Complete gravimetry of urban solid waste in the city of Manaus – AM

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ABSTRACT

82 million tons of municipal solid waste (MSW) are generated per year in Brazil, which are destined for landfills and dumps. In the city of Manaus alone, one million tons of garbage are generated per year, which results in many public health problems, soil and river pollution, emission of gases into the air, etc. Factors such as progressive population increase combined with consumption and waste behavior, lack of awareness, low percentage of other possible treatments, such as recycling and composting have contributed to this. This work aims to describe the activities developed to characterize urban solid waste destined to the landfill of the city of Manaus-AM through gravimetric analysis, composed of three steps, required by NBR 10.007/2004: quartering, identification and weighing of waste categories. It was also possible to determine the apparent specific weight of these residuals. The studies were carried out in eighteen neighborhoods, between the years 2022 and 2023. With these data, it was found a large amount of material with the capacity to be recycled (60% + 2% on dry days and 50.0% + 1.6% on rainy days) and an average apparent specific weight of 74 Kg/m³. Thus, it is concluded that selective collection and sorting are of paramount importance, as alternatives for the reduction of waste destined to the city's landfill, enabling its useful life and the reuse of recyclable materials, bringing economic, social and environmental benefits to the city and its inhabitants.

Keywords: Urban solid waste, Gravimetrics, Physical characterization of waste, NBR 10.007/2004, Recycling.

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INTRODUCTION

Federal Law No. 12,305/10, which instituted the National Solid Waste Policy (PNRS), gave a period of 10 years for the problems arising from MSW to be extinguished. After the deadline, approximately 60% of the country's cities had not yet reached this goal. Dumps and controlled landfills currently occupy large areas in large urban centers, contaminating soils and groundwater, attracting animals and insects, increasing the risks to the health of the population and increasing the emission of greenhouse gases. A considerable portion of this MSW ends up in the beds of rivers and streams, obstructing rainwater systems and causing flooding.

Between 2012 and 2022, MSW generation in Brazil increased by 11%, from 62.7 million tons to 81.8 million tons. In turn, per capita generation increased from 348 kg/year to 380 kg per year, on average, which is equivalent to 1.04 kilograms of urban waste per day for each inhabitant (ABRELPE/IBGE, 2022).

In the city of Manaus, capital of the state of Amazonas, the largest state in Brazil, with its ecological and environmental riches, approximately 1,000,000 (one million) tons of MSW are landfilled every year, in an area of 660,000 m² whose capacity is completed in 2024. In addition, the Brazilian Institute of Geography and Statistics (IBGE) classified Manaus as being the fourth worst city in Brazil with accumulation of garbage in public places. Approximately 6.2% of the surroundings of the households have the presence of accumulated garbage. Only near the streams are 108,000 residents affected with unpleasant odors, diseases and a lot of dirt. A total of 345,000 families are affected by the dirt in the streams of Manaus (IBGE, 2020).

The study area of this work focuses on the urban area of the city, on the 06 (six) administrative regions that the city of Manaus divides the city and on the urban solid waste landfill of Manaus, located at Km 19 of the AM-010 Highway – Manaus - Itacoatiara road. The objective is to describe the activities developed to characterize the urban solid waste destined to the landfill of this city through gravimetric analysis, composed of three steps, required by NBR 10.007/2004: quartering, identification and weighing of the waste categories, as well as determining the apparent specific weight of these wastes. To achieve the proposed objectives, selective collections of MSW were carried out in eighteen neighborhoods, between 2022 and 2023, in the six administrative regions of the city, namely: North, South, East, West, Center-South and Midwest. Approximately 3200 liters of MSW were collected in the neighborhoods that are part of these regions, using the labor of experienced collectors and a vehicle with a body. For each collection site, gravimetry tests were performed: quartering, identification, volume and mass measurement, and calculation of percentages, as well as calculation of apparent specific weight.

DEVELOPMENT

ENVIRONMENTAL IMPACTS

Rapid urbanization and the absence of effective waste management systems have turned landfills into one of the world's biggest problems. About 40% of the planet's solid waste goes to these areas, harming the lives of about 4 billion people. One of the solutions is the creation of sanitary landfills, a strategy taken by the Brazilian government since 2010 to deactivate dumps and promote better management of what is discarded (MMA. 2019).

A study carried out by the World Wide Fund for Nature (WWF) shows that Brazil is the fourth country in the world that produces the most garbage. There are more than 11 million tons per year. Our country is behind only the United States (1st place), China (2nd) and India (3rd). The Abrelpe study (2019) shows that the impact of landfills here in Brazil entails a cost of more than R$ 3 billion per year for the health system (MMA. 2019).

Latin America and the Caribbean region has one of the highest urbanization rates in the world, with an estimated 500 million people living in cities, which translates to about 80% of the population. Among the various problems caused, those related to mobility, safety, health, well-being, sanitation and adequate management of USW stand out. About 354,000 tons are produced daily, through inhabitants with the most diverse consumption habits, cultural characteristics and purchasing power. Of this fraction, it is estimated that 50% (or more) of the MSW generated are from food waste and materials of organic origin. Despite this great potential for recovery through different technological options that exist today, the portion of organic waste from MSW is discarded and deposited in landfills or dumps, bringing severe impacts to the environment, with the generation of Greenhouse Gases (GHG) in the face of the emission of methane gas (CH_4), which is 25 times more harmful than carbon dioxide (CO_2). and currently accounts for 3% of total GHG emissions in the atmosphere (ABREN, 2019).

In addition, there is the risk of contamination of water resources by leachate or leachate, that is, a reduction in the drinking water available on the planet. Because of its enormous volume (approximately half of MSW in developing countries), municipal organic waste deserves proper and specialized management. In addition to minimizing costs and severe environmental impacts, it is possible to produce important by-products such as energy (electricity and thermal), fertilizers, and fuels (ABREN, 2019).

PUBLIC HEALTH

Dumps are a global emergency for health and the environment. Landfills receive about 40% of the world's waste and serve 3 to 4 billion people. The 50 largest dumps affect the daily lives of 64 million people, a population the size of France. As urbanization and population growth continue, several hundred million people will be served by dumps, particularly in low-income countries. If the situation follows the usual scenario, landfills will generate 8 to 10% of man-made greenhouse gases by 2025 (ISWA, 2019).

More than 750 people died due to poor waste management in dumps in the first half of 2016 alone (ISWA, 2019). Abrelpe (2020) reports that dumps cost health systems one billion dollars a year. Even in times of pandemic, dumps continue to operate in Brazil and affect the health of more than 77 million people.

In addition to being a source of diseases such as dengue, yellow fever, zika and chikungunya, parasitosis and many others, combined with the deficient structure and scarcity of resources of the Unified Health System (SUS), there are also high social and economic costs in public spending by the municipality, state and federal government. In addition, zoonoses – infectious diseases capable of being naturally transmitted between animals and humans – represent 60% of all infectious diseases in humans and are on the rise due to the destruction of wild habitats resulting from the most diverse economic activities. These diseases certainly affect the tripod of sustainability – the economy, society, and the environment, in addition to the negative impacts on community life (SANEAMENTO BÁSICO, 2020).

Basic sanitation portal (2020) suggests that proposals for the environmentally correct disposal and treatment of garbage, in all its classifications, first involve massive investments, in a planned and responsible way, in sustainable alternatives and with substantial gains for health, the economy and the environment with all the complexities that affect it. He cites what governments have done during the Covid-19 pandemic, concerned with protecting populations, with even emergency and reserve investments, in two consecutive years so far.

The garbage that human beings produce and throw on the planet every day is a very serious risk to the health of all living beings and the planet itself. Here are some of the problems that garbage can cause: Diseases: Garbage that goes to open dumps or vacant lots produces bacteria and fungi. It also attracts cockroaches, rats, flies, mosquitoes, etc. These animals can transmit serious diseases, such as dengue, typhoid, cholera, dysentery, bubonic plague and leishmaniasis (RETEC, 2015).

Air accidents: garbage accumulated near airports causes accidents, because the plane collides with a vulture or other large bird, for example. It can cause the death of people, in addition, of course, to the death of the bird, which could have been avoided (RETEC, 2015).

Air pollution: garbage – burned or not, produces gases that are harmful to the health of living beings and the planet, such as methane gas and hydrogen sulfide gas. These gases pollute the air and can cause respiratory diseases. The burned garbage produces carbon dioxide, a gas that is toxic if it is in large quantities. And if you remember that the planet's air is already full of carbon dioxide because of cars and factories (RETEC, 2015).

Floods: PET bottles, plastic bags and other garbage are washed away in a heavy rain. They end up clogging storm drains and even preventing rivers from flowing through their beds. This causes terrible flooding. Dirty water from floods spoils people's homes, kills domestic animals and causes more diseases in the population (RETEC, 2015).

The problem of the disposal of USW is great and affects the entire country, but it can be reduced if each one of those involved does their part, the governments, the institutions, the companies and each inhabitant of the nation. An example was studied by Ferreira (2018) in Brasília – DF. Due to the type and amount of waste that was received at the controlled landfill of Jóquei, in the 1990s, when approximately 100 waste collectors moved to the region. When the landfill was deactivated, approximately three thousand people lived in the place and made their living from the region, under very harsh conditions. The landfill did not have the minimum conditions for survival, such as lack of drinking water, lighting, violence, sub-human working conditions, health risks, child labor and proliferation of diseases, exposed to extreme pollution, with the possibility of suffering attacks by wild birds and rodents. The lack of structure and inadequate conditions of The work of the waste pickers resulted in several accidents. From 2009 to 2017, at least 47 accidents were recorded, ranging from burns and falls, to more serious cases, such as truck overturning and loss of fingertips, severed arm, being run over, and death (FERREIRA, 2018).

SORTING AND RECYCLING

The sorting process is the separation of materials that will be sent for recycling, according to their physical and chemical characteristics. This is an essential step in the recycling process, being considered the initial step for the production of new products. The Ministry of Cities defines a shed or sorting unit as the set of buildings and facilities intended for the handling of materials from the selective collection of dry waste from household waste or similar to them (paper, plastics, metals, among others), by workers with recyclable materials, formally linked to organizations of this category, according to the logistics of implementation and operation (MINISTRY OF CITIES, 2010). In Manaus, these activities are not carried out. The MSW collected by the transport trucks unload the waste and are then scattered and landfilled in the city's landfill.

In a sorting plant, the material from mixed collection and selective collection is received and then separated into materials of equal characteristics, at least in 03 (three) fractions: recyclable, organic and waste. Depending on the population, which generates a lot of waste, it would need a large place and many people to separate all the MSW that arrives every day. The PNRS (2010) requires that organic material be destined for biodigesters or composting. Pyrolysis and incineration lose in economic viability. Composting is best applied when there is waste with many vegetables and tree remains (PRS, 2021).

Recyclable materials account for around 45% of all waste. A recycling facility is required for any material (plastic, paper, glass, electronics, plaster, etc.). The process of separating materials is a very simple service and Brazilian legislation requires that selective collection personnel and low-income people be classified in this process. Anyone who receives 15 to 30 minutes of training can join the team. The separated material must go to the industry to be reused in the production line. The recyclable materials market emerges, which seeks the right buyer for the material to be evaluated, packages and delivers it to the industry (PRS, 2021).

Screening can be done manually, automatically or semi-automatically. The first type involves the separation of household waste and the activity of waste pickers. This is a type of sorting that requires little investment, but has low production capacity and, therefore, is inefficient (FRAGMAQ, 2015).

Automatic sorting can receive a much larger volume of garbage, executing the sorting process with agility and without interruption for rest. In addition, the separation of garbage is done with more quality and in a more reliable way. On the other hand, automatic garbage sorting requires high investment in equipment and space rental. It is a method more suitable for large cities. There is also semi-automatic sorting, which combines the work of garbage collectors with the installation of modern machinery (PRS. 2021).

CHARACTERIZATION OF MSW

The characterization of MSW is important to obtain data on their behavior under certain conditions, also allowing the study of ways to control or minimize their impacts on the environment. From these qualitative and quantitative data, and with the application of statistical methods and analysis, it is possible to propose selective collection and recycling actions, verify if the recyclable materials have marketing value and if the organic matter is appropriate for composting or biodigestion, or, establish the appropriate treatment or destination, determine the necessary adaptations for the development of solutions for reduction, or even elimination, of the MSW from that community. In order to carry out a reliable characterization of waste, it is necessary to carry out a reliable sampling, according to NBR 10007 – Solid waste sampling (ABNT, 2004).

Preparation for sampling

This subsection establishes the basic lines that must be observed before taking any sample in order to define the sampling plan (sampling objective, number and type of samples, samplers, sampling location, vials and sample preservation).

Purpose of sampling

The objective of sampling is to collect a representative amount of waste, in order to determine its characteristics in terms of classification, treatment methods, etc.

Pre-characterization of a residue

The pre-characterization of a waste is done through a survey of the processes that gave rise to it. The information thus obtained (approximate volume, physical state, main constituents, temperature, etc.) allows the definition of the most appropriate type of sampler, the parameters to be studied or analysed, the number of samples and their volume, the type of collection bottle and the preservation method(s) that should be used.

Sampling plan

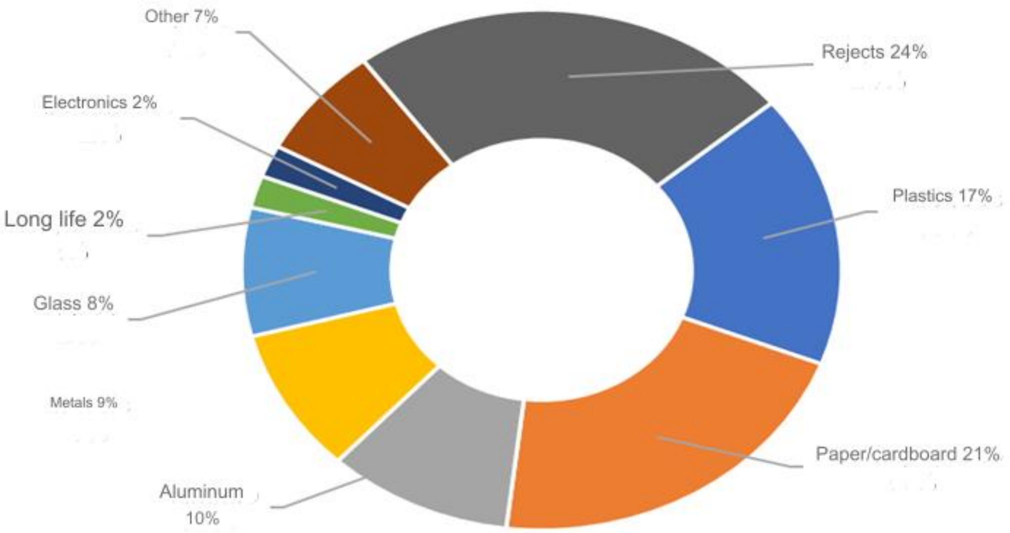
The sampling plan shall be established prior to the collection of any sample, be consistent with the purpose of sampling and with the pre-characterization of the residue, and shall include: evaluation of the site, form of storage, sampling points, types of samplers, number of samples to be collected, their volumes, their types (plain or compound), number and type of collection bottles, preservation methods and storage time, as well as the types of protective equipment to be used during collection. This plan should also establish the date and time of arrival of the samples at the laboratory. In NBR 10007 (2004) there are tables that present the methods of preservation and storage of solid and liquid samples.

Physical characteristics

Gravimetry

Gravimetric composition of USW is the percentage survey of the materials that make up the USW deposited in a given location. This is accomplished by measuring the mass of each material and calculating the percentage of that mass. For example, the gravimetric composition of USW in Brazil is represented in Figure 1. Waste that is composed of residential garbage, remains from fairs, various packaging (long life, aluminum cans, glass) is equivalent to half. There is a large amount of organic matter that is thrown into the dumpsters mixed with other types of waste. As in other studies, paper/cardboard shavings continue to be the most collected types of materials (by weight), followed by plastics in general. The percentage of tailings is still high (about 24%), demonstrating the need for investments in raising awareness among the population to carry out the correct separation of waste (CEMPRE, 2019).

Figure 1. Percentage composition of the residuals. Source: CEMPRE, 2019.



It is estimated that in the years 2020 and 2021 the situation tends to worsen as a result of the pandemic. According to Abrelpe (2020), solid waste generation increased by approximately 25% during the pandemic. Due to the protective quarantine measures, with home office work and children at home, there was an increase in consumption, delivery orders and a greater number of meals at home, and as a consequence a growth in the generation of MSW.

Apparent specific gravity

It is the weight of the loose waste by the volume freely occupied, without any compaction, given in kg/m³. The determination of the apparent specific weight is extremely important for the design of equipment and facilities. In the absence of more precise data, the following values can be used: 231 kg/m³ for the specific weight of household garbage (average); 280 kg/m³ for the specific weight of waste and health services; 1,300 kg/m3 for the specific weight of construction debris. Some other examples: 1213 Kg/m³ for organic matter; 338 kg/m³ for paper/cardboard; 240 kg/m³ for others (sand, rubble, among others); 224 kg/m³ for plastic film; 135 kg/m³ for rigid plastic; 119

kg/m³ for rags; 73 kg/m³ for rubber; 60 kg/m³ for Treta Pak; 53 kg/m³ for metal; 50 kg/m³ for glass; 41 kg/m³ for wood (DIAS, 2016).

INFORMATION ABOUT THE CITY OF MANAUS-AM

Manaus, the capital of the state of Amazonas, is in seventh place in the ranking of capitals with a population of 2,116,254 people, being the largest and most populous city in the state of Amazonas, located right in the center of the Amazon rainforest, as shown in Figure 2. In territorial extension it is the second largest in the country with an area of 11,401.092 km² (the largest is Porto Velho – RO, with 34,090.952 m²), so extensive that if you add all sixteen capitals of the south, southeast and northeast regions (9,023 km²) Manaus alone still exceeds all in area.

In urban areas, the city of Manaus has the fourth largest in the country, with 427 square kilometers, according to IBGE data (2020). The area of the Metropolitan Region of Manaus, on the other hand, has an area of 127,287.789 square kilometers. It is the largest Brazilian metropolitan area, larger than the area of some Brazilian states such as Pernambuco, Santa Catarina and Rio de Janeiro (being more than twice as large as this one) and has approximately the same dimensions as some nations such as Iceland (103,000 km²) and South Korea (99,538 km²), and larger than countries such as Hungary (93,032 km²) and Portugal (92,391 km²) (IBGE, 2020).

NEIGHBORHOODS OF THE CITY OF MANAUS.

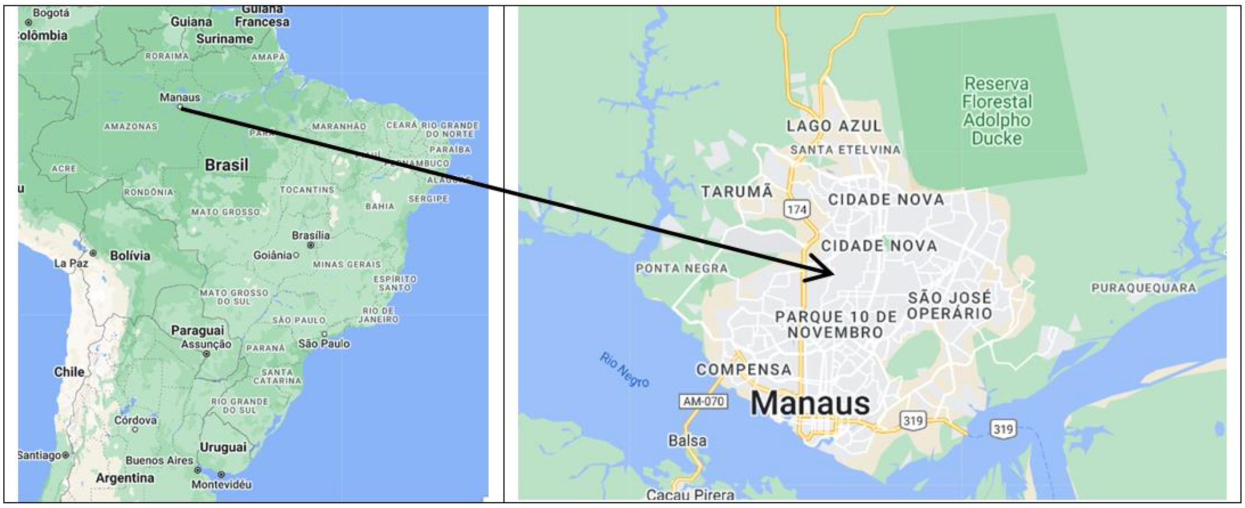
Since 2010, the city of Manaus has recognized 63 official neighborhoods (IBGE, 2010). Neighborhoods that are not recognized by the administrative body are considered to be part of other neighborhoods. The rural area is not divided into neighborhoods and is therefore not represented on the list. Among all the administrative regions of the city, the South Zone is the largest in number of neighborhoods, with a total of 18 neighborhoods, and is also the most densely populated. However, the most populous neighborhoods are found in the North and East zones, such as Cidade Nova and Jorge Teixeira, which each have more than 100,000 inhabitants. The last territorial division occurred in the municipality on January 14, 2010, through Municipal Law No. 1,401/10.1 By this measure, the neighborhoods of Cidade de Deus Distrito Industrial II, Gilberto Mestrinho, Lago Azul, Nova Cidade, Novo Aleixo and Tarumã-Açu were approved.

According to the IBGE (2020), the neighborhood in Manaus with the best quality of life and Human Development Index is Nossa Senhora das Graças, which has an HDI of 0.943, a quality of life similar to that of Norway, for example. However, there are also places in Manaus with poverty rates similar to those of poor countries, such as the community of Greater Vitória, which has an HDI of 0.658, similar to that of Bolivia, or the community of Parque São Pedro, which has an HDI of 0.688, which allows it to be compared to Vietnam. In total, thirteen communities and neighborhoods in Manaus were classified as in a state of "poverty" and another two as in "extreme poverty". The region of the city considered to have the best quality of life is the Center-South, in addition to other locations such as Ponta Negra and some parts of the Cidade Nova neighborhood. The region with the highest incidence of poverty is found in the communities of Nova Vitória, Grande Vitória and in the neighborhoods of Cidade de Deus and parts of Jorge Teixeira and Tarumã. Table 1 summarizes the population of the city's administrative areas.

Table 1. Population of the administrative zones of the city of Manaus-AM. Source: IBGE, 2020.

Zona Administ	Population	Area (m²)
NORTH	592.325	9.876,84
EAST	529.543	15.568,39
SOUTH	338.674	4.707,97
WEST	299.782	12.829,44
CENTER-SOUTH	180.577	3.556,97
CENTRAL-WEST	175.353	1.799,31
Total	2.116.254	48.338,92

Figure 2. Location of the city of Manaus- AM. Source: GOOGLEMAPS, 2022.



METHODOLOGY

GRAVIMETRY

A team consisting of a driver, three waste pickers and four assistants properly equipped with their PPE traveled to the neighborhoods of the city of Manaus, state of Amazonas, and collected approximately 3200 liters of MSW from each of the neighborhoods, in a car with a body, as illustrated in Figure 3. This amount was taken to a covered shed where another team of recyclers and helpers unloaded the MSW that were removed from the plastic bags, disaggregated and homogenized on plastic sheeting that covered the floor of the shed, until forming a single pile. Soon after, a block was made and two of the diametrically opposite parts were discarded and the other two were used to fill plastic buckets of 100 liters each until a volume of 1,000 liters of waste was obtained. Each of the containers containing waste was properly placed on a Filizola scale, type 34, with a capacity of 150 kg, and its mass was measured and noted, shown in Figure 4. After weighing the total sample, the waste was sorted on the plastic tarpaulin as follows: Paper/cardboard, wood, metals, glass, hard plastic (HDPE), soft plastic (LDPE), PET plastic, PP plastic, Styrofoam, tailings and organic material. Again, each container with each type of material was properly weighed, separately, to obtain the representativeness by weight of each type of material. With these data, the percentages of each type of material existing in that 1000-liter sample were determined, according to Equation 1, by dividing the percentage of the mass of each material by the total mass of the sample, as well as the calculation of the specific weight of the MSW, by directly dividing the total mass of the sample by the total volume.

Equation 1. Percentage of each type of material after sorting.

$$\text{Percentual de cada categoria (\%)} = 100 * \frac{\text{peso de cada fração (kg)}}{\left(\text{peso total da amostra (Kg)}\right)} \qquad \text{(Equation 1)}$$

Source: Basic physics.

Where:

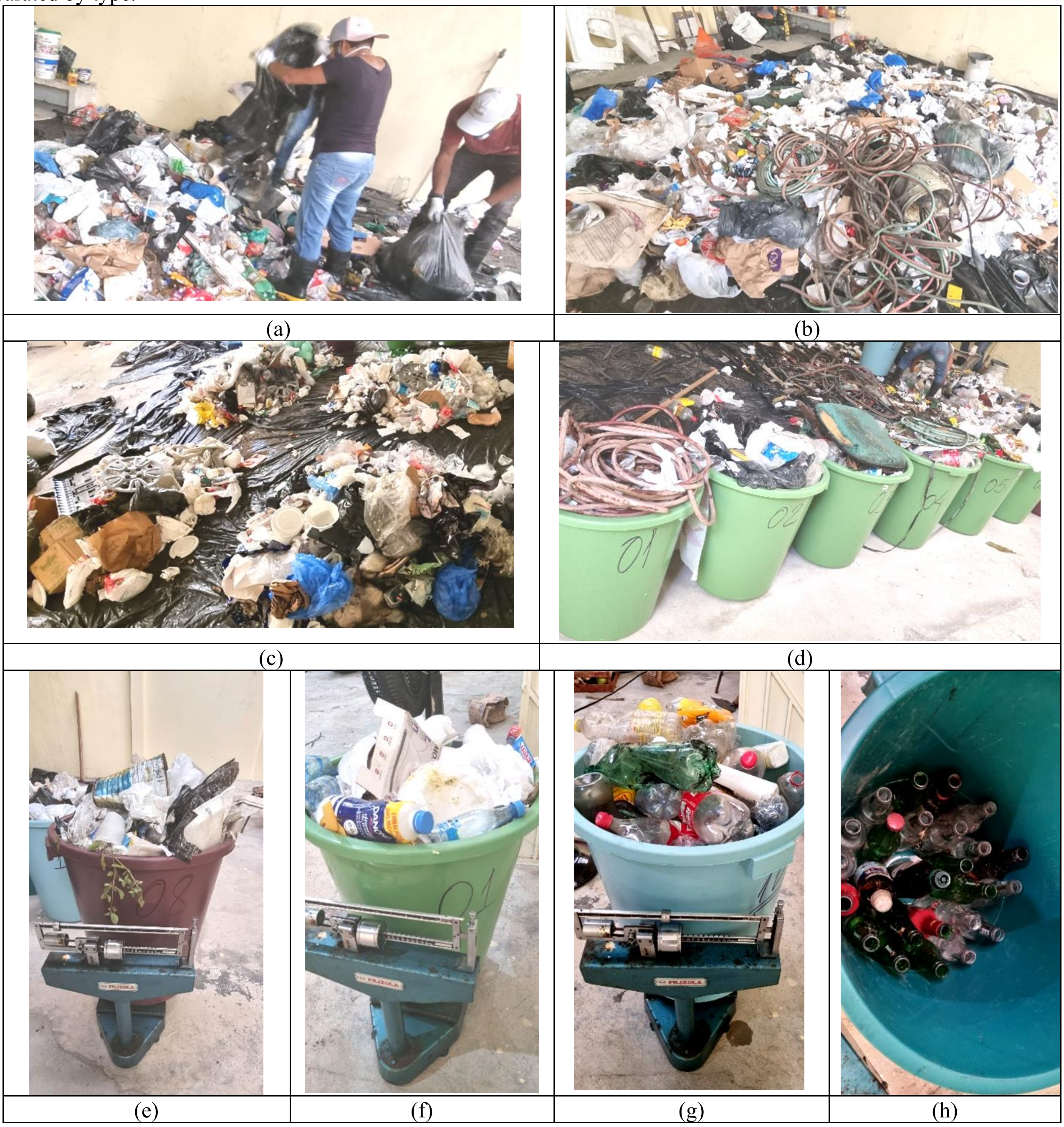
Percentage of each category = percentage of each class/type of waste present in the sample;

Weight of each fraction = weight of each class/type of waste after sorting.

Figure 3. Selective collection. (a) On the streets; (b) In community dumps; (c) vehicle used.

Source: The authors.

Figure 4. Gravimetry: (a) Removal of waste from plastic bags; (b) mixing of waste; (c) quartering; (d) separation of 1m³ of waste; (e) weighing of waste; (f) weighing of mixed waste; (g) weighing of separated waste; (h) weighing of waste separated by type.

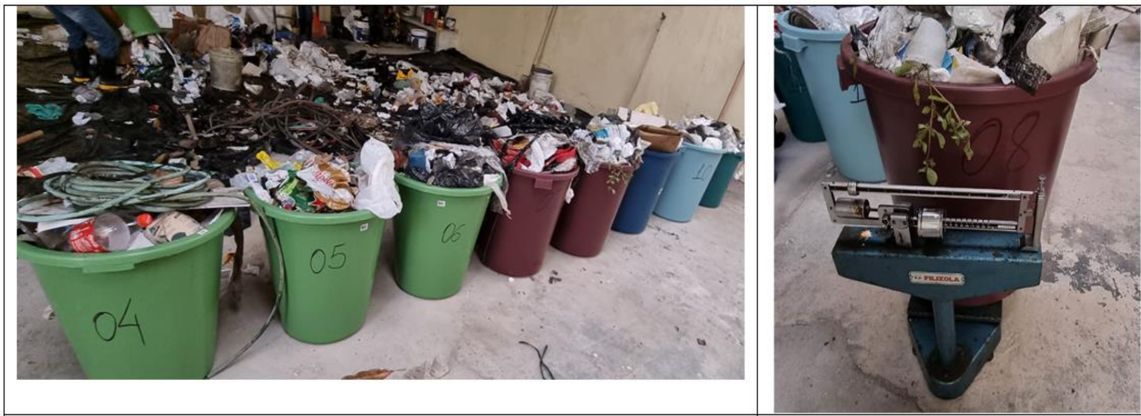


Source: The authors.

APPARENT SPECIFIC GRAVITY

From the volume of MSW collected from the clays, mixed and quarteated and placed in 100-liter bucket containers, in a total of 1000 liters for each of the neighborhoods, the mass of each of the buckets was placed on the scale and measured, obtaining the total mass of the volume of 1000 liters, as shown in Figure 5. The arithmetic division of this mass by the volume is called the apparent specific weight of the material, according to Equation 2. This parameter is of paramount importance for selective collection companies. Because it is quantitative in nature, it reflects the density of MSW and varies greatly according to its composition. Its knowledge results in an adequate sizing of routes, number of collection trucks and compaction machinery.

Figure 5. Weighing of the volume of 1m³ of MSW: (a) Measurement of the volume; (b) Mass measurement.



(a) (b)

Source: The authors.

Equation 2. Apparent specific weight.

$$Specific\ weight\ \left(\frac{Kg}{m^3}\right) = \frac{residue\ mass\ (Kg)}{residue\ volume\ (m^3)} \qquad \text{(Equation 2)}$$

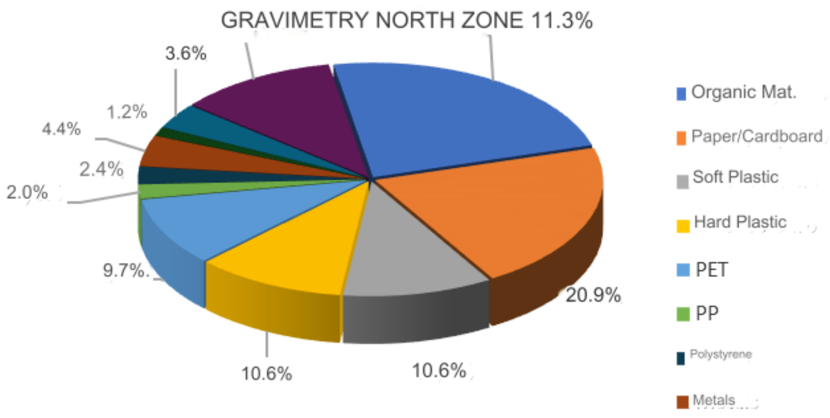
Source: Basic physics.

CONCLUSION

GRAVIMETRY

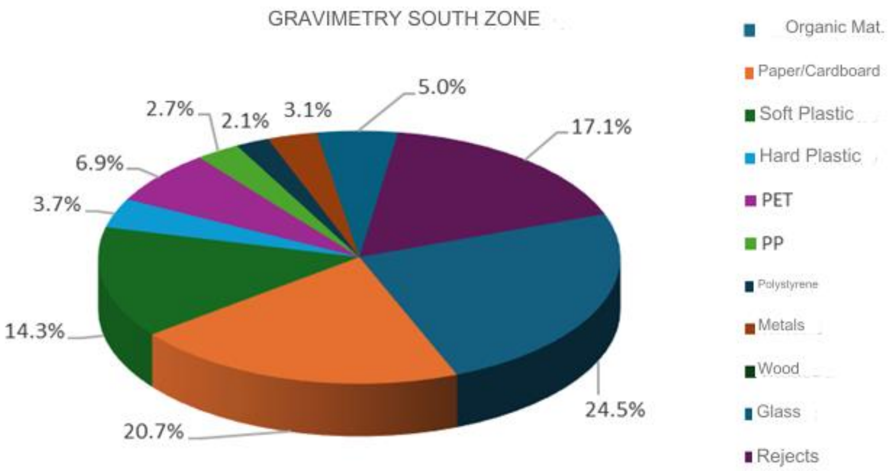
The objective is to describe the activities developed to characterize the urban solid waste of the city of Manaus-AM through the gravimetric analysis, composed of three stages, required by NBR 10.007/2004: quartering, identification and weighing of the categories of waste and their apparent specific weight, detailed sampling of the gravimetric profile of the urban solid waste of each of the administrative regions worked resulted in the data and percentage proportions shown in Figures: 6, 7, 8, 9, 10 and 11, referring to dry days. It is possible to perceive the quantities and percentages of each material constituting the waste collected and worked. The mean of the neighborhoods was extracted as well as the standard deviation of the sample.

Figure 6. Gravimetria da Zona Norte. Average values - dry days.



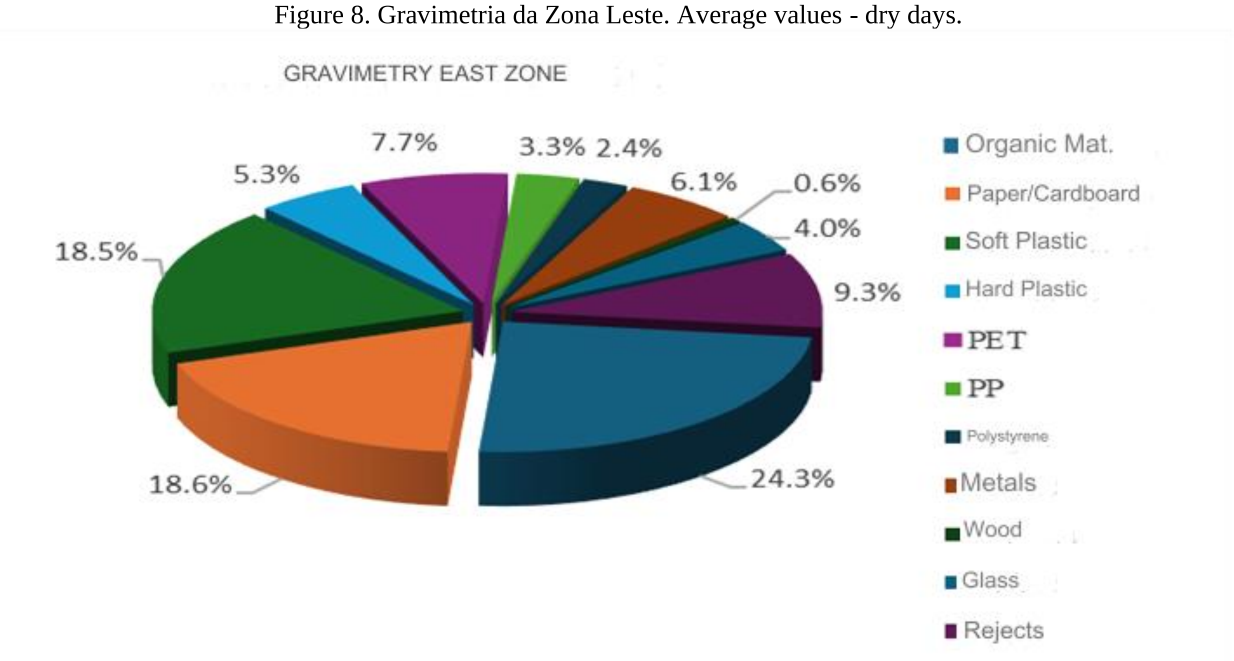
Source: The authors.

Figure 7. Gravimetria da Zona Sul. Average values - dry days.



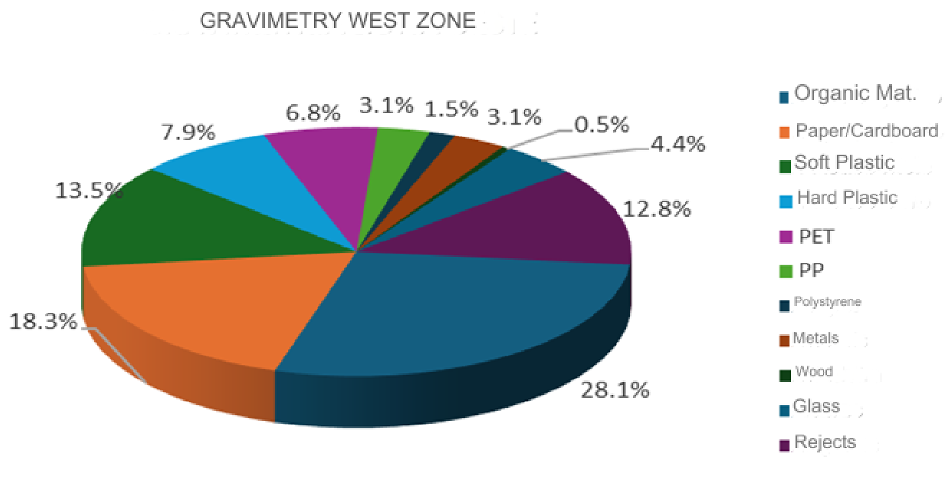
Source: The authors.

Figure 8. Gravimetria da Zona Leste. Average values - dry days.



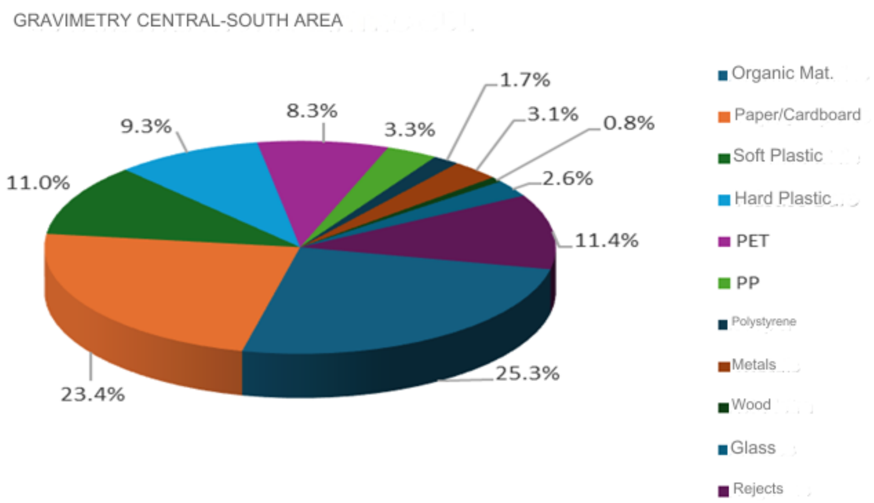
Source: The authors.

Figure 9. Gravimetria da Zona Oeste. Average values - dry days.



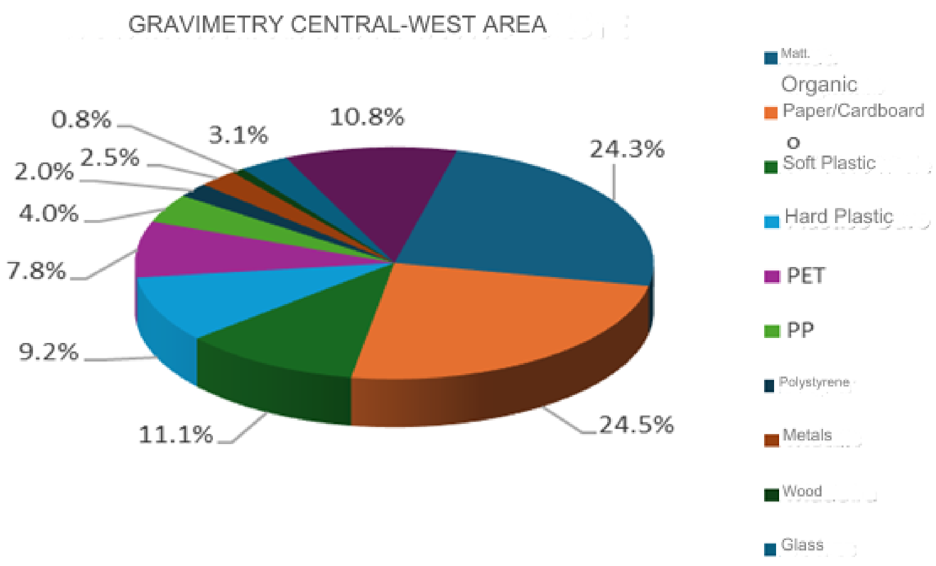
Source: The authors.

Figure 10. Gravimetry of the Center-South Zone. Average values - dry days.



Source: The authors.

Figure 11. Gravimetry of the Midwest Zone. Average values - dry days.



Source: The authors.

The results indicated a partial variation in certain materials compared to the national average. The profile of waste differs because it presents a greater amount of recyclable materials such as paper, cardboard and plastics, in relation to the national average, while organic waste is in a higher percentage. This is due to the separation carried out in this work between tailings and organic material whose destination can easily be biodigestion or composting, as summarized in Table 2 for data referring to dry days and in Table 3 for rainy days.

Table 2. Percentage fractions by administrative area and weighted average of each material that make up the MSW.

COMPONENTS	PERCENTAGE FRACTION						AVERAGE	WEIGHTED AVERAGE
	NORTH	SOUTH	EAST	WEST	CENTER-SOUTH	CENTRAL-WEST		
Mat. Organic	23,25%	24,5%	24,5%	28,1%	25,3%	28,5%	25,68%	25,04%
Recyclable	64,24%	58,47%	58,47%	58,61%	62,55%	61,23%	60,60%	60,68%
Paper/Cardboard	20,92%	20,7%	20,7%	18,3%	23,4%	22,9%	21,13%	20,81%
Mole-LDPE Plastic	10,61%	14,3%	14,3%	13,5%	11,0%	10,9%	12,42%	12,58%
Hard Plastic-HDPE	10,60%	3,7%	3,7%	7,9%	9,3%	5,5%	6,81%	6,88%
PET	9,70%	6,9%	6,9%	6,8%	8,3%	7,8%	7,74%	7,87%
PP	2,00%	2,7%	2,7%	3,1%	3,3%	4,0%	2,97%	2,73%
Styrofoam	2,44%	2,1%	2,1%	1,5%	1,7%	0,8%	1,77%	1,96%
Year	4,36%	3,1%	3,1%	3,1%	3,1%	2,5%	3,19%	3,39%
Glasses	3,60%	5,0%	5,0%	4,4%	2,6%	6,8%	4,57%	4,47%
Wood	1,20%	0,0%	0,0%	0,5%	0,8%	0,3%	0,46%	0,50%
Rejects	11,31%	17,1%	17,1%	12,8%	11,4%	10,0%	13,27%	13,78%
TOTAL	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%
Weighting factor	0,2799	0,1600	0,2502	0,1417	0,0853	0,0829		

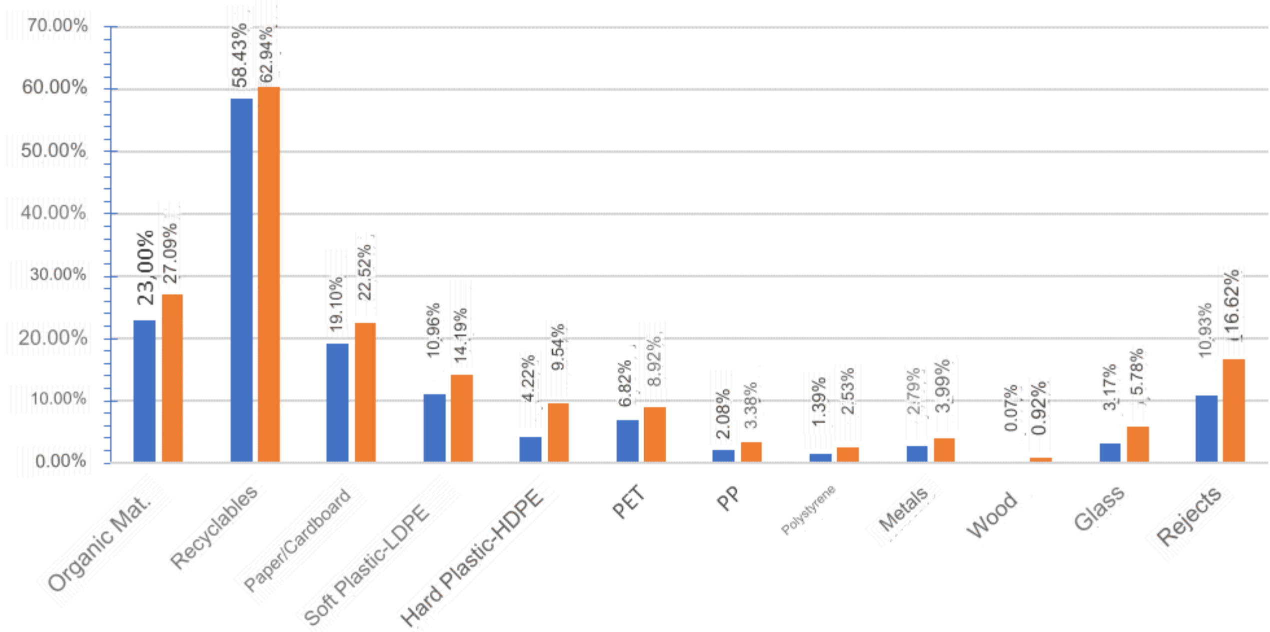
Source: The authors.

Table 3. Percentage fractions by administrative area and weighted average of each material that make up the MSW. On rainy days.

Component	NORTH	SOUTH	EAST	WEST	CENTER-SOUTH	CENTRAL-WEST	AVERAGE	D.P.	WEIGHTED AVERAGE
Mat. Organic	25,8%	27,1%	26,7%	27,6%	19,3%	21,7%	24,7%	3,4%	25,6%
Paper/Cardboard	10,1%	13,1%	17,0%	20,4%	11,2%	17,1%	14,8%	4,0%	14,4%
Plastic Mole	7,1%	9,6%	8,2%	12,0%	11,0%	7,9%	9,3%	1,9%	8,9%
Hard Plastic	6,8%	5,9%	6,9%	4,7%	4,3%	4,9%	5,6%	1,1%	6,0%
PET	8,1%	8,6%	7,5%	5,4%	7,5%	9,7%	7,8%	1,4%	7,7%
PP	5,5%	4,6%	3,5%	2,2%	3,0%	2,0%	3,5%	1,4%	3,9%
Styrofoam	1,5%	1,4%	2,4%	1,5%	0,6%	2,1%	1,6%	0,6%	1,7%
Year	2,1%	2,1%	2,7%	2,7%	1,2%	0,5%	1,9%	0,9%	2,1%
Wood	1,8%	2,4%	2,6%	0,6%	2,1%	0,3%	1,6%	0,9%	1,8%
Glasses	4,9%	4,0%	1,9%	0,5%	8,9%	5,1%	4,2%	2,9%	3,8%
Clothing/Fabrics	5,8%	0	0	0	11,6%	5,6%	3,8%	4,7%	3,1%
Rejects	20,4%	21,2%	20,6%	22,3%	19,4%	23,1%	21,2%	1,3%	21,0%
TOTAL	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	1,4%	100,0%
Recyclable	48,8%	47,7%	50,7%	49,6%	52,4%	50,1%	49,9%	1,6%	49,7%
Weighting factor	0,279893	0,160035	0,250227	0,141657	0,085329	0,082860			

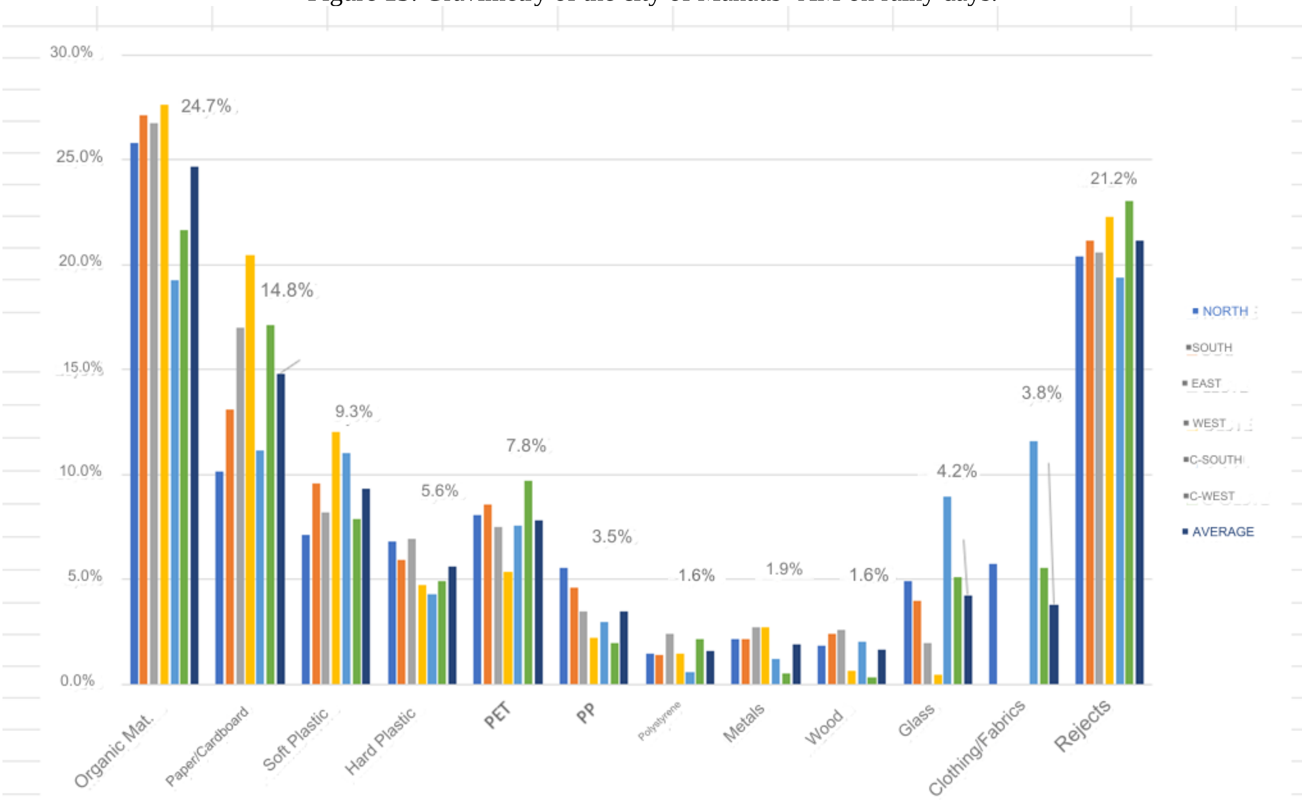
Source: The authors.

Figure 12. Final gravimetry of the city of Manaus -AM on dry days.



Source: The authors.

Figure 13: Gravimetry of the city of Manaus -AM on rainy days.



Source: The authors.

For a better understanding, Figure 12 and Figure 13 above seek to show the final values taking into account the weighting according to the population of each of the administrative areas, as shown in Table 4.

Table 4. Population and weighting coefficient by administrative area of the city Manaus – AM.

ZONE	Population (inhab)	Weighting (w)
NORTH	592.325	0,2799
SOUTH	338.674	0,1600
EAST	529.543	0,2502
WEST	299.782	0,1417
CENTER-SOUTH	180.577	0,0853
CENTRAL-WEST	175.353	0,0829
TOTAL	2.116.254	1,0000

Source: The authors.

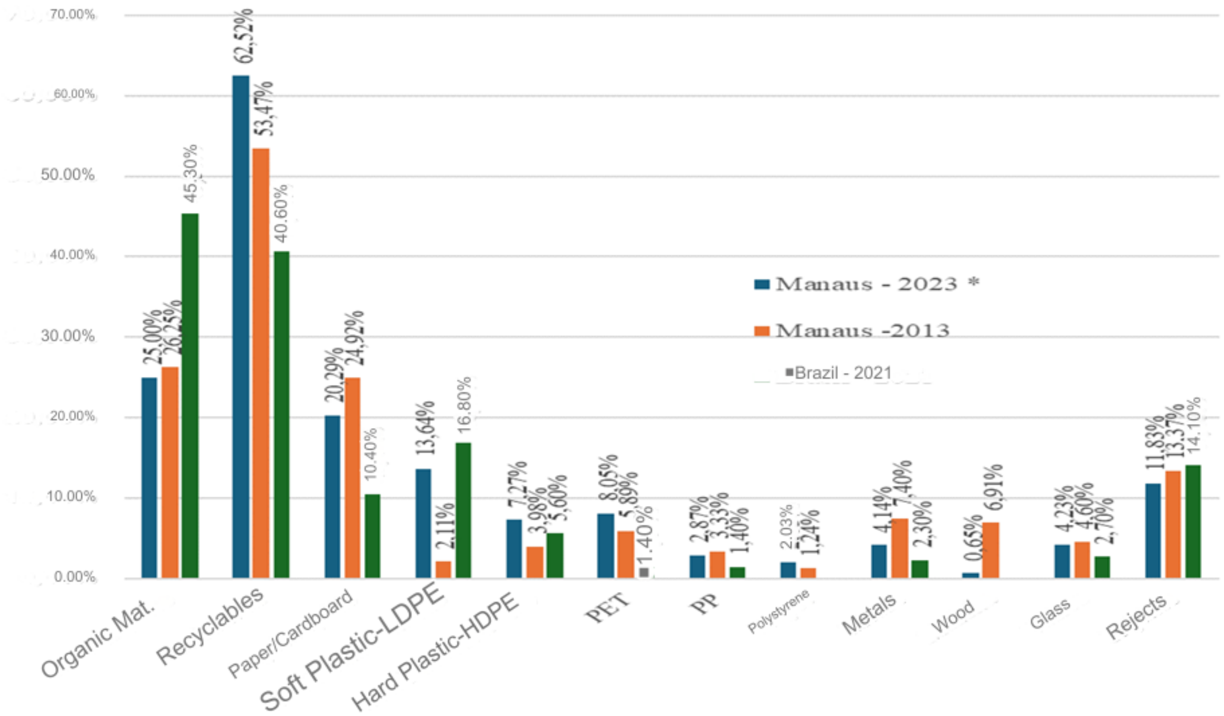
Comparing with the national average and with the values obtained from a study carried out by the city's municipal cleaning department in 2013, described in Semulsp, 2013, Table 5 and Figure 14 were prepared below.

Table 5. Percentage fractions by administrative area and weighted average of each material that make up the MSW. Carried out in 20223 (by the author), in 2013 (SEMULSP, 2013) and in Brazil (ABRELPE, 2022).

COMPONENTS	PERCENTAGE FRACTION. * Weighted average.									
	NORTH	SOUTH	EAST	WEST	CENTER-SOUTH	CENTRAL-WEST	AVERAGE	Manaus - 2023 *	Manaus -2013	Brazil - 2021
Mat. Organic	23,25%	24,50 %	24,30%	28,10%	25,30%	28,50%	25,65%	25,00%	26,25%	45,30 %
Recyclable	64,24%	58,47 %	65,81%	58,61%	62,55%	61,23%	61,82%	62,52%	53,47%	40,60 %
Paper/Cardboard	20,92%	20,70 %	18,60%	18,30%	23,40%	22,90%	20,78%	20,29%	24,92%	10,40 %
Mole-LDPE Plastic	10,61%	14,30 %	18,50%	13,50%	11,00%	10,90%	13,13%	13,64%	2,11%	16,80 %
Hard Plastic-HDPE	10,60%	3,70%	5,30%	7,90%	9,30%	5,50%	7,07%	7,27%	3,98%	5,60%
PET	9,70%	6,90%	7,70%	6,80%	8,30%	7,80%	7,86%	8,05%	5,89%	1,40%
PP	2,00%	2,70%	3,30%	3,10%	3,30%	4,00%	3,06%	2,87%	3,33%	1,40%
Styrofoam	2,44%	2,10%	2,40%	1,50%	1,70%	0,80%	1,81%	2,03%	1,24%	
Year	4,36%	3,10%	6,10%	3,10%	3,10%	2,50%	3,69%	4,14%	7,40%	2,30%
Wood	1,20%	0,00%	0,60%	0,50%	0,80%	0,30%	0,56%	0,65%	6,91%	
Glasses	3,60%	5,00%	4,00%	4,40%	2,60%	6,80%	4,41%	4,23%	4,60%	2,70%
Rejects	11,31%	17,10 %	9,30%	12,80%	11,40%	10,00%	11,97%	11,83%	13,37%	14,10 %
TOTAL	100,00%	100,00%	100,00 %	100,00 %	100,00%	100,00%	100,00 %	100,00 %	100,00 %	100,00 %
Weighting factor	0,2799	0,16	0,2502	0,1417	0,0853	0,0829				

Source: The authors.

Figure 14. Gravimetrias of the city of Manaus -AM, carried out in 2023 (by the author, on dry days), in 2013 (SEMULSP, 2013) and in Brazil (ABRELPE, 2022).



Source: The authors.

In the survey, it was evidenced that the greater representativeness of recyclable waste (62% on dry days and 50% on rainy days) and the small proportional reduction of organics (25%) and waste (12% on dry days and 21% on rainy days), while the national average these values are 45%, 40% and 14% respectively, are possibly consequences of the excessive use of packaging, due to the number of people who start to live in the vicinity of the Manaus Industrial Pole and the commercial and service area in the urban area of the city. In the field analysis, it was found that at least 50% of this plastic material comes from recyclable packaging (or easily found commercial value in the market), evidencing the possibility of selective collection if a sorting plant is installed before the waste is landfilled. Such characteristics may be a consequence of the growing increase in the use of packaging, evidencing the need for local public policies for post-consumption responsibility, product life cycle analysis and priority marketing of products with sustainable packaging.

There is a slight increase in recyclable materials, when compared to data from the Manaus report of 2013 and the national average of 2021, apparently motivated by the period of contingency of the population with the pandemic that made it possible for some habits of the daily routine to return, such as eating at home, which can be suggested by the increase in the amount of disposable packaging, such as tetra packs and milk for breakfast, styrofoam lunchboxes and bottles of soft drinks and juices, boxes of cream and condensed milk for desserts. There was also an increase in soap and toilet paper packaging. The paper that surrounds the soap, the boxes, the toilet paper tubes, as well as the toilet paper used are items of the paper/cardboard component. The increase in the percentage of plastics is due to food deliveries to homes where plastic bags are used as food delivery packaging, showing that the population's consumption pattern has really changed since the pandemic years.

APPARENT SPECIFIC GRAVITY

The volumes and masses of the samples of each of the neighborhoods of the six administrative regions are shown in Table 6, as well as the results of the apparent specific weights after the application of equation 2.

Table 6. Apparent specific weight of MSW in the administrative regions of the city of Manaus. Source: The authors.

LOCAL	VOLUME:	BRUTE:	NET:	SPECIFIC WEIGHT:
	Litres	Medical history	Medical history	Kg/m³
New Israel	988,0	105,10	82,30	83,30
New town	988,0	99,70	76,90	77,83
Learners	988,0	88,60	65,80	66,60
Square 14	988,0	102,10	79,30	80,26
Armando Mendes	988,0	98,60	75,80	76,72
Tancredo Neves	988,0	95,60	72,80	73,68
Compensates	988,0	90,90	68,10	68,93
Tarumã	988,0	133,40	110,60	111,94
Flowers	988,0	84,60	61,80	62,55
Park Ten	988,0	93,20	70,40	71,26
Dawn	988,0	87,80	65,00	65,79
AVERAGE	**988,0**	**95,60**	**72,80**	**73,68**

One of the consequences of the presence of a high percentage of recyclable packaging and materials is the average value of apparent specific weight, 73.68 Kg/m³, approximately one third of the national average, confirming the large amount of light materials containing air inside, such as packaging and enabling a high degree of compaction when dimensioning the route and the number of waste compactor collection trucks.

The studies carried out in these neighborhoods were fundamental for the collection of initial and updated data, which enabled the gravimetric characterization of solid waste in the city of Manaus, state of Amazonas, and will enable other studies that will benefit the population and enrich the data academy of this city, data that are scarce in the literature. For the time being, it has been found that there is a large amount of material capable of being recycled (62% $\pm$ 2%) and (50% $\pm$ 1.6%), respectively on dry days and rainy days, despite the publicity's advertising campaigns, with low apparent specific weight, confirming little organic matter and a lot of light material that can be recycled, leading to the idea of installing a sorting plant as an alternative to reduce waste destined to the landfill of the city, increasing its useful life and the reuse of recyclable materials, bringing economic, social and environmental benefits to the city and its inhabitants.

RECOMMENDATIONS FOR FUTURE WORK

The proposed management plan for the city of Manaus-AM aims at adequate treatment and final disposal of MSW to reduce dependence on landfill and electricity generation. A thermal characterization study with laboratory tests, such as specific heat, thermogravimetry tests (TGA), immediate analysis, elemental analysis, higher calorific value (PCS) and lower calorific value (PCI), as well as an economic analysis should be presented in the future taking into account some scenarios of recycling percentages, the amount and cost of fuel spent in incineration, the energy consumed in the process, as well as the gas emissions and financial impacts that may be caused. Finally, the calculation of the actual mass to be deposited in landfill, which includes the solid ash from incineration and the possible use of this in the composition of cementitious material to be used in civil construction.

REFERENCES

1. ABNT. (2004). *NBR 10007/2004 - Amostragem de resíduos sólidos*. Rio de Janeiro, RJ.

2. ABNT – Associação Brasileira de Normas Técnicas. (1992). *NBR 8419: Apresentação de Projetos para Aterros Sanitários de RSU*. Rio de Janeiro, RJ.

3. ABNT – Associação Brasileira de Normas Técnicas. (2004). *NBR 10.004: Resíduos sólidos - Classificação*. Rio de Janeiro, RJ.

4. ABRELPE: Associação Brasileira de Empresas de Limpeza Pública e Resíduos Especiais. (2022). *Panorama dos resíduos sólidos no Brasil 2020/2021*. Brasília, DF.

5. ABRELPE: Associação Brasileira de Empresas de Limpeza Pública e Resíduos Especiais. (2020). *Panorama dos resíduos sólidos no Brasil 2018/2019*. Brasília, DF.

6. ABREN: Associação Brasileira de Recuperação Energética de Resíduos. (2019). *Regulação Nacional e Internacional de Waste-to-Energy*. Waste Expo Brasil, São Paulo, SP.

7. CEMPRE: Compromisso Empresarial para a Reciclagem. (2019). Preço dos materiais recicláveis. *Revista Cempre Review*, 159. Disponível em <http://cempre.org.br/cempre-informa/id/115/preco-dos-materiais-reciclaveis>. Acesso em 12 nov. 2020.

8. Dias, J. O. V. (2016). *Estudo para a implementação de um sistema integrado de gestão de resíduos sólidos urbanos na Escola Superior de Tecnologia* (Monografia). Universidade do Estado do Amazonas - UEA, Manaus, AM.

9. Ferreira, R. S. (2018). *Desativação do aterro controlado do Jóquei X transferência para o aterro sanitário de Brasília: Análises dos principais aspectos sociais e ambientais* (Monografia). UNICEUB, DF.

10. GoogleMaps. (2022). Mapa de Manaus-AM. Disponível em <https://www.google.com.br/maps/place/Manaus,+AM/@-3.0443066,-60.1319187,11z/data=!3m1!4b1!4m6!3m5!1s0x926c1bc8b37647b7:0x2b485c9ff765a9cc!8m2!3d-3.1190275!4d-60.0217314!16zL20vMDJia2sz?entry=ttu>. Acesso em 12 dez. 2022.

11. IBGE. (2020). Conheça cidades e estados do Brasil. *Instituto Brasileiro de Geografia e Estatísticas*. Disponível em <https://cidades.ibge.gov.br/brasil/am/panorama>. Acesso em 29 set. 2020.

12. ISWA – International Solid Waste Association. (2019). Dumpsites: A global waste emergency. Disponível em <https://closingdumpsites.iswa.org/why/why-close-dumpsites/>. Acesso em 12 dez. 2020.

13. Lei nº 12.305, de 2 de agosto de 2010. Política Nacional de Resíduos Sólidos. Diário Oficial da União, 2010.

14. MCIDADES: Ministério das Cidades. Secretaria Nacional de Saneamento Ambiental. (2010). Termo de referência técnico: elaboração do projeto básico e executivo completo de galpão / unidade de triagem para coleta seletiva. Disponível em <https://antigo.mdr.gov.br/images/stories/ArquivosSNSA/Arquivos_PDF/16_TRProjRSUGalpao_triagem%202010_2011.pdf>. Acesso em 14 abr. 2021.

15. MMA – Ministério do Meio Ambiente. (2020). MMA abre consulta pública para alavancar a cadeia de reciclagem e reutilização de embalagens. Disponível em <https://mma.gov.br/component/k2/item/15752-mma-abre-consulta-p%C3%BAblica-para-alavancar-a-cadeia-de-reciclagem-e-reutiliza%C3%A7%C3%A3o-de-embalagens.html>. Acesso em 25 out. 2020.

16. PRS: Portal dos Resíduos Sólidos. (2021). Como montar uma usina de triagem de resíduos sólidos. Disponível em <https://www.youtube.com/watch?v=XqI-J7pRYbM>. Acesso em 11 abr. 2021.

17. RETEC: Tecnologias em Resíduos. (2015). Problemas que o lixo causa. Disponível em <https://www.retecresiduos.com.br/problemas-que-o-lixo-causa/#:~:text=Doen%C3%A7as%3A%20O%20lixo%20que%20vai,disenteria%2C%20peste%20bub%C3%B4nica%20e%20leishmaniose.>. Acesso em: 24 mai. 2020.

18. Saneamento Básico. (2020). Lixões a céu aberto são tão graves quanto uma pandemia. Disponível em <https://www.saneamentobasico.com.br/lixoes-ceu-aberto-pandemia/>. Acesso em: 25 nov. 2020.