social. Ciência e Saúde Coletiva, v. 17, n. 6, p. 1503-1510. http://dx.doi.org/10.1590/S1413-81232012000600014.
17. PURCELL, M.; MAGETTE, W.L. (2009) Prediction of household and commercial BMW generation according to socioeconomic and other factors for the Dublin region. Waste Management, v. 29, n. 4, p. 1237-1250. https://doi.org/10.1016/j. wasman.2008.10.01.
18. Dahlén, H.; Pereira, A.; Lagerkvist, P.E.O. Berg. Inconsistent household waste trajectories. Waste Management., 29 (2009), pp. 1798-1806.
19. STREB, C.S.; NAGLE, E.C.; TEIXEIRA, E.N. (2004) Caracterização do resíduo sólido doméstico: metodologia para avaliação do potencial de minimização. In: CONGRESSO INTERAMERICANO DE ENGENHARIA SANITÁRIA E AMBIENTAL, 29., 2004, San Juan. Anais... San Juan: AIDIS.
20. VEGA, C.A.; BENÍTEZ, S.O.; BARRETO, M.E.R. (2008) Solid waste characterization and recycling potential for a university campus. Waste Management, v. 28, supl. 1, p. S21-S26. https://doi.org/10.1016/j. wasman.2008.03.022
21. CARNEIRO, Paulo Fernando Norat. Caracterização e avaliação da potencialidade econômica da coleta seletiva e reciclagem dos resíduos sólidos domiciliares gerados nos municípios de Belém e Ananindeua - PA. 2006. Dissertação (Mestrado em Engenharia Civil) – Programa de Pós-Graduação em Engenharia Civil (PPGEC), Instituto de Tecnologia (ITEC), Centro Tecnológico, Universidade Federal do Pará, Belém, 2006. Disponível em: http://www.repositorio.ufpa.br:8080/jspui/handle/2011/1899;
22. Drudi, K. C.R., Drudi, R., Martins, G., Colato, G., Tofano,A. J., Leite, C. Statistical model for heating value of municipal solid waste in Brazil based on gravimetric composition. *Waste Management*, **2019**, *87*, 782-790, 0956-053X, https://doi.org/10.1016/j.wasman.2019.03.012.
23. Nizami, A.S., Shahzad, K., Rehan, M., Ouda, O.K.M., Khan, M.Z., Ismail, I.M.I., Almeebi, T., Basahi, J.M., Demirbas, A. Developing waste biorefinery in Makkah: a way forward to convert urban waste into renewable energy. App. *Energy*, 186 (2017), pp. 189-196.
24. SINGH, J.; LAURENTI, R.; SINHA, R.; FROSTELL, B. Progress and challenges to the global waste management system. Waste Management & Research,v. 32, n. 9, p. 800-812, 2014. https://doi.org/10.1177/0734242X14537868.
25. DA SILVA, Rodrigo Cândido Passos da; COSTA, Amanda Rodrigues Santos; ELDEIR, Soraya Giovanetti; JUCÁ, José Fernando Thomé. Setorização de rotas de coleta de resíduos sólidos domiciliares por técnicas multivariadas: estudo de caso da cidade do Recife, Brasil. Engenharia Sanitária e Ambiental, v. 25, n. 6, p. 821-832, 2020. DOI: https://doi.org/10.1590/s1413- 41522020200205.
26. MENDONÇA, Neyson Martins; RUSSO, Mário Augusto Tavares; PENNER, Giovanni Chaves; ALMEIDA, Hélio da Silva; ASSUNÇÃO, Maurilo André da Cunha; BRANDAO, Isaque Wilkson de Sousa; SILVA, Rafael Haruo Yoshida; PEREIRA, Filipe Castro; SANTOS, Filippe Vilhena dos; MACHADO, Paulo Christian de Freitas Machado; MARTINS, Rubens Takeji Aoki Araujo; GONCALVES, Moisés Marçal. Relatório Final do Estudo "Monitoramento das atividades decorrentes do plano emergencial na área da CPTR de Marituba (PA) para ações do tratamento do lixiviado e de emissão de gases". Belém (PA): Fundação de Amparo e Desenvolvimento da Pesquisa (FADESP), 2021.
27. Assunção, F.P.d.C.; Pereira, D.O.; Silva, J.C.C.d.; Ferreira, J.F.H.; Bezerra, K.C.A.; Bernar, L.P.; Ferreira, C.C.; Costa, A.F.d.F.; Pereira, L.M.; Paz, S.P.A.d.; et al. A Systematic Approach to Thermochemical Treatment of Municipal Household Solid Waste into Valuable Products: Analysis of Routes, Gravimetric Analysis, Pre-Treatment of Solid Mixtures, Thermochemical Processes, and Characterization of Bio-Oils and Bio-Adsorbents. *Energies* **2022**, *15*, 7971. https://doi.org/10.3390/en15217971
28. Fesseha, S.N.; Bin, F. The Assessment of Solid Waste Products Management in Ethiopians Municipal Urban Areas. *Int. J. Soc. Sci. Manag.* **2015**, *2*, 165–179.
29. IBGE. Instituto Brasileiro de Geografia e Estatística. Censo Brasileiro de 2010; IBGE: Rio de Janeiro, Brazil, 2012. Available online: https://censo2010.ibge.gov.br/ (accessed on 1 August 2022).
30. Menezes, R.O.; Castro, S.R.; Silva, J.B.G.; Teixeira, G.P.; Silva, M.A.M. Análise estatística da caracterização gravimétrica de resíduos sólidos domiciliares: Estudo de caso do município de Juiz de Fora, Minas Gerais. *Eng. Sanitária Ambient* **2019**, *24*, 271–282.
31. Pereira, D.O.; da Costa Assunção, F.P.; da Silva, J.C.C.; Ferreira, J.F.H.; Ferreira, R.B.P.; Lola, Á.L.; do Nascimento, Í.C.P.; Chaves, J.P.; do Nascimento, M.S.C.; da Silva Gouvêa, T.; et al. Prediction of Leachate Characteristics via an Analysis of the Solubilized Extract of the Organic Fraction of Domestic Solid Waste from the Municipality of Belém, PA. *Sustainability*. **2023**, *15*, 15456. https://doi.org/10.3390/ su152115456.
32. Hair, J.F.; Black, W.C.; Babin, B.J.; Anderson, R.E. & Tatham, R.L. (2009). Análise multivariada de dados. Porto Alegre, RS: ArtMed.
33. FIELD, A. P. (2009). Descobrindo a estatística usando o SPSS. Porto Alegre, Brasil, Artmed, 2a edição.
34. Issam A. Al-Khatib, Maria Monou, Abdul Salam F. Abu Zahra, Hafez Q. Shaheen, Despo Kassinos, Solid waste characterization, quantification and management practices in developing countries. A case study:

 doi:10.20944/preprints202401.1155.v2

Nablus district – Palestine, Journal of Environmental Management, Volume 91, Issue 5, 2010, Pages 1131-1138, ISSN 0301-4797, https://doi.org/10.1016/j.jenvman.2010.01.003.
35. BELÉM. Lei Municipal nº 9.656, de 30 de dezembro de 2020. Institui a Política Municipal de Saneamento Básico do Município de Belém, o Plano Municipal de Saneamento Básico (PMSB), e o Plano de Gestão Integrada de Resíduos Sólidos (PGIRS), em atenção ao disposto no Art. 9º da Lei Federal nº 11.445/2007, com as atualizações trazidas pela Lei nº 14.026/2020, o Novo Marco do Saneamento Básico, e dá outras providências. Belém, PA, 30 dez. 2020.
36. Al-Khatib, I. A., Monou, M., Abu Zahra, A. S. F., Shaheen, H. Q., & Kassinos, D. (2010). Solid waste characterization, quantification and management practices in developing countries. A case study: Nablus district e Palestine. Journal of Environmental Management, 91, 1131–1138.
37. Monavari SM, Omrani GA, Karbassi A, et al. (2012) The effects of socioeconomic parameters on household solid-waste generation and composition in developing countries (a case study: Ahvaz, Iran). *Environmental Monitoring and Assessment* 184: 1841–1846.
38. Suthar, S., & Singh, P. (2015). Household Solid Waste Generation and Composition in Different Family Size and Socio-Economic Groups: A Case Study. Sustainable Cities and Society, 14, 56-63. https://doi.org/10.1016/j.scs.2014.07.004.
39. OJEDA-BENÍTEZ, S.; VEGA, C. A. DE; MARQUEZ-MONTENEGRO, M. Y. Household solid waste characterization by family socioeconomic profile as unit of analysis. Resources, Conservation and Recycling, v. 52, n. 7, p. 992–999, 2008. http://dx.doi.org/10.1016/j.resconrec.2008.03.004;
40. PNUMA – Programa das Nações Unidas para o Ambiente. Índice de desperdício alimentar: relatório 2021. 100p. Disponível em: < https://www.unep.org/ptbr/resources/relatorios/indice-de-desperdicio-de-alimentos-2021>. Acesso em: 01 agosto 2023.
41. OLIVEIRA, S.A.; LEITE. V.D.; PRASAD, S.; RIBEIRO, M.D. (2004) Estudo da produção per capita de resíduos sólidos domiciliares da cidade de Campina Grande-PB. Revista Saúde e Ambiente, v. 5, n. 2, p. 37-44.
42. Campos, H.K.T. Evolution of income and per capita generation of solid wastes in Brazil. Eng Sanit Ambient | v.17 n.2 | abr/jun 2012 | 171-180 https://doi.org/10.1590/S1413-41522012000200006
43. Shuchi Gupta, Krishna Mohan, Rajkumar Prasad, Sujata Gupta, Arun Kansal, Solid waste management in India: options and opportunities, Resources, Conservation and Recycling, Volume 24, Issue 2, 1998, Pages 137-154, ISSN 0921-3449, https://doi.org/10.1016/S0921-3449(98)00033-0.
44. TERI, 2002. Impact of population on water and the quality of life. [Project report no. 1999d42]. Submitted to United Nations Population Fund, The Energy and Resource Institute, TERI,New Delhi.
45. ACIESP. 1987. Glossário de Ecologia. Publicação ACIESP nº57. ACIESP – Academia de Ciências do Estado de São Paulo.
46. BRASIL. Conselho Nacional do Meio Ambiente (CONAMA). (2009). *Resolução nº 420* Brasil: Conselho Nacional do Meio Ambiente, 2009.
47. S.J. Burnley, J.C. Ellis, R. Flowerdew, A.J. Poll, H. Prosser Assessing the composition of municipal solid waste in Wales Resources, Conservation and Recycling, 49 (3) (2007), pp. 264-283.
48. Gomez, G., Menesesa, M., Ballinas, L., Castells, F., 2008. Characterization of urban solid waste in Chihuahua, Mexico. Waste Manage. 28 (12), 2465–2471. http:// dx.doi.org/10.1016/j.wasman.2007.10.023.
49. LUIZARI, J. D. 2019. ANÁLISE DA GERAÇÃO E COMPOSIÇÃO DOS RESÍDUOS SÓLIDOS DOMICILIARES: ESTUDO DE CASO NO PLANO PILOTO - DF. Monografia de Projeto Final, Departamento de Engenharia Civil e Ambiental, Universidade de Brasília, Brasília, DF, 100 p.
50. TRANG, P.T.T.; DONG, H.Q.; TOAN, D.Q.; HANH, N.T.X.; THU, N.T. (2017) The Effects of Socio-economic Factors on Household Solid Waste Generation and Composition: A Case Study in Thu Dau Mot, Vietnam. Energy Procedia, v. 107, p. 253-258. https://doi.org/10.1016/j.egypro.2016.12.144
51. COSTA, L.E.B.; COSTA, S.K.; REGO, N.A.C.; SILVA JÚNIOR, M.F. (2012).Gravimétrica dos resíduos sólidos urbanos domiciliares e perfil socioeconômico no município de Salinas, Minas Gerais. Revista Ibero-Americana de Ciências Ambientais, v. 3, n. 2, p. 73-90. https://doi.org/10.6008/ESS2179-6858.2012.002.0005;
52. YANG, Wu et al. An overview of inorganic particulate matter emission from coal/biomass/MSW combustion: Sampling and measurement, formation, distribution, inorganic composition and influencing factors. Fuel Processing Technology, v. 213, p. 106657, 2021.