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Solid Waste in Urban Areas: A Multidimensional Statistical Approach on Irregular Disposal and Burning in the Municipality of Governador Valadares, Minas Gerais

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ABSTRACT

The improper disposal of urban waste is a global concern, especially in large cities considering aspects of environmental and visual pollution. This study provides a detailed analysis of the municipality of Governador Valadares, Minas Gerais, identifying local nuances and a better understanding of this issue to support decisions for corrective actions. It assesses the persistence and incidence of waste burning at irregular disposal sites in the municipality, emphasizing its environmental and health impacts. This work utilized a combined approach of georeferenced mapping with Google Earth Pro images, complemented by in-situ checks with GPS devices. The statistical analysis of the collected data was performed using the PSPP software. Statistical analyses were supported by contingency tables, the application of the chi-square test, Phi, Cramer's V, and Odds Ratio, evaluating the characteristics of the associations. A strong association was identified between the persistent disposal of solid waste in undeveloped areas and the presence of tree pruning and gardening waste. The research also demonstrated a significant association of areas with signs of burning that were located in public spaces. Additionally, a significant statistical association was confirmed at sites where paper and plastic disposals and burning were identified. This research expands the understanding of disposal practices in urban contexts and provides a replicable model of combined georeferenced analysis with physical checks, in addition to the risks to public health and the environment. The results obtained demonstrate direct implications for waste management policies, raising awareness of the consequences of improper disposal and burning.

KEYWORDS: Sanitation. Chi-square. Mapping.

1 INTRODUCTION

The issue of solid waste management in urban centers is amplified by the growing production and inadequate final disposal of this material, a crucial concern for the contemporary urban environment (GOUVEIA, 1999). ABRELPE (2020) illustrates this dynamic by presenting a portrait of the last decade in Brazil, revealing that since the implementation of the National Policy on Solid Waste (PNRS), established by Law 12.305 in 2010, the generation of urban solid waste (USW) has increased by 19%. The Southeast region is the biggest contributor, being responsible for almost 50% of the waste produced (ABRELPE, 2020).

This increase in USW production and collection, although reflecting advances in collection processes, also highlights the persistence of significant challenges, with improper waste disposal directly impacting 77.65 million Brazilians and incurring environmental and health costs estimated at USD 1 billion annually (ABRELPE, 2020).

Particularly, the construction industry emerges as the main waste generator, accounting for 40% to 70% of the total waste collected daily in many Brazilian cities, overburdening municipal systems and incurring high public costs (CHERNICHARO et al., 2008). PINTO (1999) warned of the imminent pressure of construction and demolition waste (CDW) on Brazilian municipalities, as many were not structured to manage such significant volumes of waste. Even two decades after his research, there is a persistence of improper practices in the handling of CDW in various Brazilian municipalities, indicating limited evolution in the management of urban construction waste.

PINTO (1999) categorized Construction and Demolition Wastes (CDWs) as components of urban solid waste, noting significant gaps in knowledge about volumetric aspects, impacts, costs, and potential for reuse of these wastes. This lack of understanding is often perceived by public managers only when confronted with the insufficiency of palliative measures.

The problem of solid waste management in urban centers is exacerbated by increasing

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Particularly, the construction industry emerges as the main generator of waste, representing 40% to 70% of the total waste collected daily in many Brazilian cities, overburdening municipal systems and incurring high public costs (CHERNICHARO et al., 2008). PINTO (1999) warned of the imminent pressure of construction and demolition waste (CDW) on Brazilian municipalities, as many were not structured to manage such significant volumes of waste. Even two decades after his research, there is a persistence of inadequate practices in the handling of CDW in various Brazilian municipalities, showing limited evolution in the management of urban construction waste.

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ABRELPE (2014), corroborating with PINTO (1999), observed similar restrictions in data collection on CDWs, as municipal records often restrict themselves to municipal works or disposals in public spaces, limiting the understanding of the complete waste disposal scenario. The persistence of this informational deficiency is confirmed by MATIAS (2020), who, through research in Brazilian capitals, identified significant discrepancies between federal data and local information, illustrating the continuity of challenges in solid waste management in Brazil. CHERNICHARO et al. (2008) detail that clandestine waste disposals, often initiated with the disposal of CDWs, evolve to include a variety of debris, transforming areas into degraded sites, generating multiple urban and environmental problems.

MONTEIRO (2017) further highlights that the formation of these irregular disposal areas encourages clandestine dumping of waste by various establishments, due to a lack of proper control and inspection. Therefore, the concern extends beyond the management of CDWs, resonating in the broader and deeper implications for cities and their inhabitants due to improper disposal practices and the persistence of knowledge gaps. The references evidence the presence of a variety of wastes beyond construction and demolition in irregular disposal areas. An under-represented issue in the literature is the practice of burning these wastes, often initiated by accumulations of CDWs.

ARAÚJO (2017) characterized waste in Londrina/PR, showing that the majority (87%) was CDW and 13% comprised other wastes. SCHALCH et al. (2002) report that open-air waste burning is an outdated practice to mitigate organic decomposition, avoiding vectors and odors, turning disposal areas into places of contamination and public health risk. CHERNICHARO et al.

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(2008) reiterate the risks, linking the practice to the resurgence of diseases, vector proliferation, and environmental degradation.

Palliative measures adopted by municipalities, such as debris removal, have proven to be ineffective and tend to encourage irregular disposals (PINTO and GONZÁLEZ, 2005). PINTO (1999) argues that without a solid foundation of information on urban solid waste (USW), there is no effective resolution to the problem of irregular disposal and waste burning. Such practices adversely affect both the environment and the quality of urban life, with significant implications for public health and the proliferation of diseases. Solutions to these problems require a multifaceted and in-depth approach to understand the underlying dynamics.

A meticulous analysis, combined with rigorous analytical approaches, is crucial for designing effective and informed intervention strategies, essential for policymakers, urban planners, and communities.

Furthermore, solid waste management is crucial for the UN's Sustainable Development Goals, making studies on this theme not only relevant but urgent, in the face of global urbanization and the climate impacts associated with inadequate waste management. This work aims to provide a holistic and substantiated view of the issue, hoping to instigate significant changes towards more sustainable and responsible practices.

2 OBJECTIVES

The article aimed to conduct a study on the irregular disposal of urban solid waste that affects the contributing basin formed by the urban perimeter of the Municipality of Governador Valadares/MG, in order to investigate the multiple dimensions and factors associated with the irregular disposal and burning of solid waste in urban areas, employing analytical and statistical approaches to understand its complexity and interrelations. To achieve this goal, the following specific objectives were set:Realização de mapeamento georreferenciado dos pontos de incidência de descarte irregular ocorridos dentro do perímetro urbano do Município de Governador Valadares:

a) To carry out georeferenced mapping of the points of incidence of irregular disposal occurring within the urban perimeter of the Municipality of Governador Valadares;

b) To evaluate the intrinsic characteristics of the disposed solid waste, focusing on the management of different types of waste, supported by statistical analyses such as Contingency Tables, Chi-square, Linear-by-Linear, Phi and Cramer's V, and Odds Ratio;

c) To analyze the influence of apparently secondary or not directly significant variables on the dynamics of disposal and burning of solid waste, investigating their possible moderation or mediation in the main effects, using relevant statistical analyses.

d) To develop an integrated understanding of the interaction between the various contributing factors, with the purpose of providing a solid foundation for future management initiatives and sustainable solutions, utilizing a multidimensional statistical approach.

3 METHODOLOGY

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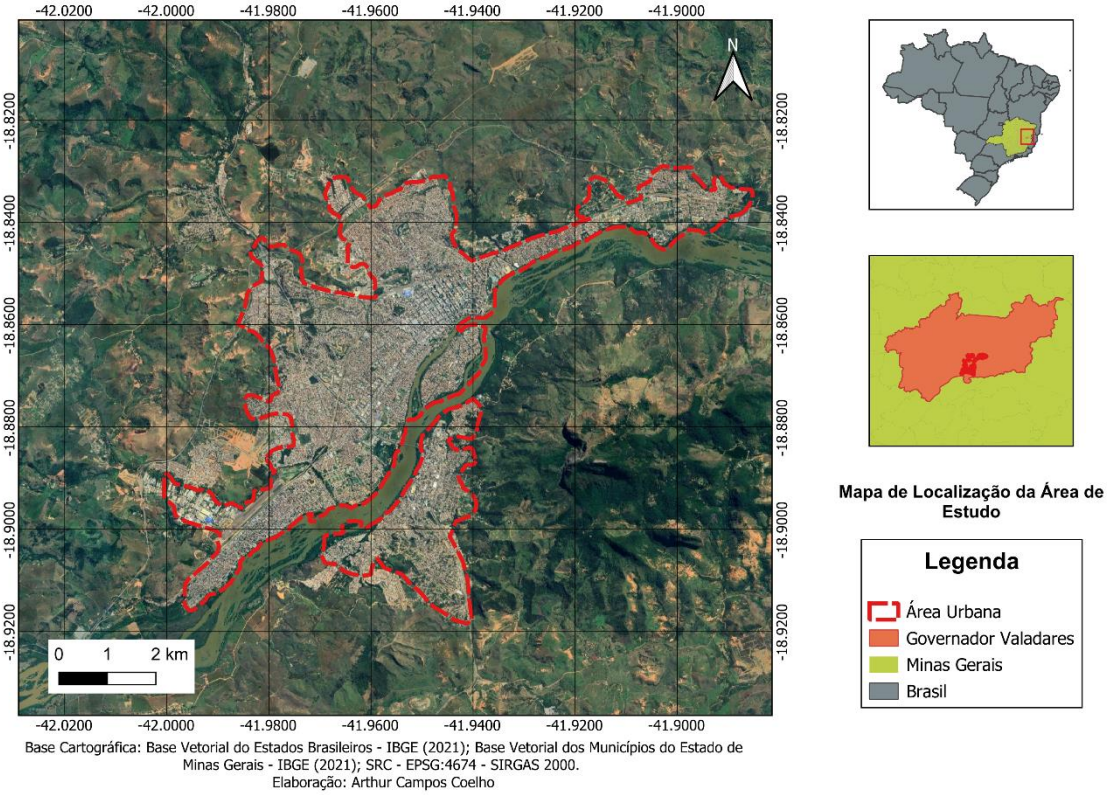
The study focuses on the municipality of Governador Valadares, located in the mesoregion of the Vale do Rio Doce, to the east of the state of Minas Gerais (IBGE, 2010). The city is about 320 km northeast of the capital, Belo Horizonte. It has a total area of 2,342 km², of which 24.37 km² are delineated as the urban perimeter, as demonstrated in the Location Map (Figure 1). In addition to leading a microregion composed of 24 municipalities, Governador Valadares is recognized as a regional economic hub of significance, influencing various areas, including regions of Espírito Santo (MINAS GERAIS, 2015). In this work, attention was specifically focused on the urban perimeter of Governador Valadares, as per the location map (Figure 1).

Figure 1 - Location Map of the Study Area



Source: Developed by the author using IBGE vectors (2021), QGIS 3.32.1, and Google Earth Pro (2023).

The mapping of irregular disposal in Governador Valadares/MG was meticulously carried out through a combined approach of remote and on-site analyses, utilizing resources such as Google Earth Pro and GIS[1] for image analysis, complemented by field inspections and GPS use for areas obscure in the images. Initially, various predominant factors for irregular disposal were considered, such as proximity to road axes, type of area (private or public), the socioeconomic condition of the region, and inclusion in Permanent Preservation Areas, integrating municipal data and using various analytical tools.

[1] QGIS 3.32.1 is a free and open-source software for Geographic Information Systems (GIS), used to create, edit, view, analyze, and publish geospatial information. Google Earth Pro is a platform that allows viewing a detailed digital model of the Earth, based on satellite imagery, aerial photos, and GIS data.

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The goal was to obtain a comprehensive and detailed view of the patterns and motivators of irregular waste disposal in the region. The analysis involved detailing the location and characteristics of disposal areas through the Municipal geoprocessing system and Google Earth, allowing for the generation of detailed thematic maps.

The socioeconomic categorizations and predominant use of properties in the region were based on local legislation. After data collection, a physical characterization of disposal points was carried out, observing different categories of waste and signs of burning. The data were then prepared for analysis in the PSPP[2] software, enabling the execution of various statistical tests. At this stage, categorical variables were coded, and 2x2 contingency tables[3] were created, essential for understanding the interaction between variables.

Pearson's chi-square[4] tests were conducted to evaluate the independence between categorical variables. The relative risk (odds ratio)[5] was also calculated, and Phi and Cramer's V[6] correlation coefficients were applied to measure the strength and direction of associations. The exploratory analysis was structured into two main groups, focusing on the key variables of persistent disposal and incidence of waste burning, crossed with a set of location and socioeconomic condition variables.

The systematic and structured approach adopted allowed for a deep understanding of the complex dynamics of irregular waste disposal. Despite the significant insights obtained, the identified associations do not directly indicate cause-and-effect relationships, requiring careful interpretation and consideration of possible unobserved confounding variables. However, the results obtained are important for informing future strategies to mitigate irregular disposals in the studied region.

4 RESULTS

Upon completing the investigation phase, a map was prepared showing the distribution of irregular waste disposal sites in the urban area of Governador Valadares (Figure 2).

[2] PSPP is a free software for data analysis, similar to SPSS. It is used for statistical analysis of sample data, including operations like cross-tabulations, frequency analyses, hypothesis testing, and more.

[3] 2x2 contingency tables are used in statistics to examine the relationship between two categorical variables, providing a basis for hypothesis testing.

[4] The Pearson chi-square test is a statistical test that assesses whether there is a significant association between two categorical variables. It is commonly used to compare observations of observed frequencies in categories with expected frequencies. In the context of this study, the test helped identify relationships between characteristics of disposal areas (such as proximity to major roadways and socioeconomic conditions) and the incidence of irregular disposal and burning of waste.

[5] Odds Ratio is a measure of association that describes the ratio between the odds (chances) of an event occurring in one group relative to the odds of the same event occurring in another group. In the case of this study, it was used to quantify the strength and direction of the association between the presence of certain types of waste (such as plastic or paper) in disposal locations and the probability of these locations exhibiting waste burning.

[6] Phi and Cramer's V are measures of association for contingency tables. The Phi coefficient is used for 2x2 tables, while Cramer's V can be applied to tables of any size, indicating the strength of the association between categorical variables.

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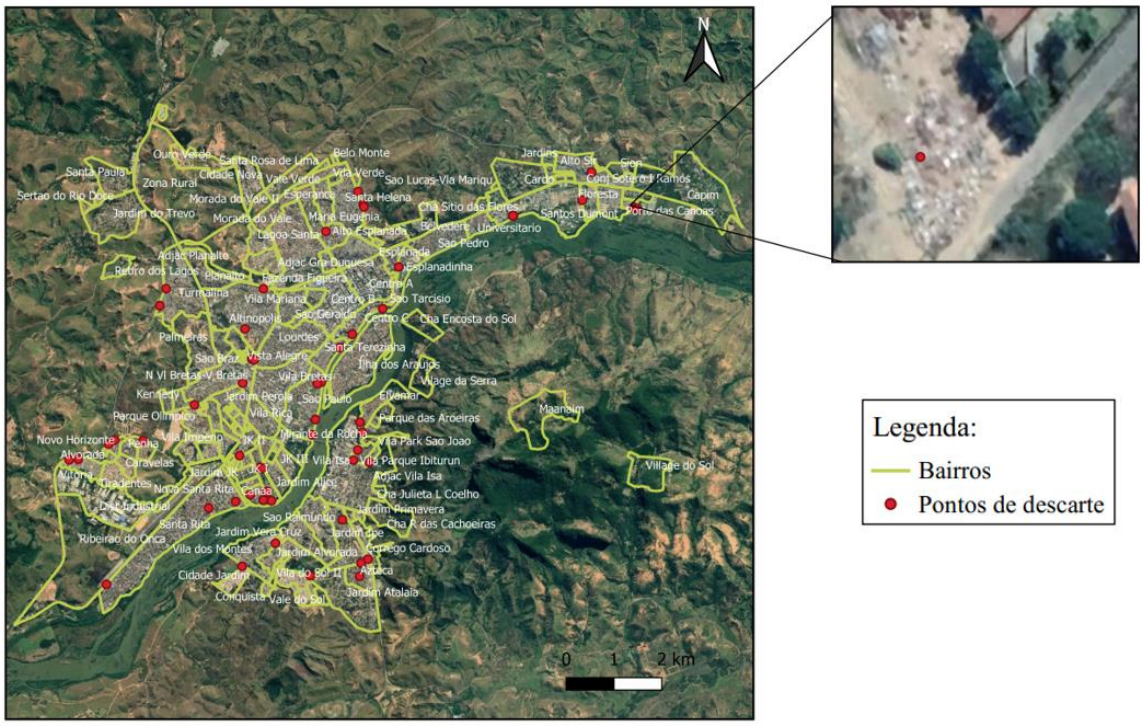
Figure 2 - Map of Construction and Demolition Waste Distribution



Source: Developed by the author using IBGE vectors (2021), QGIS 3.32.1 (2022), and Google Earth Pro (2023).

Through the photo-interpretation of satellite images, it was possible to identify 55 areas suspected of irregular disposal, of which 42 were later confirmed through in-situ inspections. For each of these 42 areas, a checklist was applied aimed at analyzing the pre-established variables, compiling a photographic report, and drawing up a specific location map.

Among the confirmed areas, it was found that 31% were located near major roadways, and 45% were located in Permanent Preservation Areas (PPA). Significantly, 74% of the disposal areas were under public jurisdiction. About 86% of the identified sites were in lowland zones, and a similar proportion was characterized by residential use of the surrounding properties.

Regarding the physical characteristics of the land, 93% of the areas were undeveloped, and, proportionally, persistent disposal was highlighted, underlining the recurrent nature of the phenomenon in question.

The in-situ inspection provided a detailed assessment of the variety of waste present at the disposal sites. Hazardous waste was detected in 17% of the sites, while electronic waste was identified in 29%. Metallic and gypsum waste were recorded, respectively, in 36% and 38% of the areas examined. The presence of styrofoam and rubber was observed in 45% of the points, organic waste in 55%, glass in 62%, and tree pruning and gardening waste in 71%. In 81% of the areas, signs of burning and the presence of paper and construction and demolition waste were observed, while the incidence of plastic was verified in 86% of the points. Notably, wood was the most recurrent waste, detected in 96% of the inspected areas.

Graphs 1 and 2 present a more detailed and quantitative visualization of the collected data, facilitating the interpretation and analysis of the patterns and distributions of different types of waste and the locations of irregular disposal sites analyzed.

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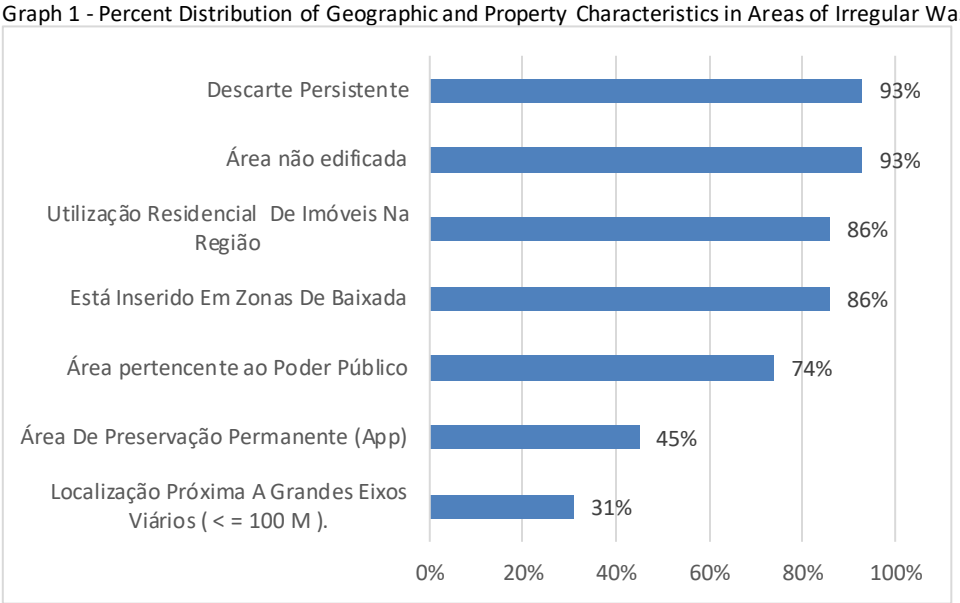
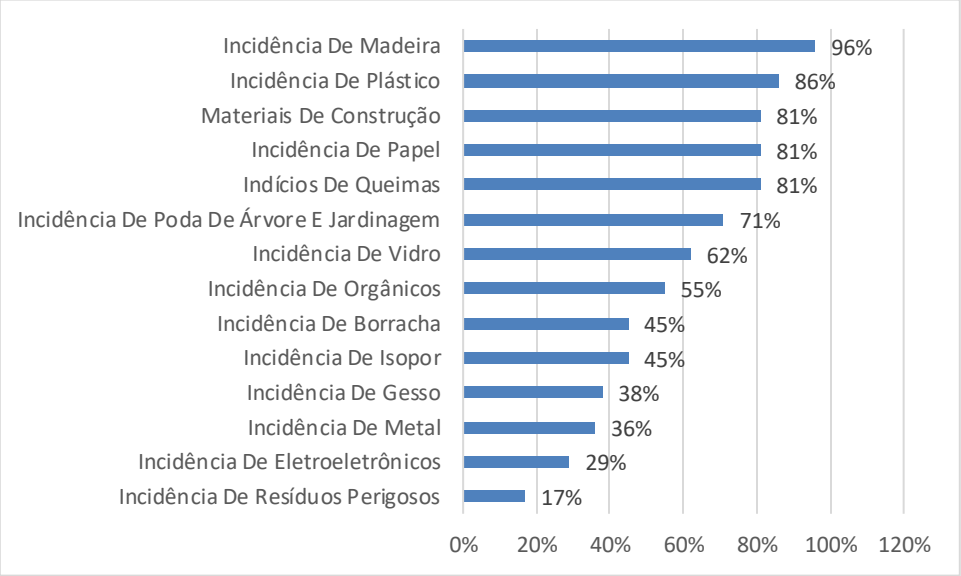
Graph 1 - Percent Distribution of Geographic and Property Characteristics in Areas of Irregular Waste Disposal



Source: Author.

Graph 2 - Percent Distribution of Types of Waste and Incidences of Burning at Irregular Disposal Sites



Source: Author.

To capture the underlying complexity of these areas and provide an accurate representation of the problem, the findings were organized into a unified tabular format. Here, Contingency Tables and statistical analyses using Chi-square, Linear-by-Linear, Phi and Cramer's V, in addition to Odds Ratio, are highlighted. Following, some of the main results of the analyses performed are presented, organized with the aim of providing a robust, data-based starting point for addressing the issue of persistent irregular disposals and the burning of waste disposed of in inappropriate locations (Table 1).

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Table 1 - Statistical Analysis Using Persistent Disposal Areas as the Main Variable

Persistent irregular waste disposal areas in built or unbuilt locations	
Analysis of Contingency Tables	**Chi-square, Linear-by-Linear, Phi and Cramer's V, and Odds Ratio Analyses**
Although built areas represent only 2.6% of the total persistent disposal, a third (33.3%) of these specific areas exhibit this behavior. However, persistent disposal is overwhelmingly dominant in unbuilt areas, accounting for 97.4% of all persistent disposals, with all (100%) of these unbuilt areas showing recurrence in disposal. Furthermore, while 66.7% of built areas do not show persistent disposal, interestingly, no unbuilt area falls into this category, indicating that once disposal occurs in an unbuilt area, it tends to persist.	The results of the Chi-square and Linear-by-Linear tests are statistically significant ($p < 0.05$), suggesting that persistent disposal is strongly associated with Unbuilt Area. Moreover, the correlation values (Phi and Cramer's V) were high (0.81), indicating a strong correlation between the two variables. The Odds Ratio for persistent disposal was 0.00 for Built Area, suggesting that persistent disposal is much less likely in Built Areas than in Unbuilt Areas.
Persistent Irregular Waste Disposal Areas in Regions of Low or Not Low Socioeconomic Condition	
Analysis of Contingency Tables	**Chi-square, Linear-by-Linear, Phi and Cramer's V, and Odds Ratio Analyses**
In areas with low socioeconomic conditions, persistent disposal was observed in 93.9% of areas, accounting for 79.5% of all recorded persistent disposals. In contrast, in areas of not low socioeconomic conditions, all (100%) registered persistent disposal, even though they represent only 20.5% of the total persistent disposals. Conversely, in areas with low socioeconomic conditions, only 6.1% of areas did not show signs of continuous disposal. However, no areas without persistent disposal were recorded in not low socioeconomic condition areas.	The Chi-square and Linear-by-Linear analyses did not show a statistically significant association ($p > 0.05$), suggesting that persistent disposal is not necessarily associated with socioeconomic condition. Furthermore, the correlation value (Phi and Cramer's V) was 0.11, indicating a very low correlation between the two variables. The odds ratio for persistent disposal was 0.00 for not low socioeconomic conditions and infinite for low socioeconomic conditions, suggesting that persistent disposal is infinitely more likely in low socioeconomic conditions than in not low conditions.
Persistent Irregular Waste Disposal Areas in Residential or Commercial Regions	
Analysis of Contingency Tables	**Chi-square, Linear-by-Linear, Phi and Cramer's V, and Odds Ratio Analyses**
In residential properties, 89.7% exhibited persistent disposal, and this percentage represents 97.2% of the total residential properties with persistent disposal. This suggests that among residential properties that engage in disposal, recurrence is a very common occurrence. On the other hand, in commercial properties, 10.3% had persistent disposal, constituting 80% of the total commercial properties with persistent disposal. This indicates that, even though persistent disposal is less prevalent in commercial properties compared to residential ones, when it occurs, it is likely to continue. When looking at properties without persistent disposal, 50% are categorized as residential, representing only 2.8% of the total residential properties. However, 50% of commercial properties are without persistent disposal, representing 20% of the total commercial properties.	The majority of cases (95.1%) exhibited persistent disposal, with the majority of these (89.7%) occurring in residential properties. The Chi-square and Linear-by-Linear tests returned p-values of 0.094 and 0.098, respectively, indicating that there is no significant association between persistent disposal and the use of the properties. The correlation value (Phi and Cramer's V) was 0.26, indicating a weak correlation between the variables. The Odds Ratio for persistent disposal was 8.75 for residential properties and 1.09 for commercial properties, suggesting that persistent disposal is more likely in residential than in commercial properties. However, this result is not statistically significant.
Persistent Irregular Waste Disposal Areas at Sites Where Pruning Waste is Discarded	
Analysis of Contingency Tables	**Chi-square, Linear-by-Linear, Phi and Cramer's V, and Odds Ratio Analyses**
At sites where pruning waste was discarded, the rate of persistent disposal is 76.9%. Notably, this rate represents 100% of the sites that had pruning waste disposal, indicating that all sites with pruning had persistent disposal. In contrast, at sites without pruning waste disposal, persistent disposal was observed in 23.1% of the sites, and this percentage	The majority of persistent disposals occur where there is pruning (100%). The p-value is less than 0.05, indicating a significant association between persistent disposal and the presence of pruning waste. The correlation is moderate. The Odds Ratio of +Infinity indicates that persistent disposals are much more likely where there is pruning waste.

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corresponds to 81.8% of the total sites without pruning and with persistent disposal. When examining sites without persistent disposal, it was observed that none of them had pruning waste disposal (0% for both criteria related to pruning). On the other hand, 100% of the sites that did not have persistent disposal did not have pruning waste disposal, representing 18.2% of the total sites without pruning waste disposal.

Source: Author.

The analysis of persistent disposal reveals different patterns and tendencies across various types of areas and socioeconomic contexts, as well as in the presence of different types of waste. It is observed that persistent disposal is more prone in public and unbuilt areas, highlighting a concerning trend in easily accessible and less supervised locations. Such areas, predominantly, represent 97.4% of all persistent disposals, indicating a strong and significant association with the unbuilt nature of the areas.

Regarding socioeconomic condition, a high prevalence of persistent disposal is notable in areas of low socioeconomic condition, reaching 93.9%. However, surprisingly, areas of not low socioeconomic condition also displayed a 100% rate of persistent disposal, signaling that the problem is widespread, although these areas represent a smaller proportion of the total disposals. Nonetheless, statistical tests do not significantly associate socioeconomic condition with persistent disposal, indicating that additional factors may be influencing this dynamic.

Exploring the characteristics of properties, it is found that persistent disposal is highly prevalent in residential property areas, with 89.7% exhibiting this behavior. Commercial properties, on the other hand, have a lower rate of persistent disposal, but once established, the disposal tends to persist. The statistical correlation between property category and persistent disposal is not significant, suggesting that other underlying factors may be at play.

Regarding different types of waste, pruning waste stands out for its total congruence with persistent disposal, indicating a significant association. On the other hand, disposals of wood, glass, paper, plastic, metal, Styrofoam, rubber, and electronics do not show robust statistical significance in relation to persistent disposal, although there are variations in the tendencies of persistent disposal for each type of waste, with some of them showing high rates of persistent disposal. The most striking data from this analysis is that in all locations where pruning waste was disposed of, there was also persistent disposal. This total congruence is a strong indication that sites with pruning waste, which often occupy a large volume, have a significantly high propensity to maintain continued disposal practices.

In summary, although various associations between persistent disposal and different factors and types of waste have been observed, statistical significance was, in many cases, absent, suggesting the need for a deeper and more contextual investigation to fully understand the dynamics and underlying influences of persistent disposal in different contexts and situations.

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Tabela 2 - Analysis of statistics using as the main variable irregular waste disposal areas with signs of burning

Analysis of statistics using as the main variable irregular waste disposal areas with signs of burning	
Analysis of Contingency Tables	**Chi-square, Linear-by-Linear, Phi and Cramer's V, and Odds Ratio Analyses**
The incidence of burning in areas close to major axes is quite high, with 92.3% of these areas having signs of burning, which represents 35.3% of the total areas with burning. In contrast, in areas far from major axes, 78.6% had burning, covering 64.7% of the total areas with burning. On the other hand, only 7.7% of the areas near major axes do not have signs of burning, while this percentage rises to 21.4% in more distant areas, corresponding to an overwhelming majority (85.7%) of the total areas without burning.	The Chi-square test and the Linear-by-Linear association test do not indicate a statistically significant association between the two variables, with p-values of 0.277 and 0.283, respectively. The correlation between Burning and Major Axes is low (Phi and Cramer's V = 0.17). The Odds Ratio of 3.27 suggests that burning is about 3.27 times more likely to occur in places with Major Axes than in places without Major Axes.
Incidência de queimas em áreas de disposição irregular de resíduos de domínio público ou privado	
Analysis of Contingency Tables	**Chi-square, Linear-by-Linear, Phi and Cramer's V, and Odds Ratio Analyses**
Both in absolute and relative terms, public areas show a significantly higher incidence of burning compared to private areas. Meanwhile, the proportion of sites without burning in private areas is notably higher, despite still representing a considerable portion of the total sites without burning.	The Chi-square test indicates a statistically significant association between the two variables, with a p-value of 0.047. The Linear-by-Linear association test also indicates a significant association with a p-value of 0.050. The correlation between Burning and Area Type is moderate (Phi and Cramer's V = 0.31). The Odds Ratio of 0.19 suggests that burning is less likely to occur in private locations than in public locations.
Incidência de queimas em áreas de disposição irregular de resíduos em regiões residenciais ou comerciais	
Analysis of Contingency Tables	**Chi-square, Linear-by-Linear, Phi and Cramer's V, and Odds Ratio Analyses**
In properties used for residential purposes, there is a burning rate of 80.6%, and these locations correspond to 85.3% of the total irregular disposals with signs of burning. This suggests that residential areas are significant sites for irregular disposal that results in burning. Commercial use properties show a concerning rate: all irregular disposals (100%) were burned, even though these locations represent only 14.7% of the total burns. Regarding disposals without burning, 19.4% of residential locations had no signs of burning, being all cases (100%) of disposals without burning. Commercial properties, in turn, did not have any records of disposals without burning.	The Chi-square test and the Linear-by-Linear test indicate that there is no statistically significant association between the two variables, with p-values of 0.279 and 0.285, respectively. The correlation between Burning and Property Use is low (Phi and Cramer's V = 0.17). The Odds Ratio indicates that burning does not occur in commercial areas, while it is very likely in residential areas.
Incidence of Burning in Irregular Waste Disposal Areas with the Presence of Wood	
Analysis of Contingency Tables	**Chi-square, Linear-by-Linear, Phi and Cramer's V, and Odds Ratio Analyses**
In disposal areas that contain wood waste, there is a burning rate of 84.8%, and such areas comprise 82.4% of the total irregular disposals with signs of burning. This indicates that the presence of wood waste in a disposal area is a relevant factor that correlates with subsequent burning. On the other hand, locations without wood waste have a burning rate of 75.0%, but these areas represent only 17.6% of the total burns. Regarding disposals that did not show signs of burning, 15.2% of the locations with wood and 25.0% of the locations without wood were not burned, representing 71.4% and 28.6% of the total disposals without burning, respectively.	The Chi-square test and the Linear-by-Linear test do not indicate a significant association between burning and the presence of wood ($p>0.05$). The correlation is low (Phi and Cramer's V = 0.10). The Odds Ratio indicates that burning is 1.87 times more likely to occur where there is wood, but this result is not statistically significant.
ncidence of Burning in Irregular Waste Disposal Areas with the Presence of Glass	

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Analysis of Contingency Tables	Chi-square, Linear-by-Linear, Phi and Cramer's V, and Odds Ratio Analyses
In areas where there is disposal of glass waste, a notable burning rate of 96.2% is observed, with these locations representing 73.5% of the total burns. On the other hand, in areas without glass waste, the burning rate is 60%, but these locations constitute only 26.5% of the total burns. Considering disposals without burning, only 3.8% of the locations with glass and 40.0% of the locations without glass were not burned. However, it is not intuitive and it is not possible to draw a clear correlation that directly associates the presence of glass as a determining variable for burns. The situation is similar to that observed with gypsum waste, where an apparent correlation does not necessarily imply causality.	The Chi-square test and the Linear-by-Linear test indicate a significant association between burning and the presence of glass ($p<0.05$). The correlation is moderate (Phi and Cramer's V = 0.46). The Odds Ratio indicates that burning is 16.67 times more likely to occur where there is glass.

Incidence of Burning in Irregular Waste Disposal Areas with the Presence of Paper

Analysis of Contingency Tables	Chi-square, Linear-by-Linear, Phi and Cramer's V, and Odds Ratio Analyses
Locations with paper waste disposal exhibit a notable burning rate of 94.1%, with these locations equally representing 94.1% of the total burns. In contrast, in areas without paper waste, the burning rate is substantially lower, at 28.6%, though these areas represent only 5.9% of the total burns. Regarding disposals without burning, 5.9% of locations with paper and 71.4% of locations without paper were not burned. The presence of paper at disposal sites appears to have a direct and significant correlation with the incidence of burning.	The majority of burning sites (94.1%) contained paper. There is a strong positive association between burning and the presence of paper, indicated by the p-value and high values of Phi and Cramer's V. The Odds Ratio suggests that the occurrence of burning is 40 times more likely when paper is present.

Incidence of Burning in Irregular Waste Disposal Areas with the Presence of Plastic

Analysis of Contingency Tables	Chi-square, Linear-by-Linear, Phi and Cramer's V, and Odds Ratio Analyses
The data show a remarkable burning rate of 100% for sites with plastic waste, suggesting a strong association between the presence of plastic and the incidence of burning. These sites comprise 94.4% of the total irregular disposals with signs of burning. Surprisingly, areas without plastic disposals did not register any burning. However, regarding disposals without burning, 5.6% of sites with plastic and all (100%) of the sites without plastic were not burned.	The chi-square test indicates a very strong association between burning and the presence of plastic ($p < .0001$), corroborated by the Phi and Cramer's V correlation coefficient (.82). The Odds Ratio indicates that burning is infinitely more likely in the presence of plastic.

Incidence of Burning in Irregular Waste Disposal Areas with the Presence of Electronics

Analysis of Contingency Tables	Chi-square, Linear-by-Linear, Phi and Cramer's V, and Odds Ratio Analyses
Locations with electronic waste disposal have a burning rate of 35.3%, and these areas represent 100% of all electronic waste disposals that show signs of burning. On the other hand, locations without electronic waste disposal exhibit a burning rate of 64.7%, and these areas correspond to 75.9% of all disposals without electronics that indicated burning. Regarding locations without burning, no signs of burning were recorded in electronic waste disposal areas, but 100% of locations without electronic waste disposal showed no signs of burning.	The Chi-square test indicates a possible association between burning and the presence of electronics, although the p-value is not very strong (0.062). However, the p-value from the likelihood ratio test (0.020) indicates a significant association. The Odds Ratio value indicates that burning is infinitely more likely to occur when electronics are present.

Incidence of Burning in Irregular Waste Disposal Areas with the Presence of Organic Waste

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Analysis of Contingency Tables	Chi-square, Linear-by-Linear, Phi and Cramer's V, and Odds Ratio Analyses
Locations where organic material disposal occurs have a high burning rate, reaching 67.6%. Moreover, these locations correspond to 100% of all points where organic materials were disposed of and also indicated burning. In contrast, areas without organic material disposal have a lower burning rate of 32.4%, but still represent 61.1% of the total disposals without organic materials that showed signs of burning. Regarding disposals without burning indications, there are no records of burning in locations with organic materials; however, where organic materials were not disposed of, 100% showed no evidence of burning.	There is a moderate and significant correlation ($p<0.001$; Phi and Cramer's V=0.51) between the occurrence of burning and organic waste, confirmed by the Chi-square and Linear-by-Linear test. The Infinity Odds Ratio indicates that burning is much more likely to occur with organic residues.

Source: Author.

The detailed investigation of burnings associated with irregular waste disposal (Table 2), focused on various dimensions, highlights several considerable nuances, especially in the context of proximity to major roadways and the disposition in public and private areas, as well as in commercial and residential regions.

Regarding proximity to major roadways, the analysis indicated that such proximity does not correlate significantly with the incidence of burning, even with the perception that locations adjacent to these axes have a higher probability of experiencing such events.

The type of property showed a striking difference, with public areas presenting a significantly higher propensity for the incidence of burning compared to private properties. This suggests an urgent need to implement regulations and awareness in these areas to mitigate the risk of burning.

In the context of commercial and residential regions, commercial property regions stood out with a burning rate of 100%. This underscores the need for preventive measures, environmental education, and strict regulations at these locations. Residential areas, despite being significant in the study, did not present as robust a correlation as commercial environments in the incidence of burning.

The investigation also observed the disposal of different types of materials, such as wood, glass, paper, plastic, electronics, and organic waste. Among these, paper and plastic showed a robust association with the incidence of burning, as they are easily flammable materials. Wood, also flammable, presented a substantial correlation with the phenomenon of burning, necessitating attention in waste management strategies.

Glass demonstrated a moderate correlation with burnings, while electronics showed a significant association, despite variability in burning rates. This result indicates the presence of other flammable materials discarded along with electronics. Organic waste, although a significant environmental concern, did not show a direct and significant correlation with the incidence of burning.

In summary, the complexity and multifactorial nature of the phenomenon of burnings associated with irregular waste disposal demand integrated and multifaceted strategies, involving stricter regulations, public awareness, and proper waste management, with special attention to waste disposal in public areas, proximity to major roadways, and the type of waste discarded, especially in commercial regions.

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4 CONCLUSION

As we delved into the investigative paths of this study, a multifaceted, intricate, and complex panorama emerges that entangles persistent disposal and the occurrence of burning in urban areas. Both phenomena, as evidenced in this article, are not at the mercy of a single driving force; rather, they are the fruits of a combination of factors that, in many cases, interconnect and mutually influence each other.

The analysis of persistent disposal in urban areas led us through numerous variables. Although unbuilt areas stood out as critical points for persistent disposal, we cannot overlook variables that, even if not emerging as primary determinants, such as proximity to major roadways and the nature of the property, contribute to the complexity of the problem. This finding reinforces that sometimes initial intuitions and visual perceptions may not align with statistical reality, reminding us of the need for rigorous and impartial investigations.

The issue of pruning waste highlights not just its disposal per se but also the subsequent challenges that these wastes can precipitate, such as attracting other debris. Thus, it becomes evident that waste management cannot be dissociated from the intrinsic characteristics of these materials, and that each waste category requires specific attention.

On the other hand, in the analysis of burning occurrences, we discovered an equally complex scenario. The incidence of paper and plastic waste in irregular disposal areas indicated a strong statistical association with the occurrence of burning in these locations, signaling a gap in proper management and disposal. The relationship between public property and the incidence of burning, another perceived statistical association, sheds light on areas where enforcement and regulation may be lacking. However, as important as identifying these critical areas is recognizing that many of our explored variables, even those that did not demonstrate statistical robustness, play secondary or indicative roles in our understanding of the phenomenon.

The fact that some variables did not show robust statistical associations does not render them irrelevant. Instead, it serves as a reminder that persistent disposal and burning in urban areas are outcomes of an interactive ecosystem of factors. Variables that do not show direct significance may, in reality, exert indirect influences, possibly moderating or mediating the effects of other variables, or playing roles in specific circumstances that were not captured in a broad analysis.

Thus, the resonating message from this study is clear: addressing the challenges of disposal and burning in urban areas requires a multifaceted and holistic strategy. Every variable, whether statistically significant or not, contributes to a larger, complex puzzle, and understanding it is imperative that researchers, authorities, communities, and other stakeholders collaborate, share ideas, and work together in the search for sustainable and effective solutions.

Grounded in the results of this study, it is our hope that future initiatives will not only address the most salient aspects of disposal and burning but also consider the more subtle details and nuances presented by the "less obvious" variables, as it is these nuances that often hide the keys to innovative and effective solutions.'

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