











## Determinants of Household Waste Handling Practices in a Rapidly Growing Indonesian City: A Case Study of Medan City

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### ABSTRACT

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*household waste handling practices, improper waste disposal, waste segregation, waste collection fee payment, developing countries*

This study examines the determinants of household waste handling practices in Medan, Indonesia. A cross-sectional survey covering 21 sub-districts involving 401 households was conducted to assess waste disposal and segregation behavior and socio-demographic characteristics. Improper waste disposal, defined as open burning and disposal into rivers, was observed in 18% of households. Chi-square analysis revealed a strong association between waste collection fee payment ( $\chi^2 = 212.51$ ,  $p \approx 0.000$ ) and improper waste disposal, as well as a significant association with education level ( $\chi^2 = 14.85$ ,  $p = 0.0006$ ). Household size ( $\chi^2 = 2.50$ ,  $p = 0.286$ ) showed no significant association. Logistic regression analysis also confirmed that waste collection fee payment (odds ratio (OR) = 0.01,  $p < 0.001$ ) significantly reduces the odds of improper waste disposal, while higher education level (OR = 0.46,  $p = 0.028$ ) is associated with lower odds. In contrast, analysis of waste segregation indicates that education level (OR = 1.28,  $p = 0.185$ ), waste collection fee payment (OR = 0.91,  $p = 0.718$ ), and household size (OR = 1.05,  $p = 0.580$ ) do not show a significant effect. This study highlights a fundamental distinction between system-driven and behavior-driven waste practices. While improper waste disposal is system-driven, it can be effectively reduced through improvements in waste collection services; promoting waste segregation as behavior-driven requires targeted behavioral interventions.

## 1. INTRODUCTION

Municipal solid waste management has become a critical challenge in rapidly urbanizing cities, particularly in developing countries. Developing countries face significant challenges in managing municipal solid waste due to rapid urbanization [1-4]. Household waste generation is driven by population growth, rising living standards, and changing consumption patterns, resulting in increasingly complex waste streams that exceed the capacity of existing municipal solid waste management systems [5]. Consequently, many cities continue to rely heavily on landfills, while limited waste separation and recycling contribute to environmental degradation, public health risks, and greenhouse gas emissions [6-9]. The long-established “collect–transport–dispose” paradigm, combined with only partially implemented

principles of environmental governance, particularly in relation to central–local government coordination, further exacerbates the situation in Indonesia [10]. Landfill waste combustion, in particular, imposes high environmental costs, especially in terms of greenhouse gas emissions, compared to alternative waste management systems such as composting and anaerobic digestion [11]. Households are the largest contributors to municipal solid waste, making them a critical sector in waste management decision-making [12]. Household behavior, including waste disposal, waste separation, and participation (or non-participation) in formal collection services, shapes daily interactions among numerous public and private actors within interconnected formal and informal systems, ultimately influencing environmental outcomes [6, 13-15]. Numerous studies highlight the substantial impact of improved household-level practices on urban waste

management, particularly in developing countries with limited infrastructure [16-18]. Urban waste management systems in developing countries are also highly heterogeneous, both geographically and in terms of service provision [19, 20]. In Indonesia, disparities in service coverage, such as limited access to communal bins, irregular collection schedules, and the prevalence of informal settlements, have been widely documented [21]. These conditions significantly influence household waste disposal behavior, particularly in low-income areas. Although formal waste collection services cover a large proportion of urban households, service quality and reliability vary across neighborhoods [22-25]. When collection services are perceived as inadequate, households may resort to alternative disposal methods, such as open burning, disposal into rivers, or individually transporting waste to informal collection points (e.g., markets or vacant land). This indicates that household waste management decisions are strongly influenced by service performance and systemic gaps. Similar challenges have been observed in other Indonesian cities; for instance, in Salatiga, progress toward a circular household waste system is constrained by low public awareness, limited supporting infrastructure, and insufficient resources [26].

A range of factors, including education, household size, and income proxies, has been associated with household waste management behavior [27-30]. Higher level of education is generally linked to greater participation in practices such as waste segregation, while larger households may face logistical constraints [31, 32]. Despite this, improper disposal practices remain prevalent in urban areas, often attributed to population behavior [33, 34]. However, recent evidence suggests that service-related determinants, such as the reliability of collection services and infrastructure availability, are equally, if not more, influential. Trust in the waste collection service provider is also a key determinant of household compliance and should therefore be a central focus in waste management strategies [13].

It is particularly evident in developing countries, where significant challenges in waste management, including waste segregation and disposal, persist. People's responses to this issue point to several barriers, including perceived lack of time, inconvenience, knowledge gaps, and the belief that waste separation is futile because everything ultimately ends up in the same landfill [35, 36]. Research on Indonesian landfills has shown that losses at the household level due to non-segregation are considerable, with large quantities of recyclable plastic being lost as a result of inadequate source segregation [37]. These findings indicate that household inaction is not solely a behavioral failure but also reflects inadequate systems and services to support proper waste management practices.

Furthermore, the interaction between financial mechanisms and service performance presents a systemic paradox. Fee-based waste collection systems have been introduced to promote cost recovery and improve service performance; however, households often continue to exhibit poor disposal behavior even when paying for these services, particularly when they are perceived as unreliable [38, 39]. This suggests a mismatch between financial participation and actual service outcomes, highlighting deeper structural issues within the waste management system.

Like many previous studies, research on waste disposal, segregation, and willingness to pay is often examined in isolation. Most studies focus on only one or two of these aspects, leaving others underexplored or unexplained. In

addition, many studies rely on traditional regression methods without addressing methodological challenges such as sparse categorical data or perfect separation, which are common in urban household survey data. These limitations reduce the informativeness and policy relevance of empirical findings, and researchers often compensate by relying on more readily available datasets. Within this context, Medan represents a significant yet underexplored case study. As one of Indonesia's largest and most developed cities, Medan exhibits heterogeneous socio-economic conditions alongside unequal waste service provision across its sub-districts. The city's waste management system largely follows a "collect-transport-dispose" model, in which residential waste is collected by both formal municipal services and informal operators, and then transported directly to landfill sites with minimal treatment or source segregation. Although waste collection services are available, their frequency and reliability vary significantly between neighborhoods. The presence of communal bins, irregular collection schedules, and reliance on informal transport modes contribute to inconsistent waste collection service in several districts. Source segregation remains low, as recycling activities are predominantly informal and not fully integrated into the formal system. Even in areas with relatively good coverage of formal waste collection services, issues such as illegal dumping, low levels of waste segregation, and heavy reliance on informal practices persist. These conditions make Medan representative of systemic inefficiencies in urban waste management in developing countries and justify its selection as the study area.

This study addresses this gap by integrating bivariate and multivariate analyses to identify the determinants of improper waste disposal and to explore waste segregation as a complementary behavioral dimension, particularly in relation to socio-demographic factors and waste collection service constraints. This study highlights the role of waste collection service participation as a critical determinant of environmentally responsible behavior. The findings of this study provide both empirical evidence and policy-relevant insights for improving urban waste management systems. Furthermore, the use of penalized logistic regression provides more robust estimates in situations where survey data are sparse.

## 2. MATERIALS AND METHODS

This study aimed to analyze behavioral profiles related to household waste disposal and segregation as a complementary analysis. The methodology involved structured questionnaire-based data collection, followed by descriptive, bivariate, and multivariate statistical analysis. This approach provides a suitable strategy to address common challenges in urban household surveys, including heterogeneous service levels and multiple categorical variables, thereby enhancing the strength, robustness, and reproducibility of the results.

### 2.1 Study area

The study area, as illustrated in Figure 1, is Medan, the capital city of North Sumatra Province, Indonesia. Medan is one of the largest metropolitan areas in Indonesia and is characterized by rapid urbanization, population growth, and diverse socio-economic conditions. These characteristics significantly influence the generation, composition, and

management of MSW. The city predominantly relies on a landfill-based waste management system, which remains a common practice in many developing urban areas. In Medan, household waste collection services are primarily managed by third-party contractors appointed by local authorities. Waste generated at the household level is typically collected and transported to temporary transfer depots before being conveyed to final disposal sites, mainly landfills. However, the effectiveness of this system varies across different areas due to disparities in service coverage, infrastructure availability, and community participation. Administratively, Medan is divided into 21 sub-districts, as presented in Figure 1. This spatial diversity supports the selection of Medan as a representative case study for urban environments in developing countries. The city exhibits a wide range of socio-

economic and infrastructural conditions, which are crucial for examining variations in waste management practices. In particular, Medan faces challenges commonly observed in developing regions, including low levels of waste segregation at the source, limited waste collection efficiency, and the widespread presence of informal waste disposal practices. Furthermore, the heterogeneous urban structure, ranging from densely populated settlements to more planned residential areas, combined with variations in the performance of waste management services, provides a robust foundation for analyzing the key factors influencing improper waste disposal behaviors and household waste segregation practices. These conditions make Medan a relevant and insightful case for understanding the complexities of urban waste management in developing country contexts.



Figure 1. The study area and its administrative sub-districts

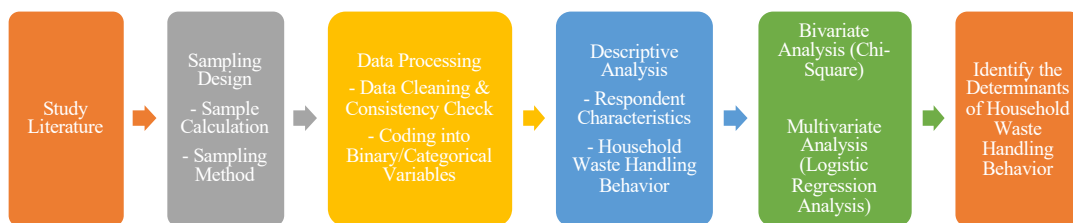


Figure 2. Study framework

## 2.2 Study design

As illustrated in Figure 2, a cross-sectional study design was employed through a household survey to investigate urban household waste handling practices. Data were collected using a structured questionnaire designed to capture the state of household waste handling practices at a specific point in time.

A total of 401 households were selected as respondents. The structured questionnaire covered socio-demographic characteristics, household waste handling practices, and waste collection service-related factors. Then, the data were

processed. Data preprocessing included consistency checks, handling of missing values, duplicate records, and recoding of variables into appropriate binary or categorical formats. Descriptive analysis was conducted using Microsoft Excel, and statistical analysis was performed using Python.

## 2.3 Data collection

A purposive stratified sampling technique was employed to select households across Medan, which comprises 21 sub-districts with approximately 618,542 households in 2023 [40-

42]. Purposive selection ensured inclusion of households actively engaged in waste handling practices, while stratification enhanced representativeness across city density gradients. For the calculation of sample size, a margin of error of 5% was applied, and Yamane's formula was used. With a total population of 618,542 households, the calculated sample

size was 399.74, which was rounded to 400 to ensure adequate representativeness of the study area. The primary sampling frame consisted of official RT/RW household data from each Sub-District Office and BPS Medan City. Allocation details are presented in Table 1.

**Table 1.** Allocation sample size across Medan

No.	Sub-District	Population (Households)	Proportion (%)	Sample Quota Target (Households)	Approached (Households)	Sample Valid (Households)
1	Medan Tuntungan	25,033	4.05%	16	16	16
2	Medan Johor	38,717	6.26%	25	26	26
3	Medan Amplas	32,943	5.33%	21	21	21
4	Medan Denai	42,974	6.95%	28	28	28
5	Medan Area	29,514	4.77%	19	19	19
6	Medan Kota	21,195	3.43%	14	14	14
7	Medan Maimun	12,427	2.01%	8	8	8
8	Medan Polonia	15,170	2.45%	10	10	10
9	Medan Baru	9,048	1.46%	6	6	6
10	Medan Selayang	26,036	4.21%	17	17	17
11	Medan Sunggal	33,318	5.39%	22	22	22
12	Medan Helvetia	42,073	6.80%	27	27	27
13	Medan Petisah	18,108	2.93%	12	12	12
14	Medan Barat	22,312	3.61%	14	14	14
15	Medan Timur	29,259	4.73%	19	19	19
16	Medan Perjuangan	26,329	4.26%	17	17	17
17	Medan Tembung	37,319	6.03%	24	24	24
18	Medan Deli	47,936	7.75%	31	31	31
19	Medan Labuhan	33,906	5.48%	22	22	22
20	Medan Marelan	47,367	7.66%	31	31	31
21	Medan Belawan	27,560	4.46%	18	18	18
	<b>Total</b>	<b>618,542</b>	<b>100.00%</b>	<b>400</b>	<b>401</b>	<b>401</b>

A total of 400 households were approached via door-to-door enumeration in December 2024. This yielded 401 valid responses (n = 401), with one additional volunteer household included in the Medan Johor sub-district. No questionnaires were excluded post-collection, as all were complete (>95% item response) and consistent following preliminary quality checks, such as logical consistency and no duplicates.

Within each sub-district, purposive sequential selection was implemented. Enumerators initiated at a randomly selected RT/RW block, using a random number generator from the frame list, then approached the first eligible household, which is defined as a head/responsible adult present, actively managing household waste. Subsequent households were selected every 1–3 doors, skipping ineligible ones, such as vacant or commercial, until the approached quota was met. This quota-based approach ensured strata proportionality while accommodating field practicality in non-probability purposive sampling.

Non-response was minimal (<5 cases total across 400 approaches), attributed to intensive fieldwork (up to two callbacks per household within 48 hours). Refusals or non-contacts were immediately substituted by the next eligible household within the same sub-district, maintaining quota integrity without introducing substitution bias. Daily response monitoring prevented drift from targets. Potential non-response bias was mitigated by stratification, and eligibility criteria focused on waste-engaged households.

## 2.4 Questionnaire design and variables

The household questionnaire included items on socio-demographic characteristics and waste handling practices. It

was structured into two sections. Section A collected general household information, including the number of household members, the highest level of education attained by any member, and geographic location. These variables were used for subsequent analysis. Section B focused on household waste handling practices, including waste disposal methods, waste segregation at source, participation in waste collection fee payment systems, and perceived barriers to waste segregation.

For analytical purposes, variables were transformed into binary, ordinal, and categorical formats. Dependent variables consist of improper waste disposal behavior (binary) and waste segregation behavior (binary). Improper waste disposal refers to practices that do not follow the formal waste collection system, including open burning and dumping into rivers. Proper disposal refers to waste handled through formal collection services provided by municipal or authorized operators. Waste segregation indicates whether households practice the separation of waste at the source, such as separating organic and inorganic waste. Households that did not practice any form of waste separation were categorized as non-segregators. Independent variables are education level (ordinal scale), household size (categorized), and waste collection fee payment (binary).

These variables formed the basis for descriptive, bivariate, and multivariate analyses. The questionnaire items were carefully constructed using clear and simple language to minimize respondent misinterpretation and ensure data reliability and consistency. Prior to full deployment, the instrument was reviewed to ensure alignment with the research objectives and analytical framework. The questionnaire design also facilitated systematic data coding and comparability across households.

## 2.5 Data analysis

This study conducted data analysis, consist of descriptive, bivariate, and multivariate analyses. Descriptive statistics were used to summarize household characteristics and waste handling practices across Medan.

The chi-square test served as a preliminary screening method prior to multivariable modeling to identify potential associations between variables. Bivariate analysis using the chi-square test examines the association between two categorical variables. It tests the null hypothesis of independence (no relationship) by comparing observed frequencies in a contingency table against expected frequencies under independence. The chi-square test result is deemed statistically significant when there is strong evidence of an association between two categorical variables, leading to the rejection of the null hypothesis ( $H_0$ : no association). Decisions are primarily based on two complementary approaches: comparison of the p-value or the calculated  $\chi^2$

statistic. When  $p < 0.05$  ( $\alpha = 0.05$ ), it means a significant association (reject  $H_0$ ); when  $p \geq 0.05$ , it means no significant association (fail to reject  $H_0$ ). Meanwhile, when based on the  $\chi^2$  value, it is considered significant when  $\chi^2$  calculated  $> \chi^2$  critical (at specified df and  $\alpha$ ), and it is not significant when  $\chi^2$  calculated  $\leq \chi^2$  critical.

Given the presence of sparse categorical data and multiple predictor levels, logistic regression analysis was subsequently employed. Logistic regression analysis as multivariate analysis used to analyze the influence of independent variables.

## 3. RESULTS AND DISCUSSIONS

### 3.1 Respondent characteristics

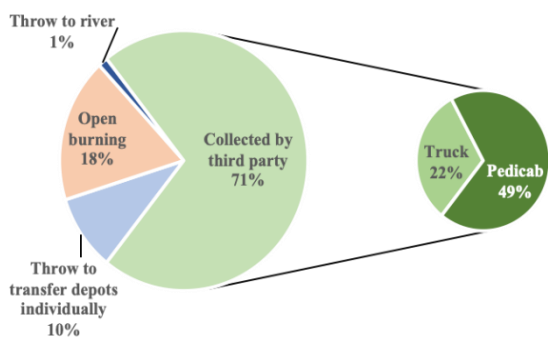
A total of 401 valid household responses were included in the analysis. The full socio-demographic characteristics of the respondents are presented in Table 2.

**Table 2.** Socio-demographic characteristics of respondents (n = 401)

No.	Variable	Category	Frequency	Percentage (%)
1	Household Size	2 people	54	13.5%
		3-4 people	204	50.8%
		5-6 people	123	30.7%
		>6 people	20	5.0%
		<b>Total</b>	<b>401</b>	<b>100.0%</b>
2	Education Level	Primary School	6	1.5%
		Junior High School	11	2.7%
		Senior High School	181	45.2%
		Diploma	17	4.2%
		Bachelor Degree	169	42.2%
		Master Degree	13	3.2%
		Doctoral Degree	4	1.0%
<b>Total</b>	<b>401</b>	<b>100.0%</b>		

### 3.2 Analysis descriptive

The descriptive analysis in this study aims to examine the overall household waste handling practices across the city of Medan. The likelihood of using different waste disposal methods varied among respondents, as illustrated in Figure 3. The majority of respondents (71%) reported relying on third-party waste collection services. However, despite the relatively high usage of formal services, a considerable proportion of households still engage in improper waste disposal practices. The persistence of these practices indicates that improper waste disposal remains a significant operational challenge.



**Figure 3.** Distribution of household waste disposal practices

The third-party waste collection system also exhibited variability in collection methods. Pedicabs accounted for 49% of waste collection, while collection trucks represented 22%. This indicates that urban waste management systems still rely heavily on traditional collection mechanisms, such as pedicabs and small-scale transport services, rather than fully standardized systems.

The frequency of household waste collection and disposal varied significantly among respondents, as can be seen in Figure 4(a). These variations indicate differences in service regularity, household routines, and neighborhood-level waste collection arrangements. Waste volume indicators were illustrated in Figure 4(b) using the size of plastic bags commonly used by households. The use of larger bags (over 20 kg) and medium-sized bags (10–20 kg), as shown in the figure, suggests relatively high levels of household waste generation.

As shown in Figure 5, of the 76% of households that reported participating in the waste collection fee payment, the majority consistently practice formal waste disposal. Specifically, 71% of these households remain committed to disposing of collected waste by third-party services, and 2% utilize government-provided transfer depots. Nevertheless, a small proportion of households continue to engage in improper disposal practices, with 2% reporting open burning and 1% disposing of waste into rivers. This indicates that participation in waste collection fee payment is associated with improper waste disposal behavior. Further analysis will be presented in the following section to better ascertain whether improper

waste disposal behavior is indeed associated with household participation in waste collection fee payment.

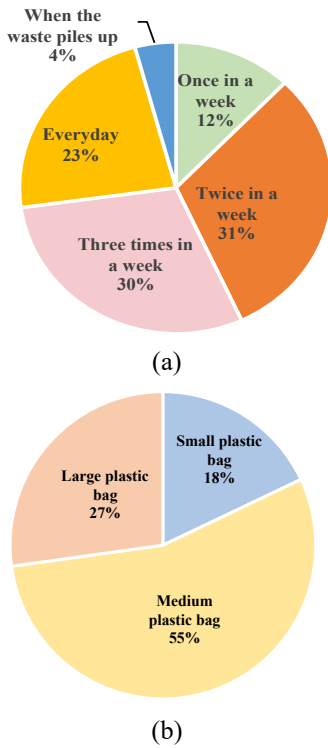


Figure 4. (a) Household waste collection frequency and (b) waste volume indicators

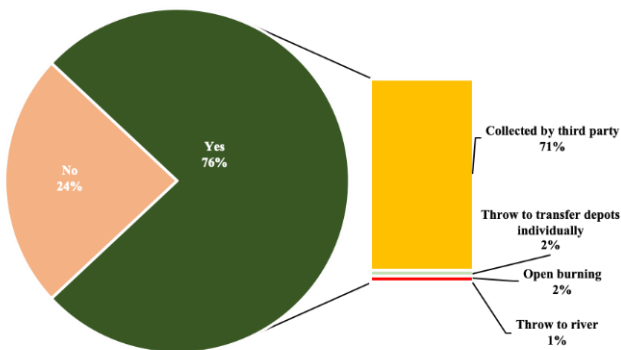


Figure 5. Household participation in waste collection fee payment

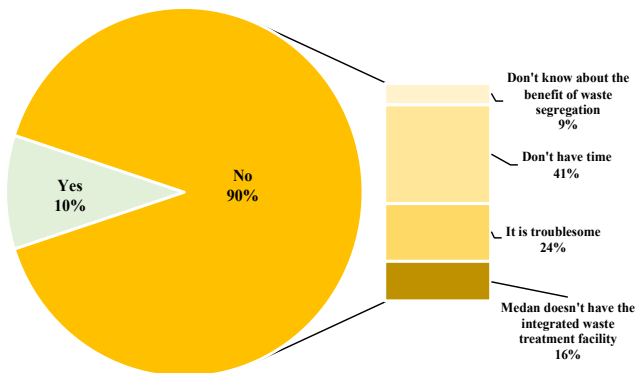


Figure 6. Distribution of household waste segregation behavior

For waste segregation, only 10% of the 401 households reported practicing waste segregation. The majority did not do so for several reasons, including 9% indicated that they did not understand the benefits of waste segregation, 41% stated that they did not have sufficient time to segregate waste, 24% considered waste segregation troublesome, and 16% were unwilling to separate their waste because Medan lacks an integrated waste management system. The overview is presented in Figure 6.

### 3.3 Bivariate analysis (Chi-square test)

This study examined bivariate associations between household characteristics and waste handling practices using chi-square tests of independence. Specifically, associations between household size, education level, and waste collection fee payment were assessed in relation to improper waste disposal and waste segregation behavior. Each independent variable was first categorized. Household size was classified into three groups: small ( $\leq 3$  household members), medium (4–5 household members), and large ( $> 5$  household members). Education level was also grouped into three categories: low (primary, junior high, and senior high school), medium (diploma and bachelor’s degree), and high (master’s and doctoral degrees). Meanwhile, waste collection fee payment was categorized into two groups: yes and no. The results of the chi-square test are presented in Table 3 and illustrated in Figures 7 and 8.

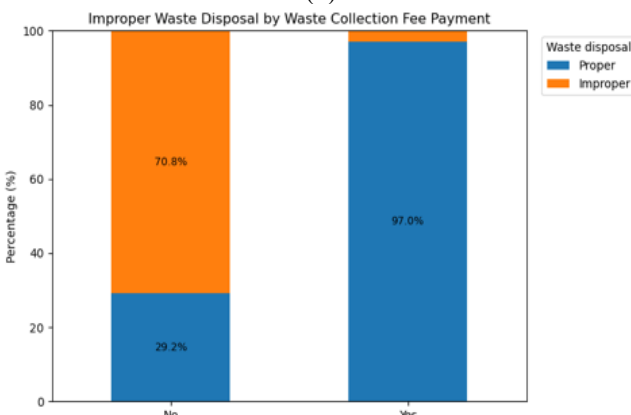
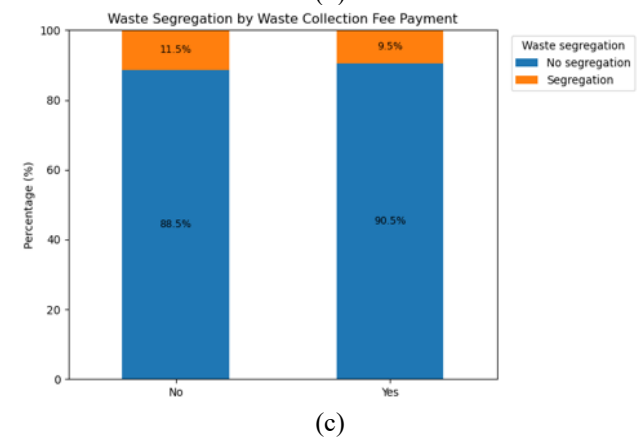
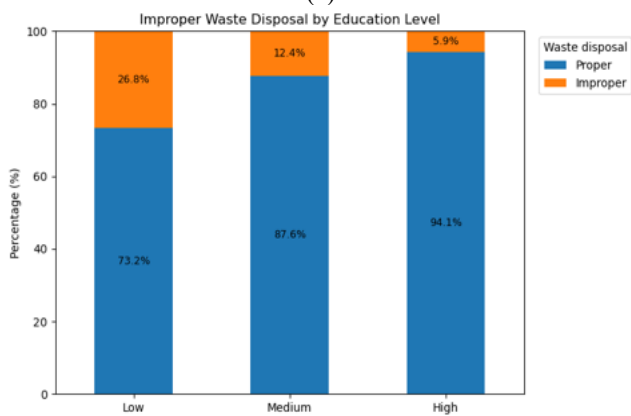
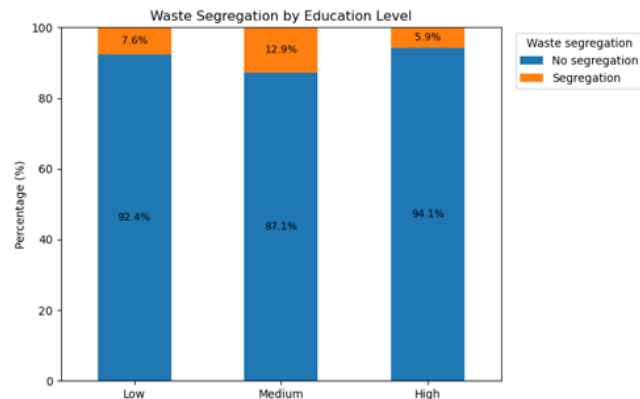
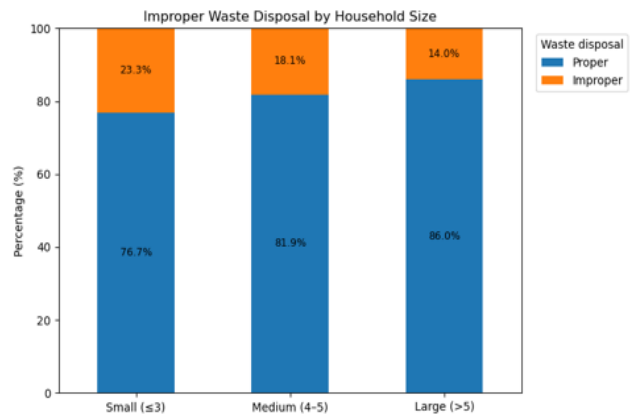
Table 3. Bivariate analysis between household characteristics and waste handling practices (chi-square test)

No.	Variable	Improper Waste Disposal ( $\chi^2$ , p-value)	Waste Segregation ( $\chi^2$ , p-value)
1	Household Size	$\chi^2 = 2.50$ p = 0.286	$\chi^2 = 1.07$ p = 0.586
2	Education Level	$\chi^2 = 14.85$ p = 0.0006	$\chi^2 = 3.36$ p = 0.186
3	Waste Collection Fee Payment	$\chi^2 = 212.51$ p $\approx$ 0.000	$\chi^2 = 0.13$ p = 0.718

Waste collection fee payment showed an extremely strong association with improper waste disposal ( $\chi^2 = 212.51$ , p  $\approx$  0.000), suggesting that access to formal waste services plays a critical role in shaping household waste handling practices. A statistically significant association was also found between education level ( $\chi^2 = 14.85$ , p = 0.0006) and improper waste disposal, indicating that households with a lower education level were more likely to engage in improper waste disposal practices. In contrast, no statistically significant association was found between household size ( $\chi^2 = 2.50$ , p = 0.286) and improper waste disposal.

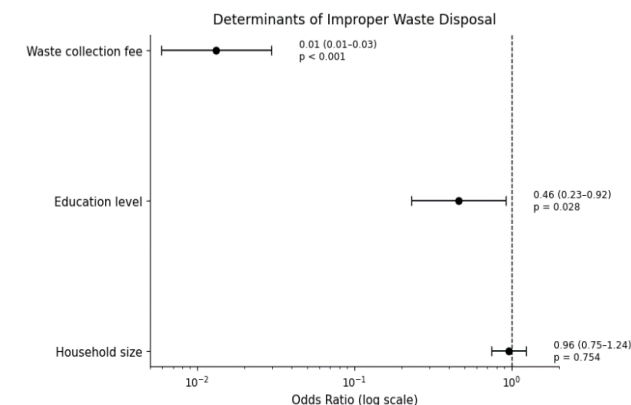
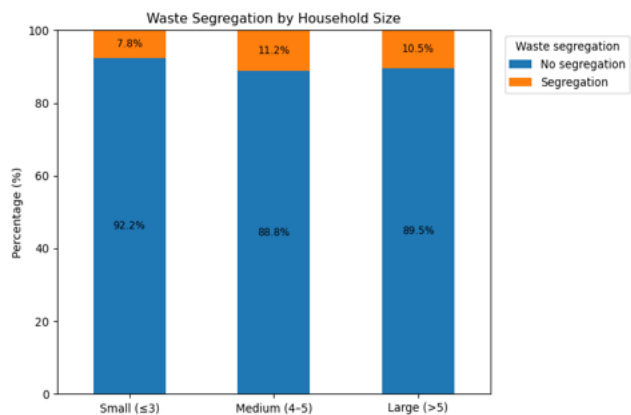
For waste segregation, the chi-square test revealed no statistically significant association between waste segregation behavior and education level ( $\chi^2 = 3.36$ , p = 0.186), household size ( $\chi^2 = 1.07$ , p = 0.586), and waste collection fee payment ( $\chi^2 = 0.13$ , p = 0.718).

These findings suggest that waste segregation behavior is not influenced by structural or socio-demographic factors. Unlike improper waste disposal, which is significantly affected by access to waste collection services and education level, segregation appears to be driven by intrinsic behavioral factors such as habits, environmental awareness, and perceived effort.



**Figure 8.** Distribution of waste segregation behavior by (a) household size, (b) education level, and (c) waste collection fee payment

**Figure 7.** Distribution of improper waste disposal behavior by (a) household size, (b) education level, and (c) waste collection fee payment



**Figure 9.** Odds ratios (ORs) and 95% confidence intervals from logistic regression analysis of factors associated with improper household waste disposal behavior

This analysis revealed that education level (Odds ratio (OR) = 0.46, p = 0.028) and waste collection fee payment (OR = 0.01, p < 0.001) were significantly associated with improper waste disposal behavior. In contrast, household size (OR =

0.96,  $p = 0.754$ ) was not significantly associated with the outcome. For waste segregation, logistic regression analysis showed no statistically significant association between waste segregation behavior and education level ( $OR = 1.28$ ,  $p = 0.185$ ), household size ( $OR = 1.05$ ,  $p = 0.580$ ), and waste collection fee payment ( $OR = 0.91$ ,  $p = 0.718$ ). This result can be seen in Table 4.

Waste collection fee payment emerges as the most influential variable to improper waste disposal, with households paying for waste services exhibiting dramatically lower odds of improper disposal. Education level also shows a statistically significant negative association, indicating that higher education levels are associated with a reduced likelihood of improper disposal. Education level shows a weaker association, suggesting a potential influence of socio-demographic factors, although the strength of this relationship is limited compared to service-related variables. However, the magnitude of this effect is substantially smaller compared to the impact of service availability. Household size does not show a statistically significant effect, suggesting that household composition does not play a meaningful role in determining waste disposal behavior. The forest plot in Figure 9 provides a visual representation of the regression results. The OR for waste collection fee payment is positioned far to the left of the reference line ( $OR = 1$ ), indicating a strong negative association with improper waste disposal. The narrow

confidence interval and clear separation from the reference line confirm the robustness of this effect. Education level is also located to the left of the reference line, though closer to unity, indicating a moderate but statistically significant effect. In contrast, household size is centered around the reference line, with its confidence interval crossing  $OR = 1$ , reinforcing the absence of a statistically significant relationship.

### 3.5 Discussion of determinants of household waste handling practices

The household waste handling practices analyzed in this study comprised improper waste disposal and waste segregation behavior. Based on the results of both statistical analyses conducted, consistent findings were obtained; education level and waste collection fee payment exhibited statistically significant associations with improper waste disposal, whereas household size showed no influence. In contrast, waste segregation behavior displayed a different pattern, with neither education level, waste collection fee payment, nor household size demonstrating statistically significant effects. This is reinforced by descriptive analysis revealing that 76% of households participated in waste collection fee payment, while only 10% practiced waste segregation.

**Table 4.** Logistic regression results further clarify the determinants of improper waste disposal and waste segregation

No.	Variable	Improper Waste Disposal: OR (95% CI)	p-value	Waste Segregation: OR (95% CI)	p-value
1	Household Size	0.96 (0.75 - 1.24)	0.754	1.05 (0.90 - 1.22)	0.580
2	Education Level	0.46 (0.23 - 0.92)	0.028	1.28 (0.88 - 1.86)	0.185
3	Waste Collection Fee Payment	0.01 (0.01 - 0.03)	< 0.001	0.91 (0.52 - 1.58)	0.718

Note: OR: odds ratio

Consequently, waste collection fee payment emerged as the strongest determinant, reducing the odds of improper disposal by approximately 99%. Among the 76% of households participating in waste collection fee payment, only 3% engaged in improper disposal (2% open burning and 1% river disposal), compared to non-payers. The  $OR = 0.01$  confirms waste collection fee payment as the strongest determinant of proper disposal behavior. This indicates that implementing a formal waste collection fee payment system effectively maintains household compliance in Medan, limiting improper disposal to just 2% open burning and 1% disposal into rivers. This finding aligns with research in Ecuador showing that institutional factors such as waste collection fees and local regulations significantly predict household waste disposal compliance [43]. Education level also served as a significant determinant of reduced improper waste disposal behavior. Higher education level was significantly associated with reduced odds of improper waste disposal, indicating that households with higher education had 54% lower odds of improper disposal compared to those with lower education, whereas household size was not identified as a determinant due to its lack of influence. The absence of a significant association between household size and improper waste disposal suggests that waste generation scale alone does not determine disposal behavior. This finding challenges the assumption that larger households are more likely to engage in improper disposal due to higher waste volumes. Instead, it reinforces the importance of systemic factors over purely

demographic characteristics. A study in Bangkalan Regency, Indonesia, also confirmed that lower education level and irregular collection services are strong predictors of illegal dumping practices [44].

The combined results from chi-square and logistic regression analyses reveal a clear divergence between the determinants of improper waste disposal and waste segregation. Although education level shows a weak positive trend, the effect is not statistically significant. Similarly, household size and fee payment do not influence segregation behavior. The results demonstrate a fundamental distinction between two types of waste-related behavior. Waste management behavior is bifurcated into system-driven and behavior-driven practices. These findings indicate that improper waste disposal is strongly influenced by system-driven factors, while waste segregation is behavior-driven, particularly access to waste collection services, while waste segregation is not explained by the same variables. Improper waste disposal is clearly system-driven, as evidenced by the strong and statistically significant effect of waste collection fee payment. Access to waste services substantially reduces the likelihood of improper disposal, indicating that infrastructure provision is highly effective in addressing this issue. In contrast, waste segregation is not significantly associated with any of the examined variables. This suggests that segregation is a behavior-driven practice, influenced by internal factors such as habits, environmental awareness, and perceived effort rather than external structural conditions. This

is reinforced by a study in Sri Lanka, which found that situational and socio-psychological factors (such as knowledge, subjective norms, and experience) have a stronger association with waste sorting behavior than demographic factors [45]. This finding aligns with the descriptive analysis results, which revealed that among the 90% of households not practicing waste segregation, several reasons were identified: 9% were unaware of the tangible benefits of waste segregation, 41% cited lack of time for segregating, 24% considered it troublesome, and 16% attributed their non-participation to Medan's lack of an integrated waste management system from upstream to downstream collection and processing. Furthermore, a spatial study in Bandung demonstrated that low environmental self-efficacy and perceived government indifference contribute to the presence of illegal dumping sites, reinforcing that targeted behavioral interventions are essential for more complex practices such as waste segregation [46].

#### **4. FUTURE PERSPECTIVES AND POLICY IMPLICATIONS**

The findings imply that different policy approaches are required for improper waste disposal and waste segregation. These findings emphasize the need for integrated policy approaches that combine infrastructure development with behavioral change strategies. Regarding improper waste disposal, the findings offer clear policy guidance. Interventions should prioritize expanding waste collection services, enhancing service accessibility and affordability, and strengthening institutional coverage. Behavioral interventions such as awareness campaigns alone are unlikely to succeed without adequate service infrastructure. In waste segregation analysis, the findings highlight a critical limitation of conventional waste management strategies that focus primarily on infrastructure development. While improving waste collection systems can effectively reduce improper disposal, such interventions do not automatically translate into higher levels of waste segregation. Even among households with access to waste services, segregation behavior remains low and relatively uniform across groups. The absence of significant variables for waste segregation suggests that promoting this behavior requires targeted behavioral interventions rather than purely structural solutions. Potential barriers include a lack of perceived benefits, additional effort required for segregating waste, the absence of downstream separation systems, and weak social norms. These factors indicate that waste segregation requires a higher level of individual commitment compared to basic disposal practices. For waste segregation, several policy implications can be considered. Behavior-based interventions should be implemented, including incentive schemes such as rewards, to increase households' willingness to segregate waste. In addition, community-based programs should be strengthened to foster the understanding that waste segregation is a shared household responsibility. Equally important, separated waste must be properly processed because without an integrated waste management system from upstream to downstream, households may perceive waste sorting at home as futile if the collected waste is ultimately mixed again at the final stage of treatment. Therefore, improving waste segregation requires not only infrastructure support but also sustained long-term behavioral change. individual commitment compared to basic

disposal practices.

The findings of this study indicate the need for a strategic shift in urban waste management in developing cities. Rather than focusing primarily on household behavior change, greater emphasis should be placed on systemic solutions. In high-density residential areas, larger household sizes place additional pressure on waste management services. Therefore, policies should prioritize service reliability, transportation efficiency, and the overall functionality of waste management systems. Improper waste disposal remains a critical challenge, often arising in contexts where regulatory frameworks and baseline service provision are insufficient. Addressing this issue requires coordinated efforts among communities, institutions, and service providers to strengthen governance and enforcement mechanisms. Future waste management systems should be designed to accommodate diverse needs, including flexible collection schedules, localized transfer stations, and expanded service coverage for larger households and densely populated areas. At the same time, household-level waste separation should be supported by downstream system integration to ensure effective waste processing and resource recovery. Further research is needed to explore behavioral patterns and mental models that influence waste management practices, particularly in relation to perceived control and service accessibility. Additionally, spatially explicit analyses and system performance indicators should be developed to better integrate household behavior with service delivery and operational gaps. Integrating material flow analysis and life cycle assessment with household survey data would provide deeper insights into environmental impacts and resource recovery potential. Ultimately, urban waste management systems should evolve toward integrated, data-driven frameworks that combine household behavior with adaptive, just-in-time service models. Recent studies support this direction. For example, research conducted in Semarang demonstrated that black soldier fly (BSF) bioconversion offers significant environmental and economic advantages in managing food waste. The study reported emissions of only 30.61 kg CO<sub>2</sub>-eq per ton of food waste, compared to 490.3 kg CO<sub>2</sub>-eq per ton for composting, while also generating potential revenue of up to USD 733.45 per ton from larvae and frass [40]. Furthermore, evidence from Budihardjo et al. [41] emphasizes the importance of integrating sorting and recycling into waste management systems. The study from Batang Regency demonstrates that implementing sorting and recycling practices significantly reduces global warming potential compared to baseline conditions.

#### **5. CONCLUSIONS**

This study aimed to investigate the factors affecting household waste handling practices in urban areas of developing countries. The findings revealed that waste collection fee payment is the most significant determinant of improper waste disposal. The implementation of a waste collection fee payment system demonstrably prevents households from engaging in improper waste disposal practices, such as open burning and river disposal. Education level also emerged as a significant determinant of improper disposal behavior, with higher-educated households exhibiting substantially lower rates of such practices compared to those with lower education levels. In contrast, household size showed no effect on preventing improper waste disposal. To

further reduce improper waste disposal among Medan households, government policy efforts should focus on expanding waste collection services, enhancing service accessibility and affordability, and strengthening institutional coverage.

This study identified distinct patterns for waste segregation. To enhance household waste segregation in Medan, behavioral interventions are required rather than improvements to waste infrastructure systems, as education level, household size, and waste collection fee payment showed no significant association with segregation behavior. Recommended interventions include incentive schemes such as reward programs, strengthened community-based initiatives, and ensuring proper processing of separated waste throughout the upstream-to-downstream management chain.

This study highlights a fundamental distinction between system-driven and behavior-driven waste practices. While improper waste disposal as system-driven can be effectively reduced through improvements in waste collection services, promoting waste segregation as behavior-driven requires targeted behavioral interventions. These findings emphasize the need for integrated policy approaches that combine infrastructure development with behavioral change strategies.

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