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ASSESSING KNOWLEDGE, ATTITUDE, AND BEHAVIOR IN HOUSEHOLD SOLID WASTE MANAGEMENT IN NORTHERN VIETNAM

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Abstract

Rapid urbanization and population growth in Northern Vietnam have exacerbated in domestic solid waste (DSW), posing environmental challenges. Law on environmental protection (2020) promoting source separation, a disconnect persists between policy and public action. This study addresses this gap by employing a Knowledge, Attitude, and Behavior (KAB) approach to conduct a novel regional analysis of DSW management practices. A stratified random sampling design was utilized, with 1,000 people participating from five different regions of Northern Vietnam: delta rural areas, mountainous rural areas, coastal rural areas, tourism development areas, and urban areas. Data analytic techniques, including descriptive statistics, exploratory factor analysis and multiple regression analysis, were employed to uncover factors that influence DSW management behavior in each location. The research revealed significant regional variations in KAB aspects of DSW services. While positive attitudes towards responsible SWM practices (80% of people) were evident, the number of factors influencing DSW management varied (3-6) across regions. These findings provide valuable insights for policymakers, guiding the development of targeted interventions that align with national law. This paves the way for more effective, regionally-tailored waste management practices in Vietnam.

Keywords:

Publish Awareness;
Behavior;
Solid waste management;
Policy Implementation;
Northern Vietnam.

1 Introduction

Solid waste management (SWM) has emerged as a critical challenge at the nexus of environmental sustainability and public health [1]-[2]. Improper disposal practices threaten not only environmental quality and resource security but also public well-being [3]-[4]. Understanding household behavior – specifically, the knowledge, attitudes, and behavior (KAB) that shape waste generation and disposal is a cornerstone of tackling this challenge [5]. Extensive research has explored KAB in SWM, particularly within large urban centers globally. Residents in major cities often demonstrate positive knowledge and express favourable attitudes towards waste reduction, reuse, and recycling (3R) strategies [6]-[8]. However, a concerning disconnect frequently emerges between these expressed pro-environmental beliefs and actual waste management practices [9]-[10]. This highlights the complex interplay between environmental knowledge, social norms, and the practical realities of integrating sustainable SWM behaviors into daily life.

Further insights can be gleaned from KAB research in rural settings. Lukman et al. [11] emphasize the significant influence of socio-economic factors on KAB in rural areas [12]. These findings underscore the need for context-specific interventions that address the unique challenges faced by diverse communities. The limited access to formal waste collection services or recycling infrastructure in rural areas can act as a significant structural barrier to implementing 3R practices, even if residents possess the knowledge and desire to do so. This underscores the importance of tailoring SWM strategies to the specific social, economic, and infrastructural realities of different locations.

Vietnam has implemented a national SWM strategy. The Environmental Protection Law of 2020 (Law No. 72/2020/QH14) provides the framework for this strategy, with some details emphasizing source segregation, waste utilization, and enforcement of regulations. These measures aim to minimize environmental pollution, promote resource recovery, and foster sustainable waste management behavior. However, a critical knowledge gap exists regarding household KAB in Vietnam. Current research focuses heavily on major urban centers like Hanoi [13], Ho Chi Minh [14] offering limited understanding of the region's diverse socio-ecological landscapes. Northern Vietnam encompasses densely populated urban areas, sprawling peri-urban zones transitioning from rural to urban environments, and vast rural communities. Each presents unique SWM challenges and opportunities. Understanding KAB variations across this spectrum – potentially through surveys and focus groups is crucial for developing effective and targeted interventions. Additionally, exploring socio-economic factors influencing KAB variations within urban settings [15] would provide valuable insights for policymakers.

Solid waste management (SWM) presents a significant challenge in Northern Vietnam, with diverse regional practices creating knowledge gaps. This research aims to illuminate these gaps by examining household behavior related to SWM across the region's varied landscapes. To achieve this, a cross-sectional survey was conducted in February-March 2023, employing a stratified random sampling design. Over 1,000 households across five distinct regions (urban areas, tourist destinations, plain rural areas, mountainous rural areas, and coastal rural areas) participated. The quantitative data collected through the survey will be analyzed using descriptive statistics, exploratory factor analysis and multiple regression analysis techniques. Additionally, focus group discussions with relevant stakeholders will provide valuable qualitative insights. This study objectives were: (1) Investigates how knowledge, attitudes, and actual waste disposal behaviors related to SWM differ across regions in Northern Vietnam (urban, tourist, rural plains, mountains, coast); (2) Exploring the Influence of socio-economic factors to understand the disconnect between knowledge, attitude, and practices.

2 Materials and methods

2.1 Description of study area

The study was conducted in five provinces in northern Vietnam, encompassing diverse economic and social development contexts (Fig. 1). To ensure representation across various types of regions, provinces were selected based on: (1) geographic location (e.g., coastal, mountainous, or plains), (2) population density, and (3) gross domestic product (GDP) per capita (e.g., urban or rural). These criteria enabled the research to capture a wide range of experiences and inform solutions applicable to different regional challenges.

Table 1: Summarizes the characteristics of research locations.

Location	Economic - social characteristics	Solid waste management
Plains rural areas (represented by Hung Yen province)	Despite economic growth, the province faces challenges. Its economic structure, dominated by agriculture, needs faster modernization. While agriculture shows positive developments, a skilled workforce shortage hinders further industrial and service sector growth.	Solid waste generation is rising in the region. While collection relies on cooperatives and self-managed teams, infrastructure and proper equipment for waste management remain inadequate.
Mountainous Rural Areas – Represented by Tuyen Quang Province	Mountainous regions confront significant obstacles due to their harsh geography, inadequate infrastructure, high production costs, and low development base. These factors inhibit investment in the region.	Difficult terrain, scattered communities, and low public awareness hinder waste collection. Residents often resort to burning, dumping, or littering, leading to improper treatment that doesn't meet environmental standards.
Coastal rural areas – Represented by Nam Dinh Province	The region has a diverse economy with coastal industries, tourism, and agriculture. Aquaculture is shifting towards larger, more efficient operations using technology, while fishing expands offshore to increase its reach.	Rising living standards have led to a surge in domestic solid waste (DSW) and overwhelming treatment facilities. Low service fees and outdated regulations further complicate DSW management. Littering is quite common
Tourism areas – Represented by Quang Ninh Province	The region's economic prosperity stems from thriving industry, services, and tourism, which are fuelled by international investment. This results in a higher standard of living. Social development is also a priority, including attempts to ensure social security.	Economic growth in the region brings more waste from residents and tourists but poor waste management practices are causing pollution. The current system can't handle the growing amount of waste.
Urban areas – Represented by Hanoi City	Cities boom with rapid growth, dense populations, and constant development. They lead in adopting new technology and building diverse economies tied to global networks. Strong education, tech infrastructure, and higher incomes fuel their economic edge.	The amount of waste generated in urban areas is increasing in terms of both quantity and composition. Organic solid waste is a major challenge for urban areas. The city's annual budget for environmental sanitation units is derived from two main sources: government allocation and environmental sanitation service fee revenue.

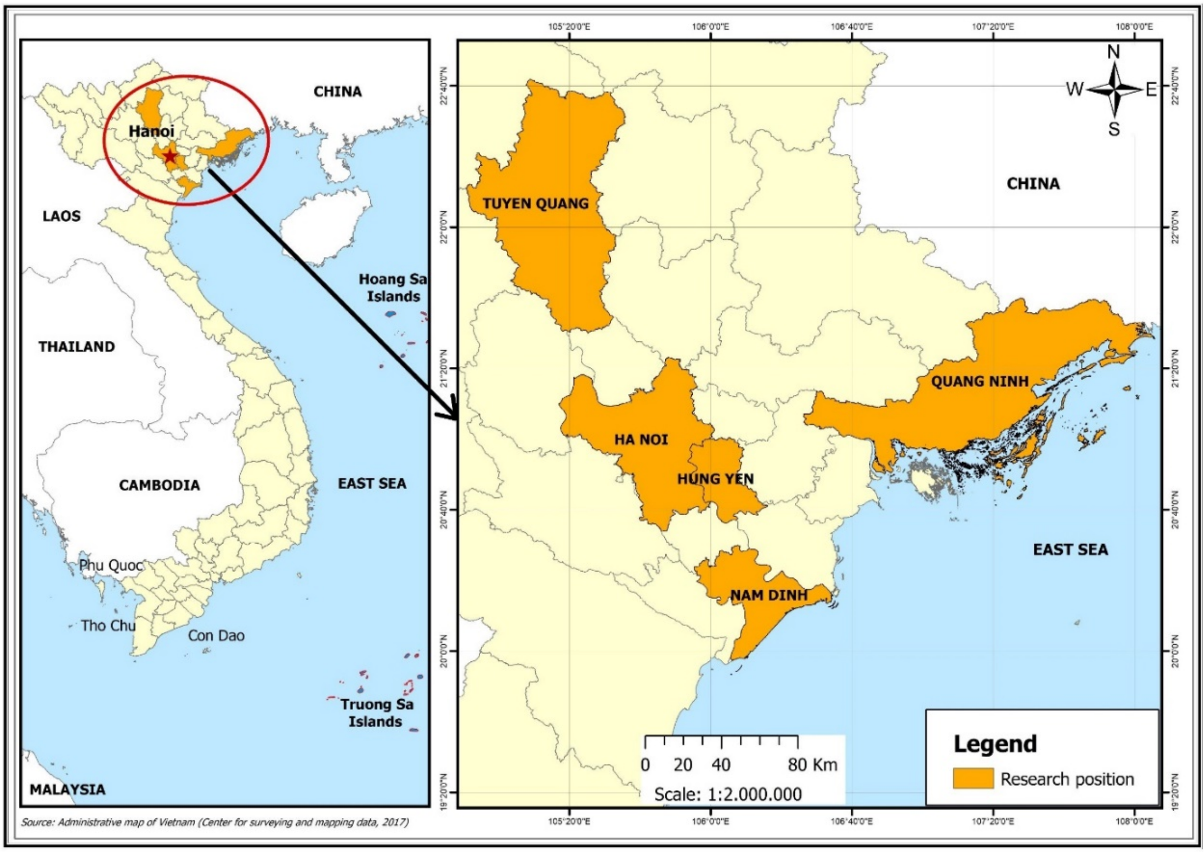

Fig. 1: Research locations in Northern Vietnam.

2.2 Materials and Methods

Fig. 2 illustrates the research process for studying knowledge, attitude, and behavior in household solid waste management in northern Vietnam. This diagram clearly shows the methodology, from gathering the initial data to the final report. It's broken down into six clear stages, each with specific actions and objectives. By collecting information, designing surveys, interviewing households across five provinces, analyzing the data, and then summarizing the findings, this research aims to provide valuable insights for policymakers and other stakeholders.

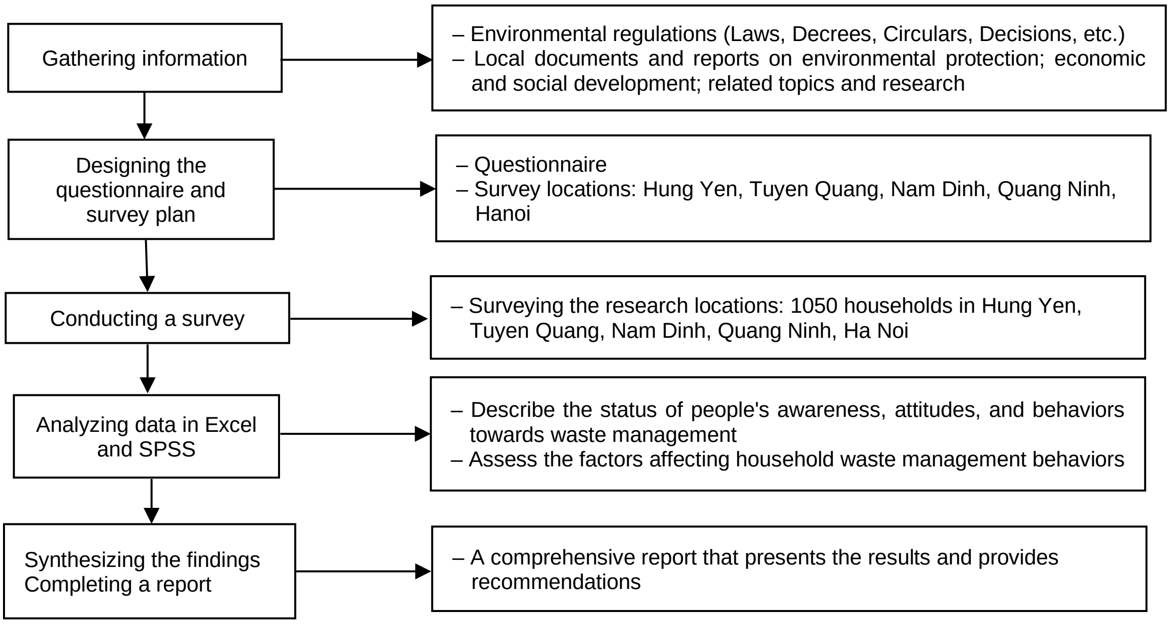

Fig. 2: Research process diagram.

2.2.1 Data collection

To collect public awareness, attitudes, and behavior toward DSW management, a sociological survey using a structured questionnaire was employed. Residents from pre-selected research locations participated, answering questions about their household waste practices, including classification, collection, reuse, and recycling. Demographic information including age, gender, education, occupation, income, household size, and estimated DSW generation was also collected. Stratified random sampling was used, dividing the population into layers based on research locations and allocating equal sample sizes to each. This method ensures representativeness and enhances the reliability of the findings.

Sample size also plays a crucial role in data reliability, with larger samples generally yielding more representative results. To ensure sufficient reliability for descriptive data at each research location, we calculated the sample size using the formula provided by Glover [16]:

$$n = \frac{N}{(1+N\times e^2)} \quad (1)$$

where n is the sample size; N is the total population in the research area; e is an acceptable error rate (typically between 0.05 and 0.1; set at 0.075 for this study).

Sample size requirements were determined considering both factor analysis (EFA) and multiple regression analysis. For EFA, Hair recommends a minimum 5:1 and ideal 10:1 ratio of observations to measurement variables [17]. With 19 measurement variables in the model and 17 corresponding survey questions, this translates to 90 and 180 minimum and preferred sample sizes, respectively, per research location. The sample size (N) was determined by applying the formula published by Tabachnick and Fidell [18]; n = 50 + 8 m which is based on using the number of independent variables (m) that will be included in the multivariate analysis model. The analysis included 4 independent factors and 6 control variables, resulting in a minimum required sample size of 130 per location.

To ensure statistical power and reliable results, we conducted a survey of 1050 individuals, ultimately collecting and analyzing 1000 valid samples (95.24% completion rate). The detailed sample structure is provided in Table 1.

Table 1: The survey sample.

Research location	Average population in 2022 (N)	Minimum sample size for analysis			Surveyed	Cleaned and used
		Description e = 0.075	**EFA** 36 variables	**Regression** 10 Independent factors		
Unit	*(Thousand people)*	*(people)*	*(people)*	*(people)*	*(Questionnaires)*	*(Questionnaires)*
Hung Yen	1.290,80	178	180	130	210	200
Tuyen Quang	805,78	178	180	130	210	200
Nam Dinh	1.876,85	178	180	130	210	200
Quang Ninh	1.362,88	178	180	130	210	200
Ha Noi	8.435,65	178	180	130	210	200
Total					**1050**	**1000**

2.2.2 Data analysis

Collected data underwent rigorous processing following the research objectives and content. This included data cleaning, classification, coding, and categorization to facilitate the creation of statistical tables and summary charts. Data processing relied on standard software, including Microsoft Excel and SPSS.

a) Descriptive statistics

To analyze participants' awareness, attitudes, and behaviors towards waste management at each research location, the study employed descriptive statistics including measures of central tendency (averages, medians), measures of variability (range, standard deviation), frequency distributions (absolute and relative frequencies), and comparisons between groups.

b) Scoring

A 5-point Likert scale (1-5) was used to measure participants' responses to behaviors and perceptions related to the study's influencing factors. Descriptive statistics specifically means and corresponding values, were calculated to summarize the responses. The distance value, 0.8, was derived from the formula (maximum-minimum)/n = (5-1)/5 = 0.8. Table 2 further clarifies the interpretation of the mean value across five levels of analysis.

Table 2: Meaning of Likert scale responses and corresponding frequency levels.

Likert Scale Value	Mean Value ranges	Agreement level	Frequency level
1	[1; 1.8]	Strongly disagree	Never
2	[1.81; 2.6]	Disagree	Rarely
3	[2.61; 3,4]	Neutral	Sometimes
4	[3.41; 4.2]	Agree	Often
5	[4.21; 5]	Strongly agree	Always

c) Exploratory factor analysis (EFA)

Exploratory factor analysis (EFA) was employed to identify underlying factors structuring the scales measuring awareness, attitudes, and behavior toward waste management at each research location. This technique condenses correlated variables into a smaller set while preserving most of the original information [19]. EFA's suitability was assessed through three criteria: Sampling Adequacy: Bartlett's test and Kaiser-Meyer-Olkin (KMO) coefficient ensured data appropriateness for EFA.

A significant Bartlett's test ($p < 0.05$) and KMO values between 0.5 and 1 indicated sufficient inter-variable correlation [20, 21]; Factor Extraction: Eigenvalues, representing the variance explained by each factor, and cumulative variance extracted indicated the explanatory power of the extracted factors; Factor Loading Significance: Factor loadings, measuring the correlation between variables and factors, were used to assess factor interpretation. Loadings exceeding 0.5 were considered practically significant [17].

d) Reliability of scale assessment

The reliability of the scales measuring awareness, attitudes, and behavior towards waste management was assessed using Cronbach's alpha, a measure of internal consistency for observed variables within a scale. Given the exploratory nature of the study and the potential novelty of the scales for respondents, a minimum acceptable Cronbach's alpha of 0.6 was adopted [22]. This approach acknowledges the potential influence of sample size, especially in new research contexts [23]. To further refine the scales, item-total correlations were calculated, and items with coefficients below 0.3 were removed [22].

e) Multiple regression analysis

Multiple regression analysis was used in this study to assess the impact of factors on the waste management behavior of people at each research location. The regression model is as follows:

$$Be = \beta_0 + \beta_1*KN + \beta_2*AT + \beta_3*SN + \beta_4*PBC + \beta_5*Age + \beta_6*Gen + \beta_7*Edu + \beta_8*In + \beta_9*HS + \beta_{10}*Q + u_i \quad (2)$$

where Be is the household waste management behavior; KN is the knowledge of waste management; AT is an attitude towards waste management; SN is the subjective norms; PBC is the perceived behavioral control; Age is an age; Gen is the gender; Edu is the education level; In is the income; HS is the household size; Q is the household waste generation.

The analysis employed a two-step approach to assess the suitability of the independent variables for explaining the dependent variable. First, correlation analysis using the Enter method identified statistically significant relationships ($p < 0.05$) with the dependent variable through the Pearson correlation coefficient (R) exceeding 0.3. Variables meeting this criterion were considered for model inclusion. The adjusted R^2 coefficient was then used to evaluate the model's goodness of fit, accounting for the potential inflation with increasing variables. Second, analysis of variance (ANOVA) assessed the model's compatibility with the data. Larger β coefficients in the regression equation indicated stronger impacts on the dependent variable, with positive β values signifying positive effects and vice versa.

3. Results

3.1 Awareness, attitudes, and behaviours of households in waste management in some areas of North Vietnam

A survey (Fig. 3) shows generally positive perceptions (average score: 4.2-5) except for understanding SWM service fee calculation (3.9). This is due to a recent regulation change (2020 Law) introducing a new fee structure based on waste volume/weight (previously only collection was charged). Knowledge of waste management services is high (average score: 4.2;5) in most areas (mountainous, coastal, urban) for criteria like waste classification, collection methods, and health risks (KN1, KN2, KN4, KN5, KN6). However, Knowledge of coordinating waste sorting/storage/transfer and Extended Producer Responsibility (EPR) implementation (KN3) is higher in rural mountainous areas (mean score: 4.2-5) compared to other areas (mean score: 3.4-4.2). This difference is because mountainous areas have existing channels for separating specific waste types (batteries) while other areas lack separate collection systems and monitoring for EPR waste (packaging, etc.). Residents attribute this to insufficient infrastructure investment in source separation and collection of sorted waste.

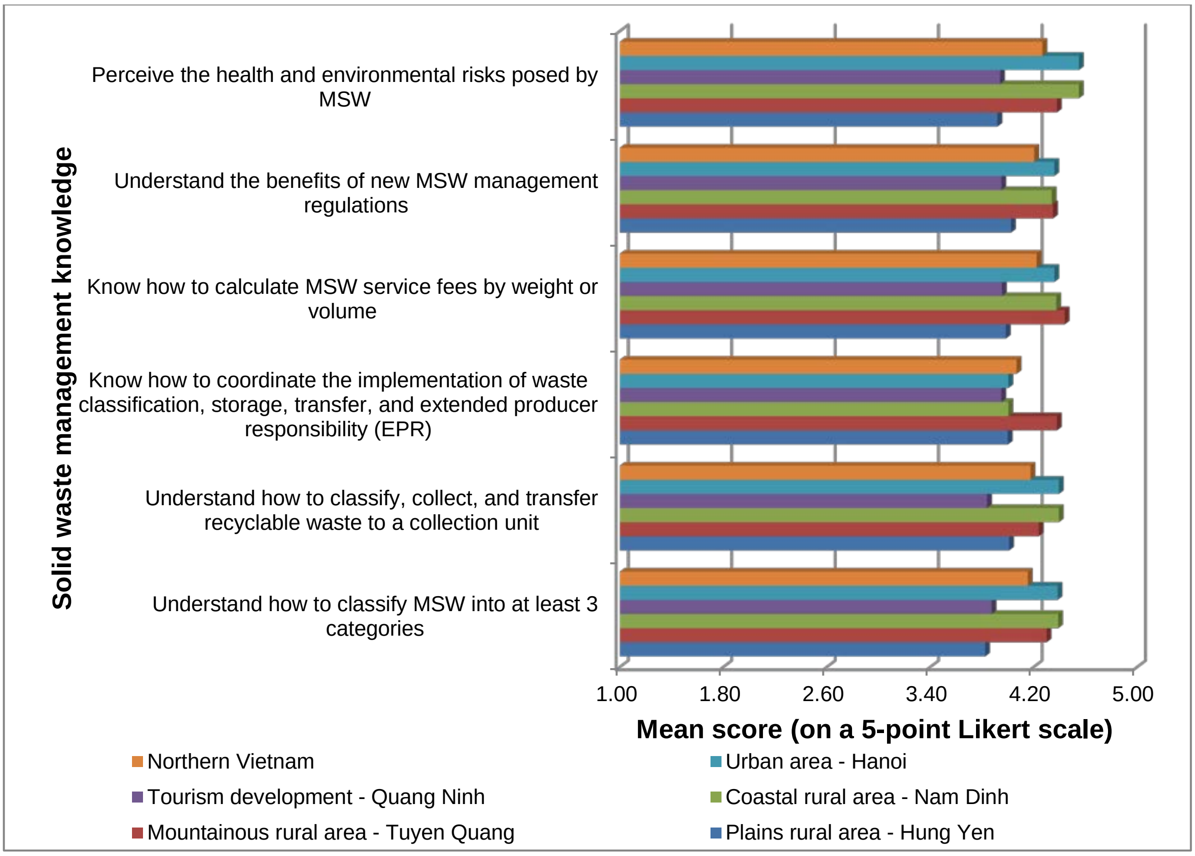

Fig. 3: Levels of knowledge on solid waste management.

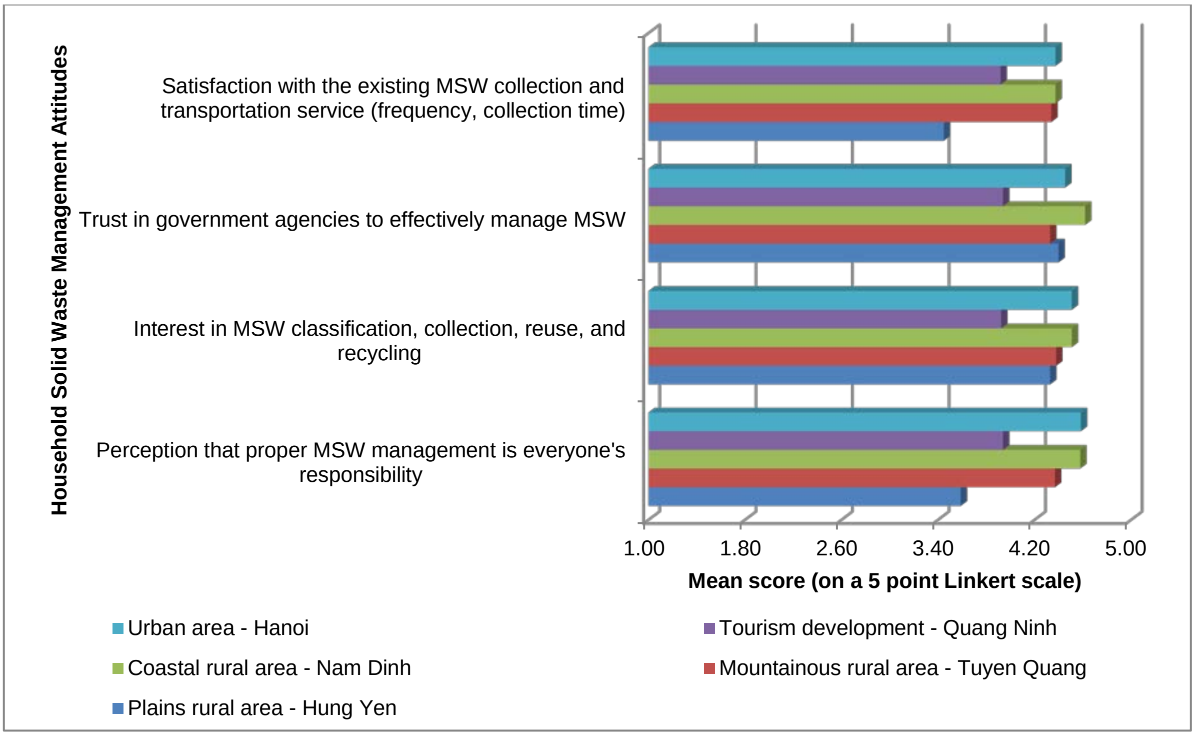

Fig. 4: Attitudes towards household solid waste management in northern Vietnam.

Field surveys conducted in Northern Vietnam show strong support for SWM practices. Over 80% of respondents in mountainous areas, coastal zones, and urban expressed very high levels of agreement with all criteria related to SWM management. Residents trust the government's management (highest score: 4.349) and support waste classification. Plain rural and tourist areas were slightly less enthusiastic (average score: 3.4-4.2) but still supportive (75% agree). Notably, these areas showed high concern for waste classification (AT2) and government trust (AT3).

The behavior of households in waste management in some areas of North Vietnam was evaluated through the self-assessment of households in the region about their waste management behavior, as shown in Fig. 5.

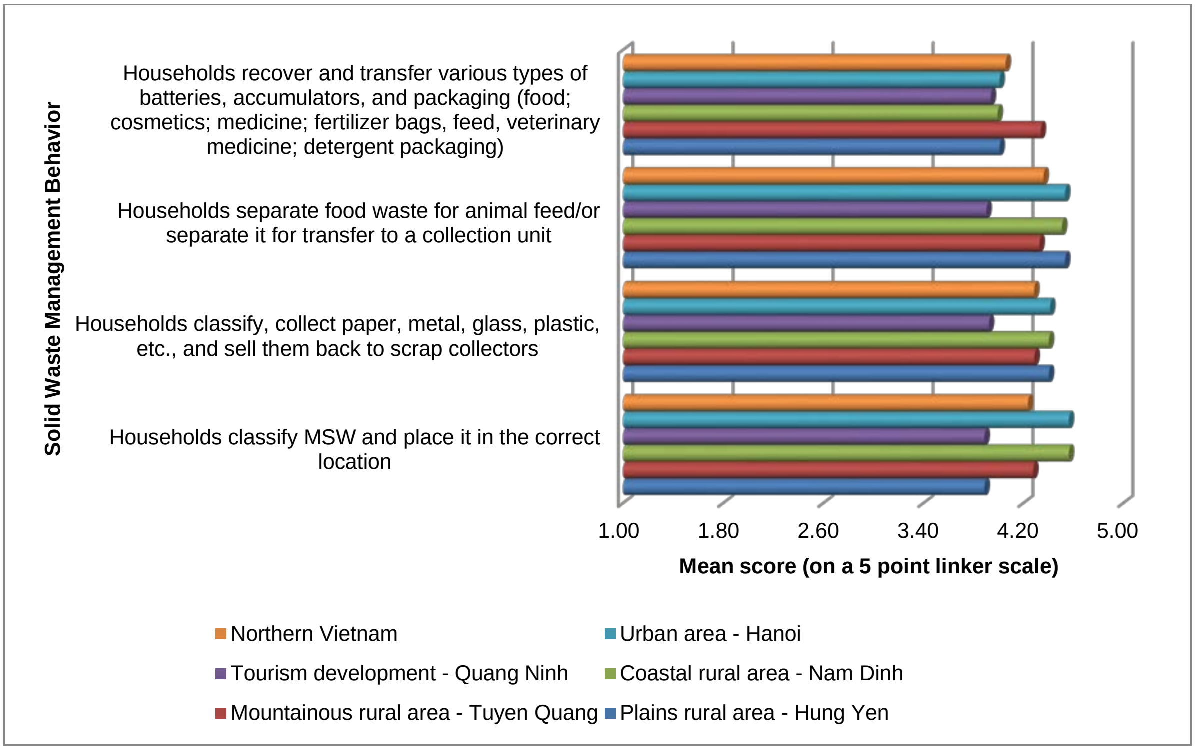

Fig. 5: Behavior Regarding Solid Waste Management.

Northern Vietnamese households reported good waste management practices (Fig. 5). The surveys results show that 89% of participants across rural and urban areas rate their practices highly (average score: 4.2-5). However, in urban areas -Hanoi, there were challenges in separate food waste storage and waste classification due to limited infrastructure for separate collection, high population density leading to smaller living spaces, and a lack of established systems for separate food waste collection (a major waste component). This gap between regulations and infrastructure hinders full compliance. Interestingly, 99.8% of urban residents wanted better infrastructure to meet new waste classification laws. Tourists and service providers in Northern Vietnam's tourist areas (67%) reported lower self-rated waste management practices (Fig. 5) compared to residents. This likely relates to their temporary stays and potentially less responsibility for waste sorting. Conversely, rural residents (higher agreement with "proper disposal") benefit from yards and gardens for composting food waste and raising livestock, creating a natural system for waste utilization.

From the results of the analysis of awareness, attitudes, and behaviors of people in localities about household DSW management and the results of in-depth interviews with local managers, it is found that Rural areas exhibit basic waste separation practices, primarily distinguishing between organic and inorganic waste. Composting initiatives have shown promise, but wider adoption requires enhanced regulations, composting guidance, and infrastructure investments. Tourist areas face lower source separation rates due to differing waste sorting responsibilities perceived by tourists and businesses. However, willingness to classify waste with proper infrastructure suggests potential for improvement. Comprehensive assessments across diverse groups are crucial to promote social responsibility and encourage collective action. Urban areas present challenges in implementing source separation due to dense populations and diverse housing types. Targeted public education campaigns and infrastructure investments, as outlined in the 2020 Environmental Protection Law, are essential to bridge the knowledge-action gap and empower responsible waste management practices.

3.2 Assessing the scale's reliability and refinement

This section assesses the reliability of the scale used to measure people's household SWM behavior in various regions of Northern Vietnam: Plains rural areas, mountainous rural areas, coastal rural areas, tourism areas, and urban areas. The table summarizing the reliability coefficients is presented in Table 3.

Table 3: Reliability of Scales Measuring Household Solid Waste Management Behavior in Northern Vietnam

Research location	Time	Coefficient Cronbach's Alpha	Number of Items
Plains rural area	1st	0.62 8	3
Mountainous rural area	1st	0.9 07	3
Coastal rural area	1st	0.622	4
	2nd	0.69 3	3
Tourism area	1st	0.9 17	4
Urban area	1st	0.643 _	3

This section assesses the reliability of the scale used to measure people's household SWM behavior in various regions of Northern Vietnam: Plains rural areas, mountainous rural areas, coastal rural areas, tourism areas, and urban areas. The table summarizing the reliability coefficients is presented in Table 3.

The table should display Cronbach's Alpha values for each factor and the overall scale for each region. Generally, an Alpha value above 0.6 indicates acceptable internal consistency and reliability. Analyze the item-total correlations for each item within each factor. Ideally, these correlations should be positive and statistically significant ($p < 0.05$), indicating that individual items contribute to their respective factors. Table 3 might also show Composite Reliability coefficients for each factor. Similar to Cronbach's Alpha, values exceeding 0.6 demonstrate good internal consistency. The majority of factors within the scale demonstrate good internal consistency, as evidenced by Cronbach's Alpha coefficients exceeding 0.6. This signifies a strong correlation between the indicators within each factor. Additionally, all individual variables exhibited a total variable correlation coefficient above 0.3, further indicating their contribution to the respective factors. However, during the reliability assessment, variable Be4 ("Families recall and transfer batteries and batteries; packaging (food; cosmetics; medicine; packaging for fertilizers, animal feed, veterinary medicine; packaging for detergents)") from the behavioral scale at the Nam Dinh research location was removed. This removal was prompted by the observation that including Be4 increased the overall Cronbach's Alpha coefficient of the variable group above its coefficient, suggesting a negative impact on internal consistency. By excluding Be4, the internal consistency of the remaining variables improved at the Nam Dinh. While Be4 was eliminated in Nam Dinh, the initial factor structure was retained for the behavioral scales at other research locations. This decision was based on ensuring both convergent and consistent factor determination across all locations.

A subsequent round of exploratory factor analysis (EFA) was conducted specifically for the Nam Dinh behavioral scale to reaffirm the remaining factors. The final EFA results are presented in Tables 4 and 5.

Table 4: Results of testing KMO and Bartlett for measuring household solid waste management behaviors in coastal rural areas.

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.623
Bartlett's Test of Sphericity	Approx. Chi-Square	127,736
	DF	3
	Sig.	0.000

The results of the KMO test and Barlet test from the survey data show that the KMO coefficient = 0.623 > 0.5 and p-value = 0.000 < 0.05 satisfy the conditions, therefore the survey data ensures reliability to perform exploratory factor analysis. The EFA exploratory factor analysis rotation matrix with Varimax rotation is shown in Table 5.

Table 5: Rotated component matrix of factors affecting household solid waste management behavior in coastal rural areas (Nam Dinh Province).

No	Code	Variable explanation	Factor
			1
1	Be1	Households regularly classify DSW and put it in the right place	0.867
2	Be3	Households regularly separate food waste to use as animal feed/or separate food waste to transfer to a collection unit.	0.810
3	Be2	Household regularly sorts and collects paper, metal, glass, plastic, etc., and resells it to a scrap collection facility.	0.710
	Eigenvalues		1,911
	Total variance extracted (%)		63,703

The results of re-running the EFA show that there are 3 variables retained in the model reflecting the DSW management behavior of people in the rural coastal area (Nam Dinh province) and extracted into 1 factor with importance in order. are: Be1, Be3, Be2.

3.3 Analysing factors affecting household solid waste management behavior

This section explores the factors influencing household SWM behavior in five regions of Northern Vietnam. Exploratory factor analysis (EFA) was conducted to identify these underlying factors. Before performing EFA, the Kaiser-Meyer-Olkin (KMO) coefficient and Bartlett's test of sphericity were used to assess the suitability of the data for factor analysis. The KMO values at each research location (0.671 in Hung Yen, 0.875 in Tuyen Quang, 0.844 in Nam Dinh, 0.848 in Quang Ninh, and 0.781 in Hanoi) were all above 0.5, and the p-values for Bartlett's test were all less than 0.05 ($p < 0.000$), indicating that the data met the requirements for EFA. Principal axis factoring with Varimax rotation was chosen as the EFA extraction method. The detailed results of this analysis are presented in Table 6, which systematically summarizes the factors affecting household SWM behavior in each region.

Table 6: Exploratory factor analysis of waste management factors.

No	Factor	Code	Number of Items	Variables
Plains Rural areas				
1	Perceived behavioral control	PBC	3	PBC1; PBC2; PBC3.1
2	Motivation	DC	4	KN1; KN6; AT1; AT4
3	Trust	NT	3	AT3: AT2; KN5
4	Knowledge	KN	3	KN2; KN3; KN4
Mountainous rural area				
1	Knowledge	KN	7	KN1; KN3; KN5; KN6; AT1; AT3; AT4
2	Perceived behavioral control	PBC	3	PBC1; PBC2; PBC3.2
3	Subjective norms	PBC	3	SN1; SN2; SN3
Coastal rural area				
1	Subjective norms	PBC	7	KN5; AT2: AT3; AT4; SN1; SN2; PBC2
2	Knowledge	KN	3	KN1; KN4; PBC1
3	Perceived behavioral control	PBC	3	KN2; PBC3; PBC3.2
Tourism area				
1	Knowledge	KN	9	KN1; KN2; KN3; KN5; KN6; AT1: AT2; AT3: AT4;
2	Perceived behavioral control	PBC	6	PBC1; PBC2; PBC3.1; PBC3.2; PBC3.3; PBC3.4
3	Subjective norms	PBC	3	SN1; SN2; SN3
Urban area				
1	Knowledge	KN	4	KN1; KN3; KN4; PBC1
2	Perceived behavioral control	PBC	3	KN2; AT1; PBC3.2
3	Attitude towards waste management	AT	3	KN5; AT2; SN1

Where KN1: Understands how to classify waste into at least 3 categories; KN2: Understands how to classify, collect, and transfer recyclable waste to collection units; KN3: Knows how to coordinate the implementation of waste classification, storage, transfer, and implementation of extended producer responsibility (EPR); KN4: Knows how to calculate waste service fees by weight or volume; KN5: Understands the benefits of new waste management regulations; KN6: Perceives the risPBC to health and the environment posed by waste; AT1: Believes that proper waste management is the responsibility of everyone; AT2: Concerned about waste collection, recycling, and reuse; AT3: Trusts the government agencies in effectively managing waste; AT4: Satisfied with the current waste collection and transportation services (frequency, collection time); PBC1: Influenced by family members in the classification, recycling, and reuse of waste; PBC2: Influenced by friends, neighbours, and colleagues on the classification, recycling, and reuse of waste; PBC3: Subject to pressure from government agencies to require the implementation of waste classification, recycling, and reuse; PBC1: Perceives the clarity of information and requirements for waste management regulations as stipulated in the 2020 Law on Environmental Protection; PBC2: Availability of infrastructure (containers, bags) and access to waste collection and transportation services; PBC3.1: Experience in classifying waste, putting it in the right place; PBC3.2: Experience in classifying, and collecting paper, metal, glass, plastic, etc., to sell to recycling centers; PBC3.3: Experience in keeping food waste separate from animal feed/or transferring it to collection units; PBC3.4: Experience in recovering and transferring batteries, accumulators, and packaging.

After conducting the EFA factor analysis, the original 4 groups of variables were adjusted differently at each research location. In Hung Yen, representing rural areas, the variables were grouped into 4 factors. In Tuyen Quang, representing Mountainous rural areas, the variables were grouped into 3 factors. Similarly, in Nam Dinh, representing Coastal rural areas, the variables were also grouped into 3 factors. In Quang Ninh, representing the tourism area, the variables were grouped into 4 factors. Lastly, in Hanoi, representing the urban area, the variables were grouped into 3 factors. The total variance extracted indicates that these groups of factors can explain 56.136%, 79.213%, 64.775%, 76.394%, and 66.854% of the variation in data at each research location, respectively. Additionally, the positions of variables in the factors were rearranged. The study then assessed the reliability of the scales reflecting factors influencing household SWM behavior in plain, mountainous, coastal, tourism, and urban areas. The scale testing results showed that Cronbach's Alpha coefficient of most factors is greater than 0.6, indicating an acceptable level of internal consistency between indicators in each scale. The detailed results can be found in Table 7.

Table 7: Reliability of Scales Measuring Household Solid Waste Management Behavior in Northern Vietnam.

No.	Variables	Time	Coefficient Cronbach's Alpha	Number of Items
	Plains rural area			
1	Perceived behavioral control - PBC (PBC1; PBC3.1; PBC2)	1st	0.849	3
2	Motivation - M (AT1; KN6; KN1; AT4)	1st	0.691	4
3	Beliefs (AT3; AT2; KN5)	1st	0.676	3
4	Knowledge - KN (KN3; KN2; KN4)	1st	0.609	3
	Mountainous rural area			
1	Knowledge - KN (AT1; KN6; AT4; AT3; KN3; KN1; KN5) *Items deleted (KN5; KN1)*	1st	0.954	7
		2nd	0.957	6
		3th	0.959	5
2	Perceived behavioral control - PBC (PBC1; PBC3.1; PBC2)	1st	0.865	3
3	Subjective norms - PBC (PBC2; PBC3; PBC1)	1st	0.848	3
	Coastal rural area			
1	Subjective norms - PBC (PBC2; AT3; AT2; PBC2; PBC1; KN5; AT4) *Items deleted: PBC1; KN5; AT4, AT2*	1st	0.827	7
		2nd	0.840	6
		3th	0.861	4

No.	Variables	Time	Coefficient Cronbach's Alpha	Number of Items
		4th	0.872	3
2	Knowledge - KN (KN4; PBC1; KN1)	1st	0.884	3
3	Perceived behavioral control - PBC (PBC3.2; KN2; PBC3)	2nd	0.751	3
	Tourism area			
1	Knowledge - KN (KN3; KN6; AT3; AT4; KN5; KN1; AT1; AT2; KN2)	1st	0.956	9
2	Perceived behavioral control - PBC (PBC3.2; PBC3.1; PBC1; PBC3.3; PBC3.4; PBC2)	1st	0.931	6
3	Subjective norms - PBC (PBC1; PBC3; PBC2)	1st	0.906	3
	Urban area			
1	Knowledge - KN (KN4; PBC1; KN1; KN3) *Items deleted KN3*	1st	0.799	4
		2nd	0.868	3
2	Perceived behavioral control – PBC (PBC3.2; AT1; KN2)	1st	0.763	3
3	Attitudes - AT (KN5; AT2; PBC1)	1st	0.632	3

3.4 Factors influencing household solid waste management behaviour

Drawing on reliability analysis and exploratory factor analysis (EFA) results, this study investigated the influence of identified factors on household waste management behavior across five regions in Northern Vietnam: plains rural, mountainous rural, coastal rural, tourism, and urban area. For each research location, extracted factors and reliable indicators were used in regression analyses to estimate the impact of these factors on waste management behavior within each region. Detailed results are presented in Figs. 7a-7e.

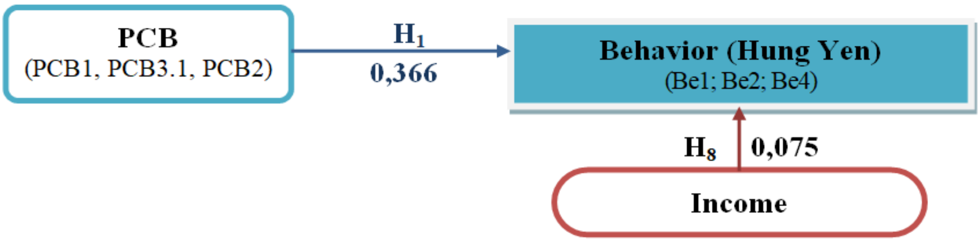

Fig. 7a: Regression analysis of factors influencing DSW management behavior in Hung Yen.

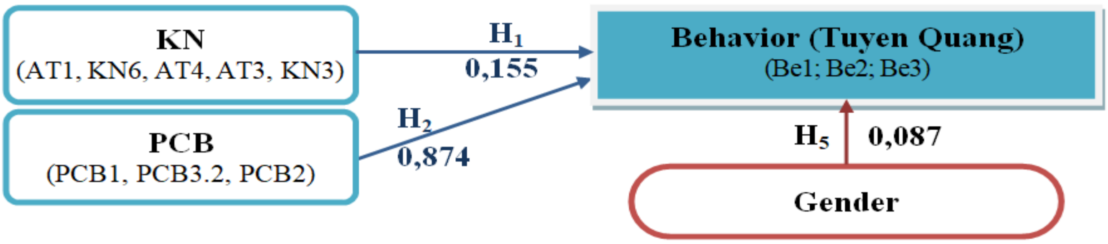

Fig. 7b: Regression analysis of factors influencing DSW management behavior in Tuyen Quang.

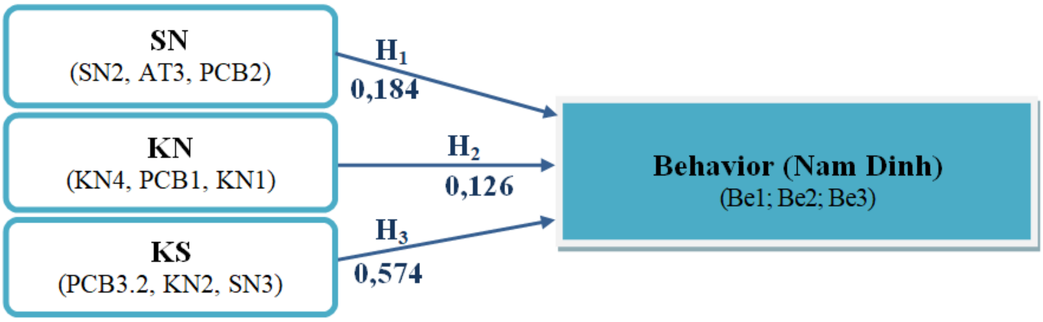

Fig. 7c: Regression analysis of factors influencing DSW management behavior in Nam Dinh.

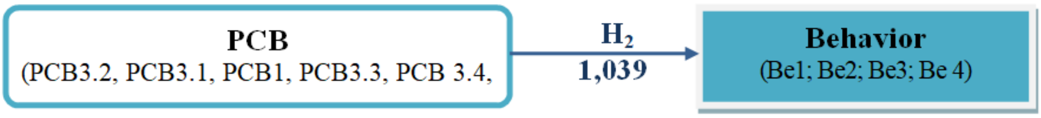

Fig. 7d: Regression analysis of factors influencing DSW management behavior in Quang Ninh.

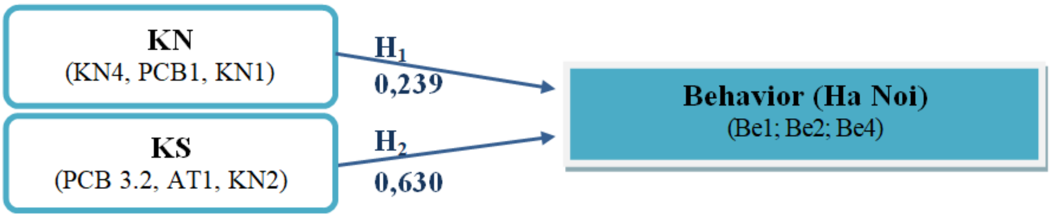

Fig. 7e: Regression analysis of factors influencing DSW management behavior in Hanoi.

The summarizes the regression results for each region, offering valuable insights into the specific factors driving responsible waste management behaviors as follows:

Plains Rural Areas: Knowledge of regulations, experience in waste sorting, and access to infrastructure positively influence waste management behavior.

Mountains: Knowledge of proper waste management techniques, environmental awareness, a sense of community responsibility, trust in authorities, and satisfaction with collection services are all crucial for responsible waste disposal. This emphasizes the importance of building trust and providing reliable collection services to promote community involvement in sustainable waste management programs.

Coastal Areas: Social pressure to recycle, trust in government agencies, awareness of available waste facilities, knowledge of waste classification benefits, and clear regulations all contribute to responsible waste management. This highlights the need for educational initiatives alongside infrastructure development and efforts to build trust with residents.

Tourism Areas: Practical skills in sorting waste, separating recyclables for sale, food waste management, and handling specific waste types significantly influence responsible waste disposal. This emphasizes the need for skill-building programs focused on proper waste handling and resource recovery in tourism-dependent regions.

Urban Areas: Knowledge of waste classification benefits, clear regulations, basic waste sorting skills, the ability to sell recyclables, and a sense of shared responsibility for proper waste management all contribute to responsible behavior in urban areas. This highlights the potential of resource recovery initiatives to motivate proper waste disposal in cities.

In the northern Vietnam, factors such as regulations, practical skills, infrastructure accessibility, peer influence, trust in government agencies, and awareness of waste management techniques play crucial roles in driving responsible waste management practices.

3.5 Discussion

Our findings reveal significant regional variations in knowledge, attitudes, and behaviors (KAB) related to SWM services across Northern Vietnam. People in mountainous, coastal, and urban areas demonstrate high levels of awareness about SWM, particularly regarding waste classification, collection procedures, and understanding of service fees. Positive attitudes towards responsible SWM practices are also evident, with over 80% of respondents in some areas agreeing on the importance of proper waste management and expressing support for changes in SWM aligned with the Law on Environmental Protection. This translates into concrete behavioral changes, as a significant proportion of households in plains rural deltas, coastal areas, and urban areas implement sustainable waste management practices. These findings align with the study by Yilmaz et al. [25], which reports increasing public awareness of environmental issues and a growing willingness to engage in sustainable activities. Our results further show similarities with recent studies documenting positive shifts in public attitudes toward responsible waste management [6], [26]-[29].

While a significant proportion of households in the plains, rural, coastal areas, and urban areas engage in responsible SWM practices, challenges remain. Our research also highlights regional variations in enthusiasm for waste segregation. Residents in plain rural areas and tourist destinations, although supportive, expressed lower levels of agreement compared to those in mountainous and urban areas. This observed discrepancy between attitudes and behavior aligns with previous research. Sinthumule and Mkumbuzi [30] found no significant correlation between people's attitudes and participation in household waste management in Nkulumane, Zimbabwe. Similarly, Laor et al. [31] reported a lack of significant correlation between knowledge, attitudes, and SWM practices in Northern Thailand. These findings suggest that positive attitudes alone may not translate into consistent participation in waste management activities. The interplay between socioeconomic factors, cultural norms, and waste management practices can significantly influence responsible waste management behavior. Investigating these aspects in more detail could yield valuable insights for future research.

Our research found infrastructural limitations and collection vehicle availability to be potential explanations for the observed regional differences in waste management behavior. Notably, the study identified challenges faced by urban areas like Hanoi due to a lack of separate waste collection infrastructure. This aligns with previous research by Kaur et al. [32], who identified similar infrastructural constraints as major barriers to effective waste management in developing countries. In our study, despite positive attitudes towards waste segregation, residents in urban areas like Hanoi were unable to fully comply due to these limitations. This finding is further supported by Guerrero et al. [33], who emphasized the critical role of infrastructure in effective waste management. The challenges of urban waste management in developing countries are further elaborated by Srivastava et al. [34]. The results highlight the complex interplay of factors such as inadequate infrastructure, limited resources, and high population density, which can significantly hinder waste collection and treatment efforts in urban areas.

Our analysis of influencing factors revealed that the observed variations across regions may be attributed to factors such as infrastructure, social norms, and economic conditions, necessitating tailored approaches. Designing region-specific interventions for effective solid waste management (SWM) is crucial. This aligns with the research findings of Kountouris et al. [35], who emphasized the value of region-specific strategies in improving SWM. Fiksel et al. [36] proposed context-specific solutions for municipal SWM in Romania, highlighting the need to address local challenges. Similarly, Ciută et al. [37] investigated waste management in Ghanaian communities, their findings supporting the need for comprehensive policies that consider location-specific needs. Therefore, context-specific interventions are of paramount importance for successful SWM implementation. For rural areas, promoting solid waste segregation and recycling methods has the potential to further enhance SWM practices, especially in areas where positive attitudes towards waste management already exist, such as mountainous rural areas. Implementing educational programs and fostering community-based initiatives could be valuable strategies for achieving this goal. The effectiveness of such approaches is supported by existing research. Boateng et al. [30] compared SWM practices in rural and urban India following an intervention using creative teaching methods. Their findings revealed significant improvements in knowledge, attitudes, skills, and waste management behaviors among the group exposed to these methods. This suggests that educational programs can have a particularly significant impact in fostering enthusiasm for SWM, especially in rural areas with limited access to formal education. Furthermore, the study also emphasizes the importance of social aspects in successful waste management. Communities need to be informed and involved in the development of environmental protection covenants that are tailored to local specificities. These covenants should include regulations on SWM, as well as provisions for rewards, penalties, and community-based monitoring and implementation. A study conducted in Guilin, China [38], highlighted the critical role of community participation in the effectiveness of rural SWM programs. Tourist destinations face distinct challenges in managing the large amounts of waste generated by tourists and the tourism industry. Effective solutions require targeted approaches that promote active participation from tourists, local communities, tourism businesses, and government agencies in waste management efforts [39]. Stakeholder engagement strategies can be tailored to address these specific challenges. For example, Munar [40] proposes leveraging social media platforms to promote waste management initiatives to tourists and tourism businesses. This aligns with the potential of targeted interventions using social media to engage stakeholders and raise awareness in tourist destinations. Furthermore, managing marine waste, a significant environmental issue in coastal tourist destinations, requires collaboration between stakeholders. Chen [41] emphasizes the importance of regulations and management strategies that involve local communities, tourism operators, and environmental organizations. Finally, Kaur and Lodhia [42] stress the need for stakeholder engagement in sustainability initiatives, including waste management activities and reporting. This concept can be directly applied to tourist destinations, where stakeholder engagement can enhance accountability and transparency in waste management efforts. Specific recommendations for different stakeholders include tourism businesses: Print and paste waste segregation instructions on corresponding bins for 3 or more waste types. Establish a team to guide and monitor the implementation process at tourist attractions; Tourists and travel agencies: Enhance social responsibility and comply with waste segregation regulations when visiting tourist destinations; Accommodation facilities and households: Participate in activities, training sessions, and comply with general regulations on SWM. By implementing these targeted measures and fostering active stakeholder participation, tourist destinations can effectively address the challenges of waste management and contribute to a more sustainable tourism industry.

The success of SWM measures greatly depends on the participation of all stakeholders, including the responsible role of local authorities. Our study confirms a high level of public trust in government efforts to manage solid waste, suggesting a potential to influence and encourage community-based initiatives for responsible waste management. Studies have shown that community participation is crucial for successful waste management [43]. However, research has also highlighted cases of failed waste management where the community remains indifferent and local authorities are solely responsible [44]. To achieve sustainable waste management, it is important for local authorities to actively engage and sensitize residents, provide adequate waste management services, and incentivize community participation. The challenges faced by local authorities in waste management include poor community engagement, understaffing, urban sprawl, political interference, shortage of resources, and natural hazards [26]. Effective SWM requires a multi-pronged approach that fosters collaboration among stakeholders. Local authorities play a pivotal role in tackling waste management challenges. To achieve this, they must implement effective strategies and policies that encourage the active participation of all stakeholders. Investing in essential infrastructure, such as waste storage, collection, transportation, and treatment facilities, is crucial for a robust SWM system. Additionally, implementing fee systems, promoting knowledge sharing about waste reduction and recycling practices, and developing appropriate waste management models tailored to local needs are essential measures. Furthermore, establishing effective inspection and monitoring mechanisms is critical to ensure compliance with regulations. At the provincial level, optimizing regulations to streamline processes, determining a fair and reasonable pricing structure for SWM services, and ensuring financial transparency are crucial actions to support the long-term sustainability of the system.

4 Conclusion

There are significant regional variations in knowledge, attitudes, and behaviors related to solid waste management (SWM) across Northern Vietnam. The study found that people in mountainous, coastal, and urban areas demonstrate high levels of knowledge on SWM, waste classification, collection procedures, and understanding of service fees. Positive attitudes towards responsible SWM practices are also evident, with over 80% of respondents in some areas expressing support for changes in SWM aligned with the Law on Environmental Protection 2020. Results of regression emphasizes the need for region-specific interventions tailored to address the unique challenges faced by each locality. Rural areas might benefit from programs promoting advanced sorting practices, while tourism zones could prioritize initiatives that encourage tourist and travel agency participation in waste management. In densely populated urban areas with varied housing contexts, the development of innovative strategies for source separation implementation is crucial. While this study provides valuable insights into public awareness and self-reported solid waste management activities in Northern Vietnam, it is important to acknowledge some limitations. Relying on self-reported data from surveys may introduce a social desirability bias, where participants could potentially exaggerate their SWM activities. To address these limitations in future research, integrating observational studies with surveys can offer a more objective evaluation of real waste management behaviors. Additionally, longitudinal studies can effectively monitor changes in public perception and practical behaviors over time, especially in response to policy adjustments or infrastructure advancements.

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