Assessing public awareness, attitudes, and behaviors toward domestic solid waste management in mountainous areas of Tuyen Quang province, Vietnam

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Abstract: Domestic solid waste (DSW) management in mountainous areas faces significant challenges due to limited infrastructure and low levels of public awareness. This study aims to assess the awareness, attitudes, and behaviors of residents in three mountainous communes of Tuyen Quang province (Nhu Khe, Luong Vuong, and Cong Da) regarding the implementation of the 2020 Law on Environmental Protection, particularly provisions on DSW segregation and collection. Using a sociological survey of 660 households, the study analyzes the factors influencing residents' waste management behaviors through a theoretical framework, descriptive statistics, exploratory factor analysis (EFA), and multivariate regression. The results reveal that while local resident attitudes toward DSW management are generally positive, with 80% expressing agreement with the necessity of proper waste management, but knowledge of local resident remains limited, especially regarding the calculation of service fees under new regulations. Key determinants of behavior include perceived behavioral control, legal knowledge, and social influence. Based on these findings, the study proposes policy recommendations aimed at enhancing communication strategies, improving DSW management infrastructure, and strengthening community participation to increase the effectiveness of DSW management in mountainous regions.

Keywords: Domestic solid waste management, public awareness, environmental behavior, mountainous areas, Tuyen Quang, law on environmental protection 2020.

1. Introduction

The 2020 Law on Environmental Protection, with its primary goal of raising public awareness and improving domestic solid waste (DSW) management, has introduced critical regulations concerning waste segregation, collection, reuse, and recycling. These regulations aim to minimize the negative impacts of DSW on the environment and human health (Ministry of Natural Resources and Environment (MONRE, 2020). However, the success of these regulations largely depends on effective and accurate implementation at the household level, where DSW management behaviors can be influenced by various factors (Cuong et al., 2022).

In major urban centers, residents typically demonstrate good knowledge and positive attitudes toward 3R strategies-Reduce, Reuse, Recycle (Zand et al., 2020; Almasi et al., 2019; Padilla & Trujillo, 2018). In contrast, in rural and mountainous areas, the lack of adequate infrastructure, underdeveloped DSW collection services, and limited understanding of the regulations may lead to significant discrepancies between policy and practice. Previous studies have shown that community awareness and attitudes toward DSW management are not uniform and have a direct influence on DSW -related behaviors, especially in rural and mountainous settings (Lukman et al., 2022; Giao & Thien, 2022; Meng et al., 2019; Ma et al., 2020; Zhang et al., 2015).

Tuyen Quang, a mountainous province in northern Vietnam, faces various challenges in effectively implementing DSW management policies. Differences in natural conditions, demographics, infrastructure, and waste services across communes result in inconsistency in how legal requirements are met. Some previous research has also emphasized the importance of social factors and local government support in shaping environmentally responsible behaviors (Bagher et al., 2018; Sharaf et al., 2015).

This study aims to: (i) assess the level of public understanding of legal regulations related to DSW management; (ii) analyze community attitudes toward DSW segregation, collection, reuse, and recycling; and (iii) identify key factors influencing DSW management behavior and propose appropriate solutions adapted to the mountainous context.

A structured sociological survey was conducted with 660 households in three representative communes of Tuyen Quang province. The data were processed and analyzed using modern statistical tools, including SPSS, exploratory factor analysis (EFA), and multivariate regression, to ensure the scientific rigor and reliability of the results.

2. Study Area and Methodology

2.1. Study Area Description

The study focuses on Tuyen Quang province, a mountainous region located in the Northeast of Vietnam. Tuyen Quang features diverse topography, including high mountains, hills, and small lowland plains. The province's economic and social development characteristics differ significantly from those of urban or lowland rural areas.

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Its complex terrain poses specific challenges for developing DSW management infrastructure, particularly in terms of DSW collection and treatment systems. The provincial economy is primarily based on agriculture and forestry. Although there have been improvements in recent years, Tuyen Quang continues to face considerable difficulties in enhancing public service delivery, including DSW management. Limited financial resources and underdeveloped infrastructure further constrain the province's capacity to effectively implement the regulations on DSW segregation and collection mandated by the 2020 Law on Environmental Protection (General Statistics Office of Tuyen Quang, 2022).

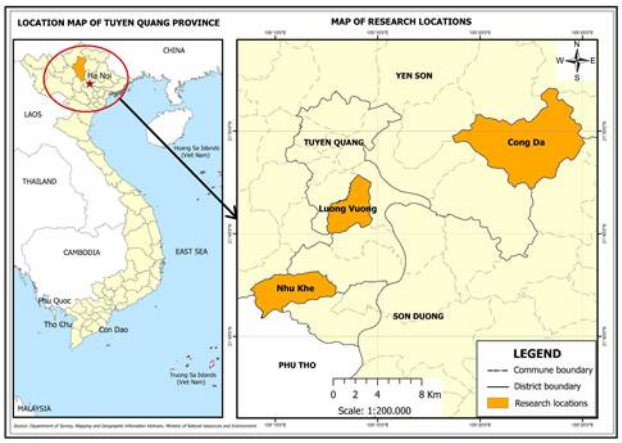


Figure 1. Map of the Study Area

This study focuses on assessing the current state of awareness, attitudes, and behaviors of local communities in Tuyen Quang regarding the requirements for waste segregation and collection at three typical mountainous communes in Tuyen Quang province: Nhu Khe, Luong Vuong, and Cong Da. Nhu Khe commune is located in a hilly area with many valleys and small streams. The local economy is predominantly agricultural, with 81% of the population engaged in farming activities. Major crops include rice, maize, and various fruit trees. The commune has a diverse ethnic composition, mainly consisting of the Tay (about 50% of the population) and the Dao (approximately 30%). Its mountainous terrain and difficult road access create obstacles to efficient waste collection and transportation. Luong Vuong commune is situated on a plateau near limestone mountain areas and small river systems. Agricultural activities dominate, with rice accounting for 60% of the commune's cultivated land, along with sweet potatoes and fruit trees. The local population primarily comprises Kinh, Tày, and Dao ethnic groups. The limestone terrain poses challenges for developing effective DSW treatment infrastructure. Cong Da Commune features a mix of hills and valleys. Agriculture is the main livelihood, with over 86.7% of the population involved in farming and livestock raising. The commune has a rich ethnic diversity, including Tày, Dao, and H'mong communities. However, residents face significant financial constraints, limiting their ability to afford and access solid DSW management services (General Statistics Office of Tuyen Quang, 2022).

2.2. Research methods

2.2.1. Data collection method

This study employed a structured questionnaire-based sociological survey, conducted with 660 households across three mountainous communes in Tuyen Quang province (Nhu Khe, Luong Vuong, and Cong Da). The questionnaire included the following components: Demographic information: age, gender, occupation, income, education level, household size; Awareness, attitudes, and behaviors related to domestic solid waste (DSW) management; Influencing factors, including social norms, local government support, and infrastructure conditions.

A stratified random sampling method was adopted to ensure representativeness across communes. After data cleaning, 600 valid responses were retained, accounting for a response rate of 90.9%.

Sample Size Determination

Sample size was calculated based on Glover's formula [Glover, 2003]:

$$\mathrm{n} = \frac{N}{(1 + N.e^2)}$$

Where:

- n = required sample size;
- N = total population in the study area;
- e = acceptable margin of error (typically between 0.05 and 0.1; $e = 0.075$ was chosen as a balanced value ensuring reliability).

Additionally, for Exploratory Factor Analysis (EFA), the minimum sample size must meet a ratio of at least 5:1 observation per measurement variable, and ideally 10:1 (Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R.E., 2009). With 19 theoretical constructs and 17 individual items in the survey, the minimum sample size was calculated as: 5×36=1805 \times 36 = 1805×36=180

For multivariate regression analysis, the minimum required sample size is determined by:

n=50+8mn = 50 + 8mn=50+8m

Where m is the number of independent variables (Tabachnick & Fidell, 2007). With 4 independent variables and 6 control variables, the required minimum was:

n=50+8×10=130n = 50 + 8 \times 10 = 130n=50+8×10=130

The sample structure is summarized in **Table 1**.

Table 1. Survey Sample Structure

Study Site	N – Average Population (2022) [17]	Minimum sample Size per formula (e = 0.075)	EFA (36 Variable)	Regression (10 Factors)	Distributed Surveys	Valid Responses
Nhu Khe Commune	4,612	171	180	130	210	200
Luong Vuong Commune	5,303	172	180	130	210	200
Cong Da Commune	5,800	172	180	130	210	200
Total	–	–	–	–	**660**	**600**

2.2.2. Data analysis method

The collected data were processed through a rigorous procedure aligned with the study's objectives and content. This included data cleaning, classification, coding, and grouping to perform statistical analysis and visualization. Data processing was carried out using Microsoft Excel and SPSS software.

a) Descriptive Statistics: Descriptive analysis was conducted to examine central tendency indicators (mean), standard deviation, frequency distributions, and levels of agreement using a 5-point Likert scale.

b) Scoring Method: Responses were evaluated using a 5-point Likert scale ranging from "strongly disagree" to "strongly agree." The interval values for interpretation were calculated using the formula: (maximum – minimum)/n = (5-1)/5 = 0.8.

Table 2 shows the interpretation of average scores across five levels of analysis.

Table 2. Interpretation of Likert Scale Levels and Average Score Ranges

Likert Scale Score	Range of Average Scores	Agreement Level	Frequency Level
1	[1.00 – 1.80]	Strongly disagree	Never
2	[1.81 – 2.60]	Disagree	Rarely
3	[2.61 – 3.40]	Neutral	Occasionally
4	[3.41 – 4.20]	Agree	Frequently
5	[4.21 – 5.00]	Strongly agree	Always

Reliability Assessment of the Scales

The reliability of the scales was assessed using Cronbach's Alpha, with a minimum acceptable threshold of 0.6. Items with item-total correlations less than 0.3 were removed to improve internal consistency [Peterson, 1994].

Exploratory Factor Analysis (EFA)

Exploratory Factor Analysis was used to test the dimensional structure of variable groups. The Varimax rotation method was applied, with the following criteria for acceptability:

Kaiser-Meyer-Olkin (KMO) ≥ 0.5

Bartlett's test of sphericity significant at $p < 0.05$

Multiple Regression Analysis

Multiple regression analysis was used to examine the effects of various factors on DSW management behavior at the household level in each study site. The regression model is specified as follows:

$$\mathbf{HV = \beta_0 + \beta_1*HB + \beta_2*TD + \beta_3*CQ + \beta_4*KS + \beta_5*T + \beta_6*GT + \beta_7*TDHV + \beta_8*TN + \beta_9*SNK + \beta_{10}*Q + u_i}$$

Where: **HV**: Household behavior in DSW management, **HB**: Knowledge regarding DSW management, **TD**: Attitude toward DSW management, **CQ**: Subjective norms related to DSW management, **KS**: Perceived behavioral control, **T**: Age, **GT**: Gender, **TDHV**: Educational level, **TN**: Household income, **SNK**: Household size (number of members), **Q**: Volume of household-generated DSW, $\mathbf{u_i}$: Error term

3. Research results

3.1. Public awareness, attitudes, and behaviors toward domestic solid waste management in mountainous areas of Tuyen Quang

The survey of 600 households revealed that, overall, local resident awareness of DSW management remains at a moderate level. Average scores across awareness indicators ranged from 2.6 to 3.4 on a 5-point Likert scale (Figure 2). The lowest average score (1.34) was observed for the criterion "Knowledge the calculation of DSW service fees based on DSW volume or weight", highlighting the lack of dissemination and communication regarding the new pricing regulation introduced in the 2020 Law on Environmental Protection.

There are notable differences in awareness levels across the communes: Nhu Khe Commune: Residents demonstrated limited awareness of DSW classification, with an average score of 2.13. About 87% of surveyed households only classified DSW into two broad categories: organic and inorganic, primarily due to the lack of guidance and appropriate classification tools. Luong Vuong Commune: Awareness was significantly higher, with an average score of 2.80. Approximately 63% of households had adopted a more refined DSW classification system, dividing DSW into three categories: organic, recyclable, and hazardous waste. Cong Da Commune: The average awareness score was 2.39, indicating a moderate understanding. While residents were somewhat aware of DSW classification, actual implementation remained limited due to infrastructure constraints.

In general, local resident knowledge regarding key aspects such as environmental benefits, coordination with DSW collection units, and the implementation of Extended Producer Responsibility (EPR) remains insufficient-particularly in economically disadvantaged and remote areas.

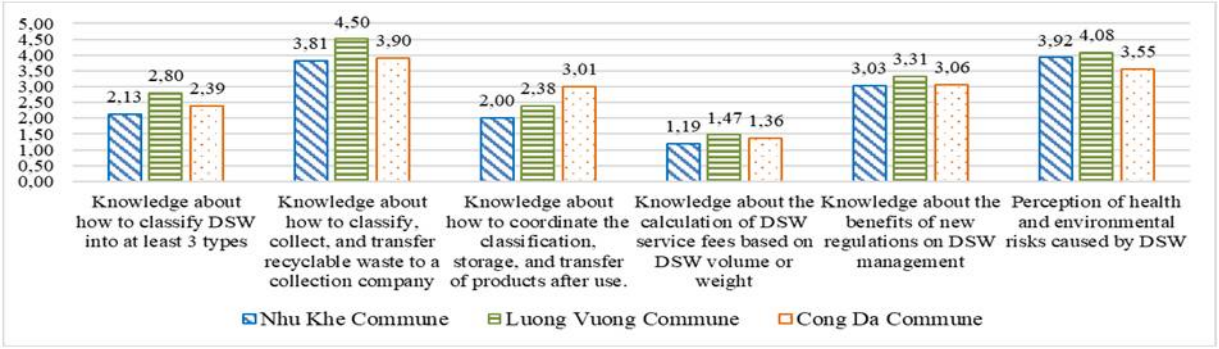


Figure 2. Awareness level of residents in mountainous areas of Tuyen Quang regarding DSW management

The analysis of attitudes indicates a generally positive trend among local residents in approaching DSW management. Approximately 80% of survey participants agreed with statements concerning the importance of sorting, collecting, and recycling DSW. On average, attitude scores ranged from 2.9 to 3.8 points.

The highest-rated criterion was "interest in sorting, collecting, reusing, and recycling DSW," with an average score of 3.8. In particular: Luong Vuong commune reported the highest attitude score (4.58), reflecting frequent participation in waste-sorting activities. Nhu Khe and Cong Da communes also demonstrated positive attitudes, although the level of participation varied due to the lack of support programs and essential infrastructure.

Conversely, the criterion “satisfaction with existing DSW collection and transportation services” received the lowest average score, especially in Cong Da Commune (2.38), highlighting inadequacies in service quality in remote and mountainous areas.

This variation in self-assessed attitudes across communes reflects underlying differences in access to information, infrastructure, and institutional support. The notably high score in Luong Vuong commune may be attributed to better exposure to awareness campaigns and the availability of organized waste sorting programs. These findings suggest that when enabling conditions are present, residents in mountainous areas are not only aware of but also willing to engage in sustainable DSW management practices.

In contrast, the relatively lower scores in Cong Da Commune, particularly regarding satisfaction with current DSW services, underscore the persistent challenges in remote regions. Poor transportation infrastructure, limited DSW collection coverage, and infrequent service schedules are likely contributing factors. These disparities point to the need for context-specific interventions that address local barriers, such as the provision of collection points, community-based waste initiatives, and targeted education campaigns.

The statistical results of self-assessed attitudes of mountainous residents in Tuyen Quang toward DSW management are presented in Figure 3.

Analysis of people’s solid waste management behavior shows a high level of consensus on positive actions, especially regarding source separation and utilization of organic waste: Luong Vuong commune has the highest behavioral score for the criterion “classifying and placing waste in the right place” (4.07). Cong Da commune stands out with the behavior of “separating food waste for animal/poultry feed” (4.75). However, the behavior of “collecting and transferring batteries to specialized purchasing units” recorded a low average score in all three communes, reflecting a lack of awareness and infrastructure to support hazardous waste collection.

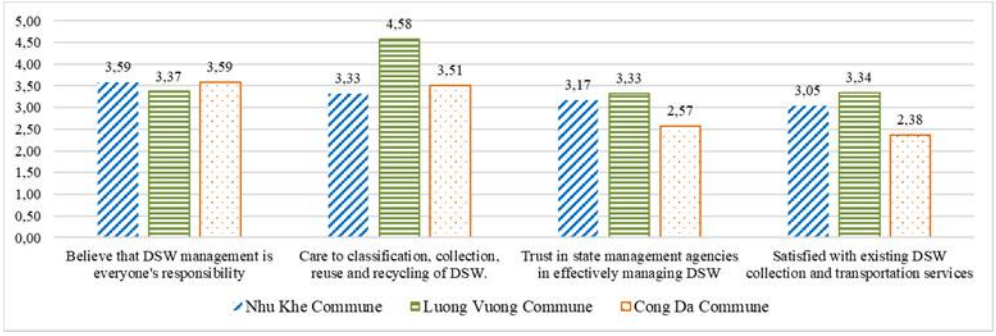


Figure 3. Self-assessment of attitudes toward domestic solid waste management among residents in mountainous areas of Tuyen Quang

The statistical results of self-evaluated behaviors concerning DSW management among mountainous residents in Tuyen Quang are illustrated in Figure 4.

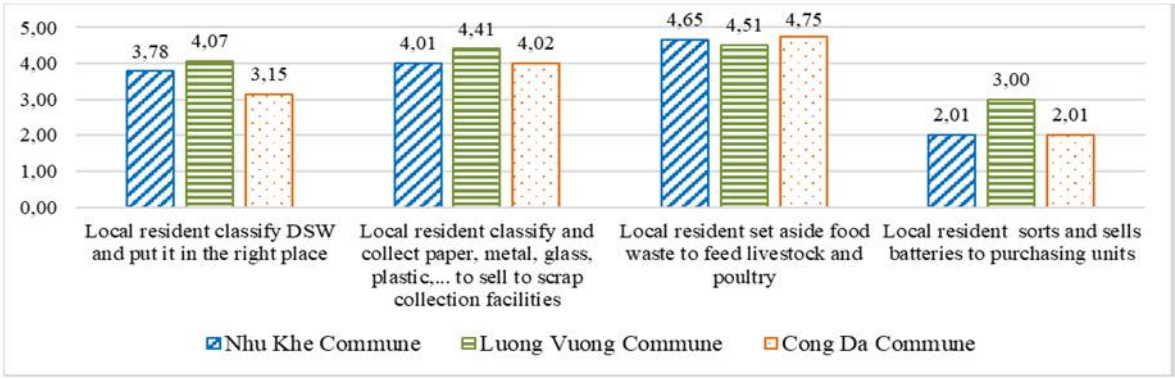


Figure 4. Self-assessment of household behaviors in domestic solid waste management among residents in mountainous areas of Tuyen Quang

3.2. Reliability Assessment and Scale Refinement

The reliability of perception, attitude, and behavior measurement scales was assessed using Cronbach's Alpha coefficient. Results from all three communes indicate that the scales meet the acceptable threshold ($\alpha \geq 0.6$), reflecting relatively good internal consistency among the observed variables.

In Cong Da Commune, the original behavioral scale included four items. However, item HV4 (battery/accumulator disposal) was removed due to its negative impact on internal consistency (the overall Cronbach's Alpha increased upon removal). The subsequent Exploratory Factor Analysis (EFA) showed that the remaining three items converged into a single factor with all factor loadings > 0.7 and a total variance explained of 61.37%.

The KMO coefficient (0.623) and Bartlett's Test ($p < 0.001$) further confirmed the data's suitability for factor analysis.

3.3. Analysis of Factors Influencing DSW Management Behaviors

EFA was conducted separately for each study site to identify key factor groups influencing household DSW management behaviors.

- In Nhu Khe Commune, the main factors included: *Perceived Behavioral Control (KS)*, *Motivation for DSW Management (DC)*, *Trust in Public Policy and Governance (NT)*, and *Legal Knowledge (HB)*.

- In Luong Vuong Commune, three primary factors were identified: *Knowledge of DSW Management (HB)*, *Perceived Behavioral Control (KS)*, and *Subjective Norms (CQ)*.

- In Cong Da Commune, the three retained factors included: *Subjective Norms (CQ)*, *Legal and Practical Knowledge (HB)*, and *Perceived Behavioral Control (KS)*.

The total variance explained by these factor models ranged from 60.2% to 65.5%, indicating a relatively good explanatory power.

Subsequently, the reliability of the refined factor scales was reassessed using Cronbach's Alpha. Most factors achieved alpha values between 0.65 and 0.85, demonstrating acceptable internal consistency and convergence of observed items.

3.4. Factors Influencing Household DSW Management Behavior

Based on the extracted and verified factors, multivariate regression models were developed to identify key predictors of household DSW management behavior in each commune.

(1) Nhu Khe Commune:

$$HVnk = 1.599 + 0.366\mathbf{KS} + 0.075Income + ui$$

KS (Perceived Behavioral Control) is the strongest positive predictor (β = 0.366), highlighting the role of access to information and infrastructure.

Income has a smaller but positive effect (β = 0.075).

(2) Luong Vuong Commune:

HVlv = -0.103 + 0.155HB + 0.874KS + 0.087Gender + ui*

KS remains the dominant factor (β = 0.874), affirming its central importance.

HB (Knowledge) has a moderate positive impact (β = 0.155).

Gender shows a minor effect, suggesting behavioral differences between men and women.

(3) Cong Da Commune:

HVcd = -0.614 + 0.184CQ + 0.126HB + 0.574KS + ui*

KS continues to play a key role (β = 0.574).

CQ (Subjective Norms) is also significant (β = 0.184), reflecting social and community influence.

HB (Knowledge) has a moderate positive effect (β = 0.126).

The findings from regression analysis reveal not only the statistical significance of perceived behavioral control, legal knowledge, and social norms, but also their practical implications when linked to awareness and attitudes. Specifically, households with higher awareness of legal obligations (Objective 1) tend to form stronger positive attitudes (Objective 2), which, in turn, translate into more consistent pro-environmental behaviors (Objective 3). For instance, in Luong Vuong commune, where residents demonstrated the highest awareness and attitudes, behavioral practices such as source separation were also the most prevalent. Conversely, in Cong Da, where awareness and satisfaction with waste services were lower, behaviors lagged despite positive attitudes. This highlights a "knowledge–attitude–behavior gap" that is particularly pronounced in remote mountainous areas.

In the specific context of Tuyen Quang's mountainous communes, these findings have direct implications for the implementation of the 2020 Environmental Protection Law. The law stipulates mandatory source separation, cost-based service fees, and community participation in waste management; however, the effectiveness of these provisions is constrained by geographical isolation, limited infrastructure, and socio-economic disparities in upland areas. Our results demonstrate that when awareness (Objective 1) and attitudes (Objective 2) are not adequately translated into behaviors (Objective 3), the legal framework cannot achieve its intended outcomes. This highlights the necessity of localized strategies that integrate legal literacy, culturally tailored communication, and infrastructure support, ensuring that national legislation is adapted to the mountainous conditions of Tuyen Quang. By explicitly aligning behavioral determinants with the requirements of the 2020 Environmental Protection Law, this study provides actionable insights for policymakers to bridge the gap between regulation and practice in rural upland settings.

Policy Recommendations

1. Strengthen environmental education and community awareness

Local environmental communication units in mountainous areas should tailor education campaigns to cultural and linguistic contexts to enhance public awareness of DSW impacts, promote source classified and explain pricing and responsibilities under the 2020 Environmental Protection Law.

Use trusted communication channels such as local radio, village loudspeakers, and community events to disseminate targeted educational content.

Promote exemplary households with effective DSW practices to create social motivation and peer influence.

Encourage collaboration between local governments, NGOs, and minority support organizations to provide financial and technical assistance for education and recycling activities.

2. Promote behavioral change in source separation, collection, and recycling

Organize community-based clean-up events, DSW collection drives, and training on DSW separation to encourage hands-on participation.

Conduct practical workshops on recycling techniques and upcycling waste into usable products.

Establish community self-management groups to maintain and expand household-level recycling initiatives.

4. Conclusion

This research has based on a survey of 600 households and multivariate regression analysis. The research result showed that the residents' awareness of legal regulations and technical aspects of DSW classification is generally at a moderate level, with considerable variation among communes. Knowledge about waste service pricing and environmental benefits remains limited. residents' attitudes toward waste separation and recycling are generally positive. Over 80% of respondents expressed strong agreement with criteria related to individual and community responsibility in DSW management. Residents' actual household behavior mainly focuses on basic practices such as source classification and reuse of organic waste. However, hazardous waste handling (e.g., batteries, accumulators) remains ineffective due to the lack of specialized collection facilities. Key factors influencing household DWS behavior include: (i) perceived behavioral control (e.g., clarity of information and availability of infrastructure); (ii) legal knowledge; and (iii) social norms and community influence. Among these, perceived behavioral control was found to be the most influential factor across all three communes. The findings provide clear evidence

to support the design of environmental communication policies and programs tailored to the unique conditions of mountainous regions.

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