International Journal of Innovative Technologies in Social Science

e-ISSN: 2544-9435

Scholarly Publisher
RS Global Sp. z O.O.
ISNI: 0000 0004 8495 2390

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ARTICLE TITLE	TRENDS OF MUNICIPAL SOLID WASTE CHARACTERIZATION AND MANAGEMENT STRATEGIES FOR AN ALGERIAN CITY
ARTICLE INFO	Sefouhi Linda. (2024) Trends of Municipal Solid Waste Characterization and Management Strategies for an Algerian City. *International Journal of Innovative Technologies in Social Science*. 4(44). doi: 10.31435/ijitss.4(44).2024.2995
DOI	https://doi.org/10.31435/ijitss.4(44).2024.2995
RECEIVED	10 October 2024
ACCEPTED	23 November 2024
PUBLISHED	27 November 2024
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TRENDS OF MUNICIPAL SOLID WASTE CHARACTERIZATION AND MANAGEMENT STRATEGIES FOR AN ALGERIAN CITY

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ABSTRACT

The characterization of household waste is a crucial step in waste management. It consists of collecting information on the composition and properties of waste produced by households. This can help waste managers plan for more efficient collection, treatment and disposal of waste. The aim of this research is to examine characterization and offer appropriate remedies for the management system of Municipal Solid Waste in Batna city. The French MODECOMTM method, developed by the French Environment Agency (ADEME) was our tool to determine characterization. Therefore, characterization should allow to bring out the properties of waste that are essential for optimizing approaches to municipal solid waste management and treatment. This research enabled the identification of the main trends in household waste in Batna city (54.8 % Organic Mater, 15.36 % textiles and 14.12 % Plastics). The ratios thus obtained are the main parameters of waste management. The study addressed household solid waste production at three different income levels (low, medium and high). The paper provides an in-depth analysis on the characterization waste and concludes which practices can be applied for the treatment of MSW to improve the Municipal Waste Management in Batna city for a sustainable development.

KEYWORDS

Municipal Waste, Characterization Waste, Management, Strategies, Algerian City

CITATION

Sefouhi Linda. (2024) Trends of Municipal Solid Waste Characterization and Management Strategies for an Algerian City. *International Journal of Innovative Technologies in Social Science*. 4(44). doi: 10.31435/ijitss.4(44).2024.2995

1. Introduction.

The main drivers of economic progress are urbanization and population growth, which increase economic activity, human resources, and resource consumption (Son and Louati, 2016). Waste is increasing rapidly globally as a result of urbanization, population growth, and economic development (Xi et al., 2010). Waste production is also increasing in quantity and quality, posing serious risks for both the environment and human health. Effective management of municipal solid waste remains a significant issue in urban areas globally, especially in fast-growing cities and towns in developing countries (Jing et al., 2009; Guerrero et al., 2013).

Thus, Developing countries utilize simple waste management methods such as landfilling and incineration to save money and reduce complexity, however, this leads to environmental pollution, posing risks to people and wildlife (The World Bank, 2022). Therefore, there is an urgent need to remove these wastes from the environment because it has been determined that they are harmful (Mrosso et al., 2023). This situation is much more worrying in developing countries, due in particular to their considerable backwardness in this field, caused by their lack of resources and their difficulty in tackling the issue with an approach adapted to their context. Even though there is a clear connection between pollution from landfills and worries about public health, there is still a notable shortage of quantitative data on the extent of contamination in soil, water, and crops and the health risks for communities living near dumpsites (Nickson et al., 2024). Consequently, managing and supervising waste is becoming challenging in every phase (Bouhadiba et al., 2014).

Over the past few decades, the population of Algeria's major cities has grown, mainly as a result of rapid urbanization. It is the larger cities, particularly the coastal ones that have received most of the rural migrant

population. Algerian urban areas are facing a situation, with rapid urban growth and uncontrolled urbanization leading to a rise in household and other types of waste. Local authorities are faced with the challenge of maintaining a better quality of public services in the context of household waste management, as waste production per inhabitant in some cities has risen to around 1 kg per day. Thus, and according to the National Waste Agency (2020), Algeria treats only 9.83% of its MSW while the rest is dumped in landfills (AND, 2020). In recent years in Algeria, there has been a new dynamic and government determination to address the waste issue comprehensively, considering the gravity of the problem and the various political, social, cultural, and environmental implications. Nevertheless the lack of waste characterization data - which is a prerequisite for any management strategy - and the difficulty of updating this data if necessary, due to the exorbitant costs of the methodologies used are the main constraints on the implementation of effective, sustainable waste management policies in developing countries. Precise and comprehensive information about Municipal Solid Waste (MSW) composition and its environmental effects is crucial in tackling these obstacles. It is within this context that this study is intended to contribute to the decision-making process by providing reference data on the composition of municipal waste in Batna. Then we choose the MODECOM method created by the French Environment Agency (ADEME), to identify and highlight important waste for improving municipal solid waste management and treatment approaches. This knowledge is important both for prevention initiatives and for optimizing recycling processes. It is a real decision-making aid for technical and organizational choices, and for monitoring policies. On a national level, it provides an up-to-date reference for the characterization of MSW.

2. Methodology.

Characterization of Batna's household waste is one of the most important levers in household waste management. Our work will focus on the composition of household waste in the city of Batna in 2023, as well as its distribution according to standing categories (high, medium, and low). We will also compare Batna's waste composition with that of other cities in different regions of Algeria, in order to highlight differences in consumption habits and waste production between these regions. A further aspect of our study is to track changes in waste composition between 2009 and 2023 in Batna. This enables us to understand changes in waste composition over time, and to identify factors that may influence these variations.

MODECOM is a method developed by ADEME the French Environment Agency to determine the composition of waste collected by the public service in a defined geographical area (ADEME, 1994). In concrete terms, waste samples are taken according to standardized protocols (and an adapted sampling plan) and then sorted on a sorting table into different categories (putrescible waste, paper, cardboard, plastics, etc.). In order to provide a detailed characterization of household waste in Batna, and to highlight the influence of the population's standard of living on its composition, we carried out a quantitative and qualitative analysis of waste according to a relatively complete inventory of 13 categories. Plastics are sorted into 3 sub-categories (PET (Polyethylene Terephthalate), HDPE (High Density Polyethylene) and others). Metals are sorted into 2 sub-categories (Iron and Aluminum), textiles into 2 sub-categories (disposable diapers and other textiles) and finally, other waste fractions are sorted by presenting hazardous waste. Site selection is a crucial step to ensure the representativeness and reliability of study results. It is essential to select sites according to a stratification approach, which requires a good knowledge of the waste in the target group (in our study households) to be sampled. Sampling in different districts of different standing (high, medium and low standing) during a waste characterization allows to capture the potential variations in the composition of waste depending on the type of habitat and socio-economic level. Each category of neighbourhood may have different characteristics in terms of lifestyle, consumption and waste generation.

2.1. Background.

Batna province is located in northeastern Algeria, in the Aures region, 410 km from the capital Algiers at an altitude of 900 m above sea level. It covers an area of 12038 km² and a population of 1,307,000 and the population growth rate is 1.6%. Batna city is the main city of Batna province, and is the fifth largest city in Algeria with 375,000 inhabitants, and Algeria's highest urban area. The evolution of the population of the city of Batna has known several important stages. In 1966, the population of the city was only 55.017. However, during the 1970s, rapid urbanization led to a massive exodus of the rural population to the city, resulting in significant population growth. Batna's population growth was among the highest in the region with 98.962 in 1977. In 2008, Batna's population reached a remarkable 290.645 and in 2012 was 314.395 (Bendib, 2022). According to 2021 statistics from the National Statistics Office (NSO), the population of the city of Batna has continued to grow, reaching around 361,544 inhabitants. However, uncontrolled urban development and strong

population growth have led to environmental problems such as air pollution, excessive water and energy consumption, and waste production.

2.2. Trends in household waste production in the city of Batna.

The evolution of household waste production in the city of Batna has been significant over the last few decades, due to the rapid growth of its population. According to data from the 2008 General Census of Population and Housing (RGPH), the city had 290,645 inhabitants, but this number has continued to rise, reaching 361,544 in 2021, according to the National Statistics Office. This increase in population has naturally led to an increase in the production of household waste in the city.

In order to better understand the impact of this development, we can also refer to data provided by the Company for the Management of the Landfill of Batna city. According to this data, annual waste production in the city reaches 107367.7 tons. With a population of 361,544 in 2021, this means that, on average, each inhabitant of Batna produces around 0.297 tons of waste per year. Given the population growth rate of 1.7% over the last decade, we have examined the data provided by the Batna landfill site to create the table below.

Table 1.
Evolution of waste production and population in Batna city

Year	2011	2013	2015	2017	2019	2021
Population	309141,6	319741,7	330705,3	342044,9	353773,3	361544,0
Waste production (T/ans)	71291,7	74752,75	99289,2	92287,57	107399,3	107367,7

Examination of the data shows a slow rise in waste generation in Batna through the years. The amount increased from 71291.7 tons in 2011 to 107367.7 tons in 2021. Several factors can be credited with causing this rise. One of the main factors contributing to the rise in waste production in Batna is its continuous population growth. As the population continues to grow, there is a higher need for consumer products and services, leading to more waste being produced. Urbanization and economic growth have also played a role in this rise. The increase in waste is a direct result of the growth of commercial, industrial, and residential activities. Modifications in behaviors and consumption habits, like the rising usage of single-use items and disposable products, have also influenced the amount of waste generated. In 2021, Batna's per capita waste production is almost in line with the national average of 0.8 kg per person per day, at 0.81 kg per day (National Waste Agency, 2020). This indicates that the city encounters comparable waste disposal difficulties as other parts of the country.

3. Results and Discussion.

The results of characterization analysis of Batna's household waste are presented in Table 2. This breakdown of waste shows that the organic fraction represents the largest share by wet weight composition, averaging 55% in Batna. This fraction is followed by textiles and plastics. The other components vary slightly from one another in small proportions.

Table 2.
Characterization household waste in Batna city (2023)

Fraction		**Household Waste in Batna city in 2023 (%)**
Organic Matter		54.8
Plastics	PET	8.76
	HDPE	1.82
	Others	3.54
Paper / Cardboard	Paper	5.55
	Cardboard	5.19
Metals	Fer	1.32
	Al	0.32
Textiles	Sanitary textile	10.04
	Other	5.32
Glass		1.43
Others	Hazardous waste	1.78
	Others	0.13
Total		100 %

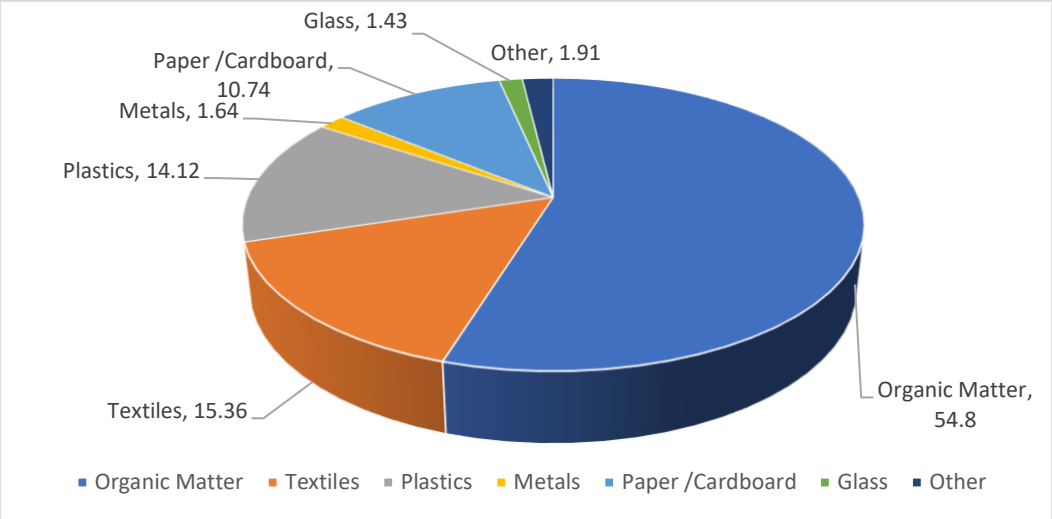

Fig. 1. Composition of Batna's household waste (Year 2023)

The percentage results of the physical characterization of household waste in the city of Batna reveal the distribution of different types of waste. Organic matter is the dominant category, accounting for 54.80% of waste, including vegetable scraps, rotting fruit, bread and gardening waste. Plastic waste is also present, with PET (8.76%) coming mainly from water and beverage bottle packaging, and HDPE (1.82%) including detergent packaging. Other plastics (3.54%) include various types of plastic not specifically classified. The paper/cardboard category includes paper (5.55%) and cardboard (5.19%), while metals, such as iron (1.32%) and aluminum (0.32%), come mainly from packaging and cans. Textile waste is divided into sanitary textiles (10.04%), which include items such as disposable diapers, sanitary cotton and similar hygiene products, and other textiles (5.32%), which include old clothes, used shoes and other textile items. Glass (1.43%) includes glass bottles, jars and crockery. Finally, miscellaneous waste includes special waste (0.13%) requiring special attention, as well as other types of unspecified waste (1.78%).

We also developed another aspect of our work, which looked at the distribution of waste by standing in the city of Batna. Waste was separated into three categories: high-standard, medium-standard and low-standard. It was then sorted and weighed. Table 3 summarizes the results of the composition of Batna's household waste by standing (Year 2023).

Table 3.
Composition of Batna's household waste by Standing

Standing / Fraction	Low standing (%)	Medium standing (%)	High standing (%)
Organic Matter	59,12	55,12	50,18
Paper / Cardboard	5,96	7,79	18,47
Plastics	11,01	15,14	16,22
Metals	1,65	1,29	2
Textiles	19,84	16,67	9,57
Glass	1,01	1,42	1,88
Others	1,41	2,57	1,68

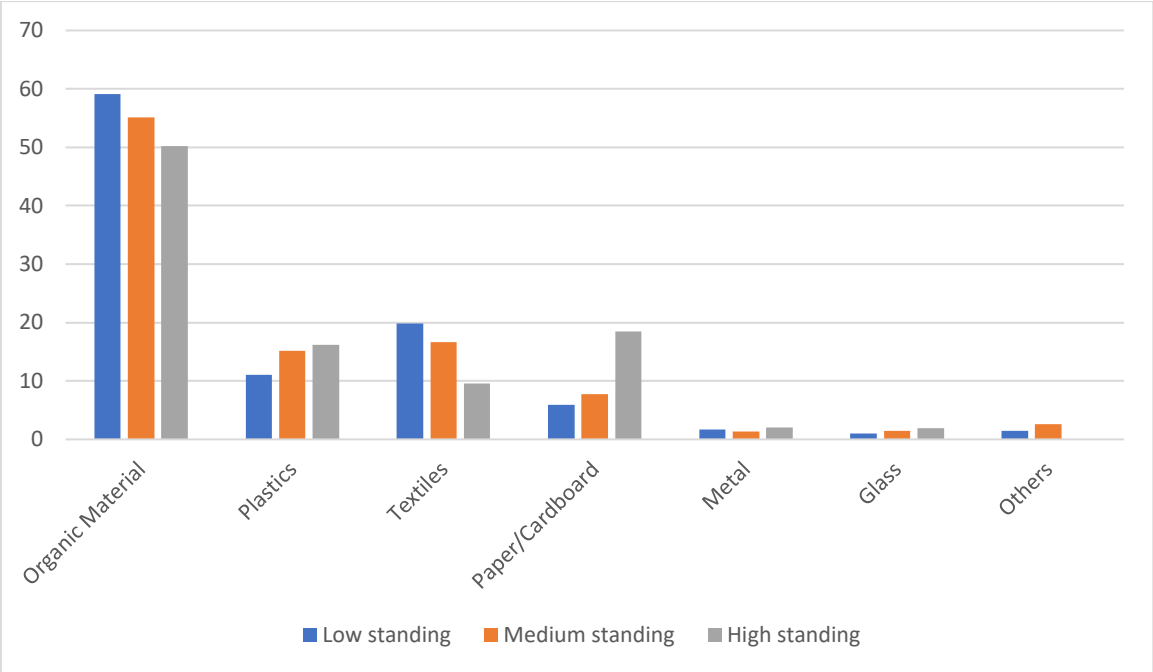

Fig. 2. Average daily composition of household waste in Batna by category and standing in %.

The results by standing show some significant differences. Looking at the percentages, we can see that low-rise housing has the highest proportion of organic matter at 59.12%, followed by medium-rise housing at 55.12% and finally high-rise housing at 50.18%. This suggests that low-rise residents generate a greater quantity of organic waste than other categories, and that this quantity is less proportional to other types of waste.

As far as other types of waste are concerned, there is a progressive increase in the percentages of paper/cardboard and plastic as standing increases, which is directly linked to lifestyle. This may be due to the fact that households in higher-status categories tend to consume more products packaged in paper and cardboard, as well as in plastic and metal, reflecting the presence of this waste in their garbage.

On the other hand, the proportion of textiles decreases as standing increases, which can be attributed to a greater preference for higher-quality, longer-lasting textile products in the higher-standing categories, thus reducing the amount of textiles thrown away. It is also interesting to note that the proportion of glass and metal waste remains relatively low across all standings.

3.1. Comparison of the composition of household waste in the city of Batna with other Algerian cities.

The composition of household waste can vary considerably from one country to another, from one region to another, and even from one city to another within the same country. Using the data collected during the literature search, we will compare the composition of household waste in the city of Batna with that of other Algerian cities (Table 4). The cities chosen for this comparison represent the different bioclimatic stages of the country. The cities are as follows:

- Jijel, Chlef, and Mostaganem (Humid)
- Constantine (Subhumid to Semi-arid)
- Batna and Mecheria (Semi-Arid)
- M'Sila and Nâama (Semi-Arid to Arid)
- Ouargla (Arid to Hyper-Arid).

Table 4.
Physical composition of household waste in selected Algerian cities

Matter / Cities	Organic Matter (%)	Paper/ Cardboard (%)	Plastics (%)	Glass (%)	Metals (%)	Textiles (%)	References
Nâama	76.3	3.97	8.38	1.1	-	2.64	(Youb et al., 2014)
Mecheria	66.91	6.16	11.32	4.52	-	2.01	(Youb et al.,2014)
Chlef	77.2	6.2	6.5	2.1	1.5	11.06	(Tahraoui et al., 2012)
Mostaganem	65.5	13	7	4	3.5	3	(Guermoud et Addan, 2014)
Jijel	58.5	6.22	14.4	0.46	1.37	2.62	(AND, 2020)
Constantine	74	08	15	0.7	01	2	(Kouloughli et kanfoud, 2017)
M'sila	74.8	6.2	6.3	0.3	0.6	2.1	(Naghel et al., 2022)
Batna	56.84	17.75	10.9	1.81	1.22	10.3	(Sefouhi et al., 2010) (AND, 2020)
Ouargla	48.53	6.82	16.57	1.58	2.76	18	

A comparison of household waste components in different Algerian cities reveals the following observations.

Organic matter dominates in all Algerian cities, with percentages ranging from 48.53% to 74.8%. However, there is a slight decrease in the proportion of organic matter in the hyper-arid zone of Ouargla. These cities are characterized by a higher proportion of organic matter due to the presence of gardens, orchards and greater agricultural activity. More arid regions, such as Ouargla, may have a slightly lower proportion of organic matter (48.53%). Plastic and textile waste increases as we move from humid to hyper-arid zones. Plastic percentages vary from 6.5% to 16.57%, while textile waste percentages range from 2% to 18%. The variation in the percentage of paper/cardboard between different Algerian cities is also notable, ranging from 3.97% to 17.75%. The amount of plastic and textile waste is gradually increasing from humid to hyper-arid zones and also for the economic development of the city. This increase is mainly attributable to higher consumption of plastic water bottles in warmer regions, as well as increased use of textile products due to hygiene needs and specific climatic conditions. The differences in the percentage of paper and cardboard waste between Algerian cities are mainly influenced by consumption habits and recovery rates specific to each city.

3.2. Evolution of the composition of household waste in the city of Batna.

Changes in the characterization of household waste in Batna varied for some materials. Table 5 shows the evolution of household waste composition in Batna for 2009 and 2023.

Changes in the composition of Batna's household waste between 2009 and 2023 show some interesting trends. The proportions of different waste categories have varied significantly, reflecting changes in consumption habits. There has been a slight but noticeable decrease in the proportion of organic matter, which has fallen from 56.84% in 2009 to 54.80% in 2023. This may be linked to changes in the population's consumption patterns: more consumption of plastic and cardboard packaging, and also a considerable increase in textiles and especially disposable diapers. The other fractions have not changed significantly.

Table 5.
Evolution of the composition of Batna's household waste (2009 and 2023)

Fraction		Household waste in Batna in % (Sefouhi et al., 2010)	Household waste in Batna in % (2023)
Organic Matter		56.84	54.8
Plastics	PET	1.41	8.76
	HDPE	0.67	1.82
	Other	8.82	3.54
Paper / Cardboard	Paper	15.03	5.55
	Cardboard	2.72	5.19
Metals	Iron	1.22	1.32
	Al		0.32
Textiles	Sanitary textile	7.88	10.04
	Other	2.30	5.32
Glass		1.81	1.43
Others	Hazardous waste	0.12	0.13
	Other	1.18	1.78
Total		100 %	100%

3.2. Management strategies for the Municipal waste of Batna city.

Since 2001, the Algerian government has opted to dispose of waste by burying it in landfill instead of dumping it in uncontrolled dumps which had been the only method of treatment, reflecting a real awareness of the need to protect the environment and the need for integrated management of solid urban waste. However, as soon as they're built, these landfills are already outdated, creating environmental and health problems due to inexorable quantities of waste and poor technical management that is totally unsuited to the type of waste being treated. These landfills are creating environmental and health problems due to their poor technical management, which is totally unsuited to the type of waste to be treated. They are a source of leachate leaks, emissions, odors, wildlife, landscape alteration and probable contamination of groundwater. The impact on the environment, ecology and health of neighboring populations is assessed by specialists as quite worrying. Numerous university studies on the technical and environmental management of these landfills confirm that the minimum conditions for the storage and recovery of household waste are neither met nor applied. Which is the case of the Landfill of Batna city. The significant increase in the quantities of waste coming from Batna's various communes and going to the Technical Landfill Centre underlines the urgent need for action to effectively manage this growing production of waste. With this in mind, it is imperative to implement sustainable and effective solutions to reduce our environmental footprint, promote recycling and preserve natural resources. Therefore, we present a number of concrete proposals for improving waste management, such as promoting selective sorting, developing composting and encouraging the reuse of recyclable materials. These actions, when implemented in a concerted manner, will help to create an environmentally-friendly circular economy and address the challenges posed by waste management in the city of Batna.

- Eco-citizenship

Eco-citizenship is an essential solution for promoting responsible waste management in the city of Batna. It is based on the idea that each individual has a role to play in preserving the environment and reducing his or her ecological footprint. By adopting an eco-citizen approach, Batna residents can take concrete steps to reduce the amount of waste produced on a daily basis. This can include simple but effective actions such as reducing excessive consumption, reusing objects rather than throwing them away, and using durable and reusable products.

Selective sorting is also a key aspect of eco-citizenship. By correctly separating recyclable waste such as plastic, paper and glass, Batna residents can facilitate the recycling process and help preserve natural resources. It is important to raise awareness of the importance of selective sorting and to provide adequate infrastructure, such as clearly identified recycling bins in residential areas.

- Biological recovery

Organic waste is the predominant component of waste in Batna, accounting for 54.8%. Composting is a tried-and-tested solution for effectively recovering this organic waste. Composting is the natural process of

decomposing organic waste such as food scraps and garden residues, transforming them into a rich organic amendment known as compost. This method converts waste into a valuable resource for improving soil fertility. By promising private investment in heap composting, we are transforming organic waste into a valuable resource, fostering economic development and contributing to the transition to a sustainable, circular economy. This approach is also cost-effective, offering a win-win solution both environmentally and economically.

- Recycling

Recycling of recyclable materials such as plastic, paper, cardboard, glass and metals is very important for promoting sustainable waste management in Batna. Although Batna has been able to efficiently recover metals from the source, mainly those from the Public Works sector, there is still work to be done for other materials. It is essential to apply the same approach to other recyclable materials, especially cardboard. The recovery rate of cardboard in Batna is lower than that of other Algerian cities. Thus, it is crucial to increase the recovery at source by working closely with merchants and the general population. By implementing awareness programs and strengthening the selective collection infrastructure, the recovery rate of cardboard in Batna can be significantly improved. It is also important to highlight the recent increase in plastic waste. To meet this challenge, it is necessary to encourage private companies specialized in recycling and collecting plastics in Batna. By supporting these companies and promoting their development, it is possible to better manage plastic waste and recycle it in a responsible way.

4. Conclusions.

The characterization of household waste in the city of Batna reveals interesting data on the evolution of waste production over time. The rapid growth of the city's population has led to a significant increase in waste production, rising from a ratio of 0.56 kg per inhabitant per day in 2009 to 0.81 kg per inhabitant per day in 2021. This increase can be attributed to the rise in consumption and changes in the lifestyle habits of Batna residents. By analyzing the composition of the waste, it is clear that organic matter dominates, representing 54.80% of the total waste. Textiles occupy the second position with 15.36% of the composition of household waste. Plastic waste ranks third in terms of composition, accounting for 14.12% of the total waste. As for paper/cardboard, it represents 10.74% of Batna's household waste. The other categories of waste also constitute a significant proportion of the total mass. When examining the distribution of waste by socio-economic status, significant differences are observed. Residents of lower socioeconomic status generate a larger amount of organic waste compared to other socioeconomic categories, which may be related to different dietary habits and limited access to packaged products. The higher-end categories, on the other hand, produce a greater quantity of paper/cardboard and plastic waste, probably due to a higher consumption of packaged products and consumer goods.

The special feature of the methodology recommended in this research is the study of household waste produced at the household level without suffering the effect of recovery. The data thus obtained are the very basis of any management policy. These are the baseline data from which projections of waste trends can be made because they reflect the reality of the quantities generated and potentially discharged. Thus, the aim of the study on household waste characterization in the city of Batna is to provide essential information and reference data to help local authorities make decisions regarding waste management and treatment. The availability of this data will allow local decision-makers to optimize their choices regarding recovery, recycling and disposal programs.

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