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Assessment of Household Waste Generation and Management in Rural Areas: A Case Study in Ha Nam Province, Vietnam

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While great attention has been focused on urban waste management, waste management in rural areas is still much less concerned both at investigation and investment levels. This study aims to survey household waste generation, treatment methods, and willingness-to-pay in a low-income province in the northern part of Vietnam. The results showed that the solid waste generation rate varied depending on household size and economic conditions. Specifically, they were 0.62 kg/person/day, 0.49 kg/person/day, and about 0.25 kg/person/day, respectively, for people living in the provincial city, town, and communes. On average, the waste generation was about 0.33 kg/person/day, which was much lower than in other provinces of Vietnam; however, this rate was at the same level as other low-income provinces internationally. The surveyees were willing to pay only about US$ 0.25/HH/month (accounting for 0.25% of HH monthly expenses). This payment rate was low, leading to many challenges in proper waste management in rural areas.

Keywords: household waste, generation rate, willingness-to-pay, rural areas.

Introduction

Household (HH) waste management has been an emerging issue for sustainable living conditions in developing countries. The amount of this solid waste generated per capita reflects the differences in income, living standards, customs, and traditions of countries/regions, as well as their level of socio-economic development and environmental management efficiency (Marshall and Farahbakhsh, 2013). According to Kawai and Tasaki (2016), other factors also affect the amount of solid waste generated, including the definition of types of solid wastes and uncertainties in the data used to calculate municipal solid waste (MSW)

generation per capita (Kawai and Tasaki, 2016). Globally, the average MSW generation reported in 2016 was 0.74 kg/person/day, of which 33% has been managed in a very conservative and environmentally unsafe manner (Levine, 2018). Organic waste (food and green waste) is the largest share of the world's MSW (44%), followed by paper and cardboard (17%), plastic (12%), glass (5%), metal (4%), wood (2%), rubber and leather (2%) and others (14%).

The most traditional MSW treatment techniques in the world are open dumping, sanitary landfilling, and incineration (Chen et al., 2020; Edjabou et al., 2015; Ferronato and Torretta, 2019; Ismail, 2021; Kaza et al., 2018; Limon et al., 2020; Maalouf et al., 2023; Masjhoer et al., 2022; Nguyen and Tan, 2020). A study on solid waste management (SWM) in 59 developed and developing countries revealed that most high-income countries effectively implemented the SWM hierarchy, focusing strongly on reducing, reusing, and recycling MSW. On the other hand, SWM in low-income and lower-middle-income countries relied mostly on dumping due to a shortage of waste infrastructure (Sharma and Jain, 2020). Waste collection plays an important role in SWM; however, MSW collection rate and management budget depend on the region and income level of the country. With regards to income level, high-income countries (HICs) have the highest waste collection rate of approximately 96%, followed by upper-middle-income countries (UMICs) at 82%, low-middle-income countries (LMICs) at 51%, and low-income countries (LICs) at 39% (World Bank, 2022).

In Vietnam, the solid waste generated in rural areas has increased significantly in volume, from 18 200 tons/day in 2011 to 28 394 tons/day in 2019 (MONRE, 2019). The volume of MSW generated in rural areas accounts for about 45% of the country's total MSW. According to the Vietnam Law on Environment Protection, municipal solid wastes from HHs in rural areas must be sorted at the source and then are encouraged to be recycled or reused as animal food or for fertilizer composting or transferred to authorized treatment facilities. By the end of 2024, fines shall be imposed on HHs that do not comply with the waste sorting requirement at source and depending on each HH's solid waste generation. Nevertheless, MSW generated in many rural areas has not been properly collected, weighed, and treated according to regulations and is considered one of the main causes of rural environmental pollution.

Accurate prediction of household solid waste generation (SWG) is key because it improves the efficiency of relevant SWM components, including collection systems as well as treatment methods. The waste volume prediction can be determined through direct or indirect surveys or via modeling. In their study, Abbasi and Hanandeh (2016) applied a variety of modeling software to project solid waste volume, including support vector machine (SVM), adaptive neuro-fuzzy inference system (ANFIS), artificial neural network (ANN) and k-nearest neighbors (kNN) (Abbasi and Hanandeh, 2016). Many other experts collected data by conducting surveys (Akhtar et al., 2017; Abed et al., 2018; Mulat et al., 2019). Each method generates accurate results for certain parameters, such as average monthly generation or maximum monthly generation.

SWM requires large investments that are beyond the knowledge of most people in rural provinces, such as investment in building and managing waste collection and transportation systems, waste treatment, and burial sites (Abed et al., 2020). Along with large costs and increasing waste volume, the complex waste composition poses a big challenge to its management (Asgari et al., 2019). In fact, it is very critical to identify the accurate amount of generated waste so as to determine the unit price for waste collection, transportation, and treatment. While there are abundant studies on MSW management, only about 20% of them discuss SWM in rural areas from the literature review in Vietnam. Some previous studies have been conducted in several provinces, such as Nam Dinh, Hai Duong, Ninh Binh, etc. It has been found that the total amount of rural domestic solid waste generated in Nam Dinh province is 660 tons/day, with an average amount of 0.31 ÷ 0.35 kg/person/day. The amount of organic in the solid waste was about 60% of total solid waste (Tran et al., 2020). The generation rates were reported to be approximately 0.37 kg/person/day in Ninh Binh province, 0.48 kg/person/day in Hai Duong province or 0.5 kg/person/day in Bac Ninh province (Nguyen et al., 2019). However, these figures have not been represented for 63 provinces in Vietnam yet and need to be verified by other studies. Additionally, solid waste generation depends quite significantly on various conditions such as economic conditions, people awareness, cultural tradition, climate (Pheakdey et al., 2022), population density, and level of commercial activity (Patwa et al., 2020; Kumar and Agrawar, 2020).

Therefore, this paper will present the survey and its findings on SWG quantity for a rural province in the Northern Delta of Vietnam to address its cost of waste collection and proper management solutions. In addition, this article also evaluates the ability to pay as well as treatment solutions that are suitable to the limited financial conditions of people residing in rural areas of Vietnam as well as in the world.

Methodology

Survey scope

Ha Nam province was selected as it is one of the low-income rural provinces in the north of Vietnam, with about 850 thousand people (about 170 thousand households) living in an 860 km^2 area (*Fig. 1a*). The study investigated household SWG in the provincial city (with three sub-urban communes) and five rural districts (*Fig. 1b*). Each rural district is composed of one town and three rural communes. The survey covered 270 households (HHs), which accounted for 0.16% of the province's households. The survey was conducted within three months in 2021.

Survey method

The survey was implemented according to the procedure presented in *Fig. 2*, which involved six steps. The questionnaire structure included two main parts: (1) general information about the HHs, including ages, occupation, number of HH members, and education (8 questions); and (2) waste generation and management, including sorting, volume generation, main waste components, willingness to pay, onsite treatment, sanitation conditions, and possible environmental impacts (11 questions). They were structured questionnaires, and most of them (85%) were multiple choice questions.

Fig. 1. *Location of the studied area (a) and sample size distribution (b)*

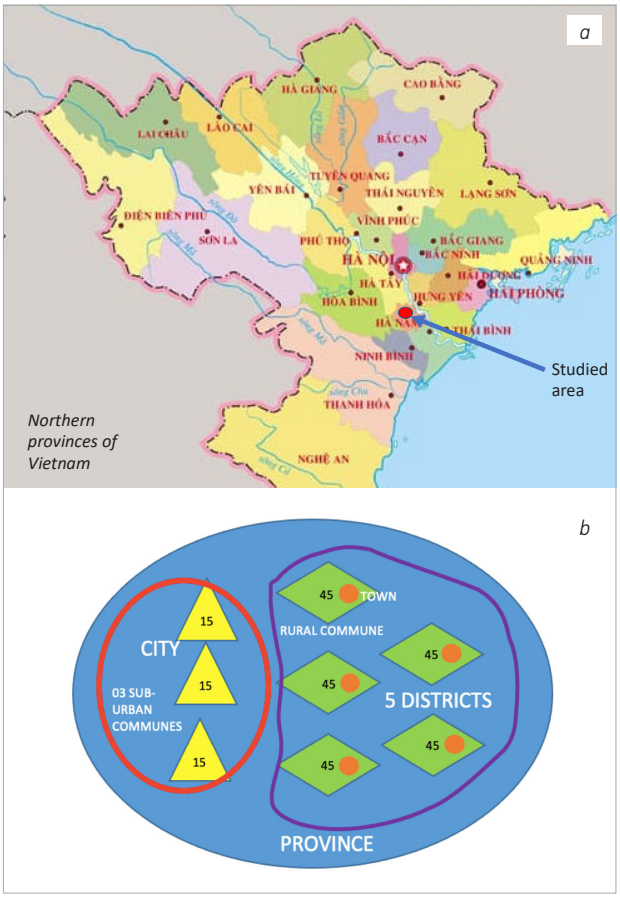
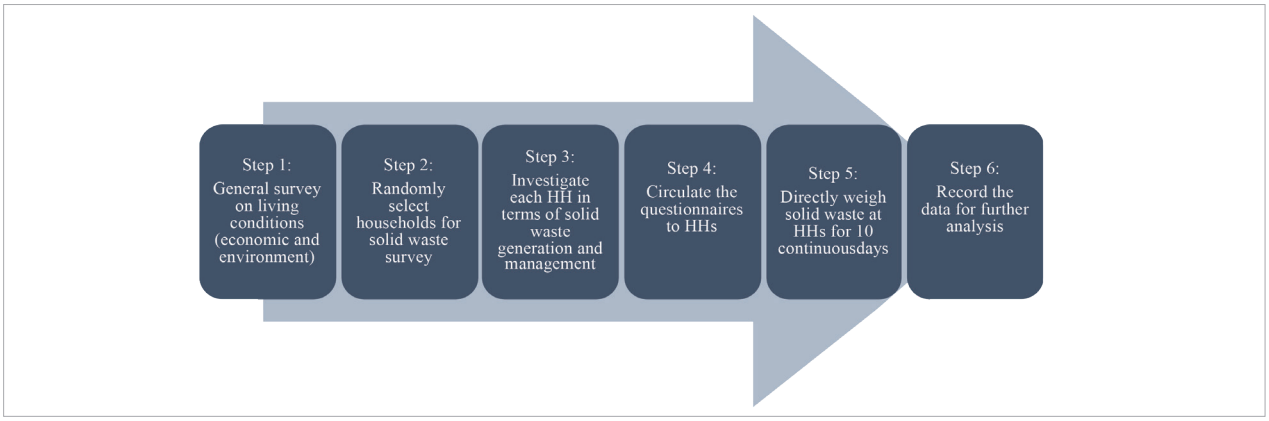


Fig. 2. *Survey and sampling procedure*

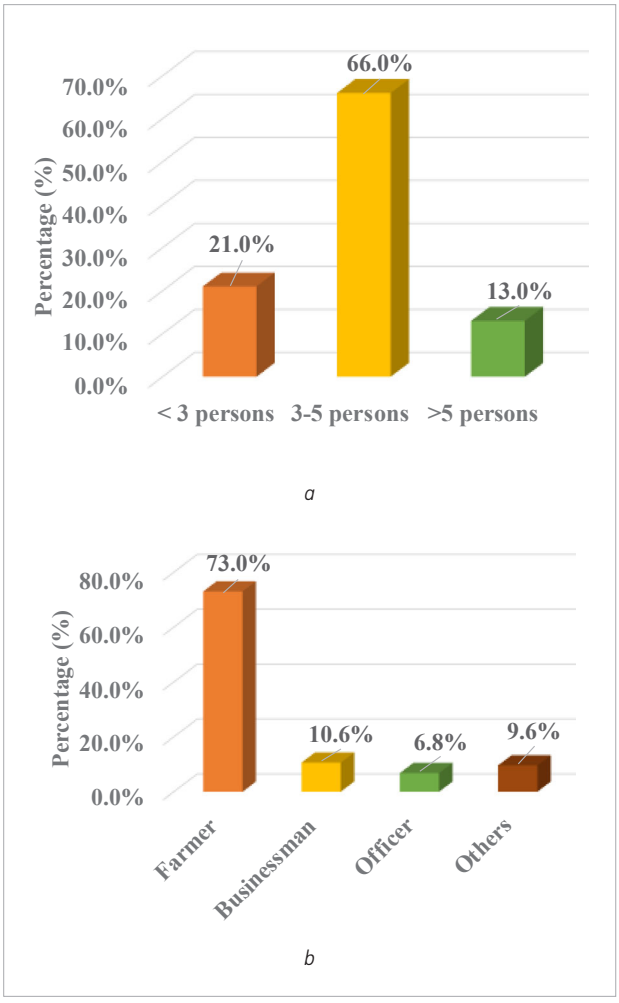


Results and Discussion

Characteristics of surveyees

Most of the interviewees (85%) were in the age range of 50–60 years old. They often stay at home while their children go to school or to work during the day. In addition, the majority of the studied HHs (66%) have 3–5 members (*Fig. 3a*). This result is similar to the data of the Vietnam national census, i.e., the average HH size was 3.8, and the majority of HHs (44%) had 4–5 members (UN, 2017). As the survey was implemented in rural areas, farmers accounted for the majority of the interviewees (73%) (*Fig. 3b*). High percentage of farmers indicates the characteristic of Ha Nam as an agriculture-oriented province, with relatively low income compared with other provinces.

Fig. 3. *Result on (a) HHs' size and (b) occupation*



Solid waste generation

In this study, SWG in rural areas was influenced mostly by HHs' size and economic conditions.

The trend of waste generation is shown in *Fig. 4*. It is logical in the sense that more people often generate more waste. That is why a big HHs' size (> 5 people) had the biggest total waste (1.26 kg per day/HH) and the highest waste generation rate of 0.337 kg/person/day. A small HH (< 3 people) produced about 0.333 kg/person/day. Household size might influence waste generation but is not associated with the monthly fee for municipal waste management service (Abed Al Ahad et al., 2020).

Fig. 4. *Impact of HH size*

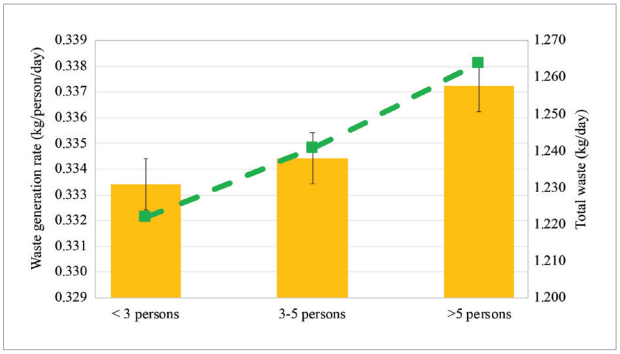
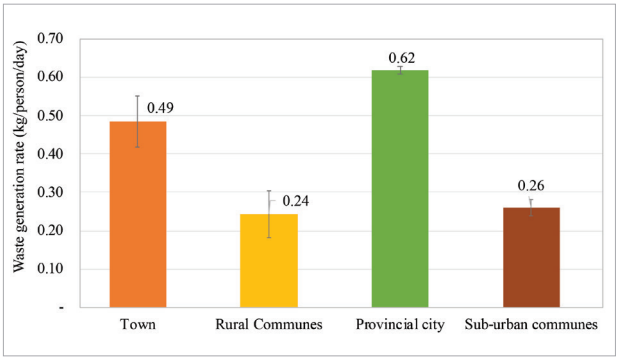


Fig. 5 depicts the influence of economic conditions on the waste generation rate. As illustrated in *Fig. 1*, Ha Nam province has one city surrounded by three sub-urban communes and five rural districts comprising one town and three rural communes each. The town is the center of the rural district but would be smaller and less busy than the provincial city. The economic conditions were proportional, following the order of the provincial cities, towns, and communes. The waste generation rates of these provincial city, towns and communes were 0.62 kg/person/day, 0.49 kg/person/day, and 0.25 kg/person/day, respectively. This is understandable, as better economic development would lead to better living conditions and expenses. As people consume more, they discharge more waste. It is noted that the waste generated at the commune level was quite similar despite their location near the city or the town (smaller city). It was probably because all these communes earn their living by farm work and, thus, have similar economic conditions. The impact of economic status on waste generation was also found in a number

of previous studies (Wang et al., 2014; Akhtar et al., 2017; Abed Al Ahad et al., 2020). The average waste generation rate in this study was 0.33 kg/person/day on average, which was lower than waste generation in rural areas of nine other provinces, being 0.51 kg/person/day (Nguyen, 2019; Nguyen and Tan, 2020).

Fig. 5. *Impact of the economic condition factor*



An effort was made to compare the SWG rate and its management in rural areas of Ha Nam province with such a status in countries as well as in other provinces of Vietnam; the results are presented in *Table 1*. The SWG volume in rural areas varied widely from 0.25 to 0.70 kg/person/day. It is quite different, even among provinces of the same country. On average, organic waste accounted for about 60% of the total volume according to the interview. The percentage of organic waste was considerably like in other Asian countries, but significantly lower than that in the Northern Africa (e.g., Egypt, Morroco). According to the survey observation, not all organic components were sorted and composted. Composting was conducted at the HH scale; a centralized composting center at the community level was not in place. The farmers would use their compost for agricultural activities. In general, solid wastes from rural areas were mostly burned or disposed of in landfills (*Table 1*). It was occasionally dumped in open sites in remote areas.

Table 1. *Comparison of SWG and its management in rural areas of developing countries*

Country	Province/Region/County	SWG rate (kg/person/day)	Percentage of organic waste (%)	Treatment method	Reference
Egypt	Fayoum	0.65	74.4	Incineration Anaerobic digestion Composting Landfill	Emara, 2023
Indonesia	Gunungkidul Regency	0.58	64.1	Incineration Composting Landfill	Masjhoer et al., 2022
India	Solapur Rewa Haridwar	0.61 (Average)	66.48 (Average)	Anaerobic digestion Composting	Patwa et al., 2020
Lebanon	Kesrouane	0.345 (Average)	52.19 (Average)	Open dumping Landfill	Ahad et al., 2018
Colombia	Cundinamarca Boyacá Santander Valle del Cauca Meta Antioquia	0.458	54	Landfill	Rodrigo-Ilarri et al., 2021
Azerbaijan	Baku Ganja / Sumgayit	0.25	55	Incineration Landfill	Levine et al., 2018
Rumania	Romania	0.4	56	Landfill Recycling Composting	
Iran	Tehran Alborz	0.44	46.14	Landfill	Asgari et al., 2019

Country	Province/Region/County	SWG rate (kg/person/day)	Percentage of organic waste (%)	Treatment method	Reference
Morocco	Khenifra	0.62	76	Landfill	Elhamdouni, 2019
Vietnam	Nam Dinh	0.33	60	Incineration Landfill	Tran et al., 2020
Vietnam	Hai Phong Quang Ninh Hai Duong Hung Yen Vinh Phuc Bac Ninh Ninh Binh	0.56 0.58 0.48 0.69 0.76 0.5 0.37		Incineration Landfill Composting	Nguyen, 2019
Vietnam	**Ha Nam**	**0.33**	**58**	**Incineration Landfill**	**This study**

It can be seen from *Fig. 6* that there was a moderate correlation between SWG and economic condition in terms of the gross domestic product (GDP). Income information in rural areas was limited, which hindered the correlation between waste generation and personal income. The relationship would be clearer if the data on income was available. Abed Al Ahad et al. (2020) revealed a significant positive association between the willing-to-pay level and the household's monthly income.

Willingness-to-pay

The willingness-to-pay depends on many factors, such as education (Han et al., 2019; Mulat et al., 2019), awareness (Song et al., 2016), personal income or economic conditions (Wang et al., 2014; Akhtar et al., 2017; Abed Al Ahad et al., 2020), occupation (Wang et al., 2018) or mode of collection (Amfo-Otu et al., 2012). In this study, economic conditions had a significant influence. Up to 57% of the surveyed households were reported willing to pay a fee of US$0.25/month/household for waste collection and treatment. The average HH income in the Northern rural areas was about VND 15.5 mil ($645)/month/household (GSO Vietnam, 2022). This cost fits well with the policy of Ha Nam Provincial People's Committee that regulates waste management fees in the range of US$0.17–0.29, depending on applied areas.

It is depicted in *Fig. 7* that Vietnam was among the countries which had a low level of willingness to pay for waste management when comparing this rate with other developing countries such as China (Han et al., 2019; Abed Al Ahad, 2018;

Fig. 6. *Correlation between solid waste generation and economic condition (GDP)*

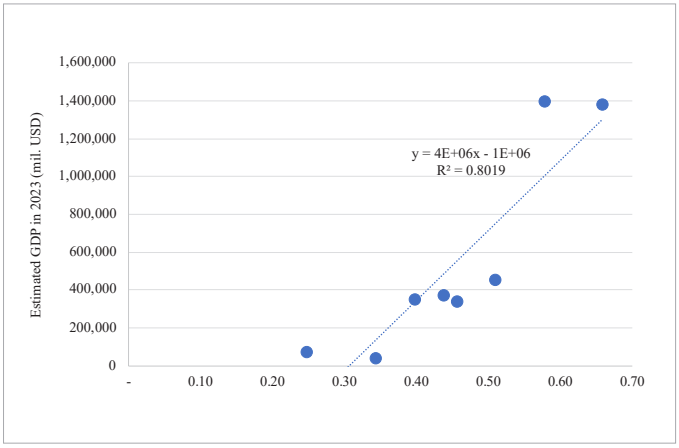
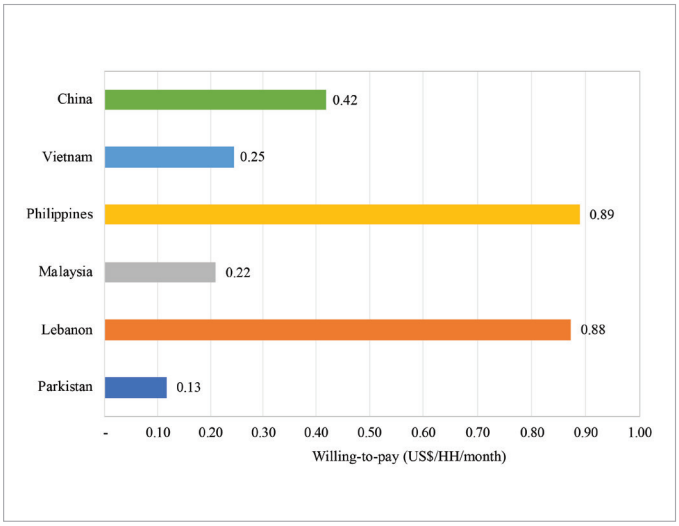


Fig. 7. *Willingness-to-pay of people residing in rural areas of developing countries*



Wang et al., 2014); Philippines (Nguyen and Tan, 2020); Malaysia (Abas et al., 2021); Lebanon (Abed Al Ahad et al., 2020); Pakistan (Akhtar et al., 2017). The low budget for waste management would lead to improper waste collection and treatment unless recycling and reusing activities bring about financial resources. Therefore, more effort should be made to raise awareness among local residents and provincial authorities to encourage them to invest more in this activity. Han et al. (2019) found that villagers who received propaganda and awareness raising were more willing to pay for waste management.

Proposal for proper solid waste management

It was noted from the survey observation and literature review that a proper approach should be introduced to improve the SWM in Vietnam in general and specifically in Ha Nam province. For instance, sorting should be enforced to be carried out at the HH scale by law. Various campaigns, projects, and plans have been implemented in Vietnam and other developing countries to promote step-by-step waste sorting at the household level (Ferronato et al., 2019). Source separation needs to be done through synchronous source collection and classification systems that are applied from city to district levels, with intensive engagement of residential communities (World Bank, 2018). It is recommended from the study that one to two sites should be arranged in each residential group and residential cluster for collecting garbage bins. Organic waste should be dumped every afternoon. Inorganic waste should only be discharged on certain days, for instance, Tuesdays, Thursdays, Saturdays, and Sundays. Source separation will significantly reduce the volume of waste to be transported to the landfills, improve waste management efficiency by reducing treatment costs and reusing recycled waste, and minimize environmental pollution risks related to toxic components of waste.

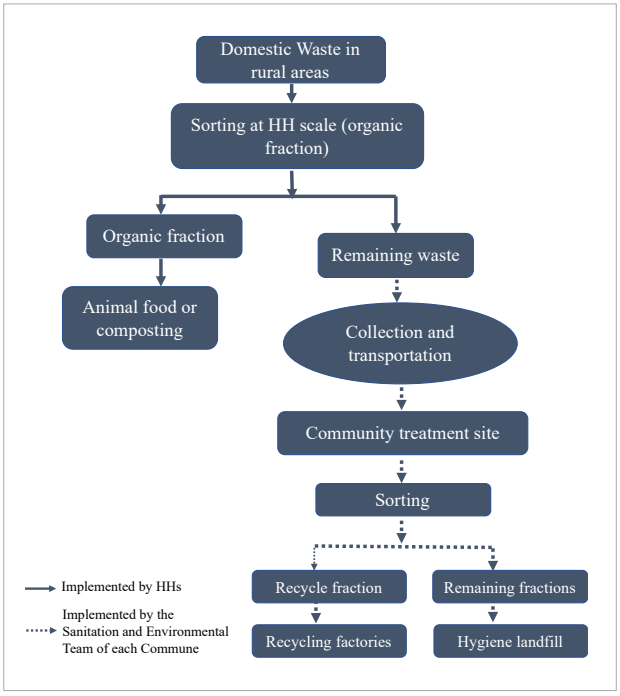
Since most of the population of Ha Nam province live in rural areas (83.3%), intensive efforts are required to improve household waste management by providing information campaigns, technical guidance, awareness raising, as well as community capacity buildings on household waste collection and treatment. Waste collection and treatment, in particular, and environmental protection, in general, can only be handled satisfactorily with the active participation of the community in identifying specific problems and suitable measures. Community participation also means increasing the community's ownership and responsibility in waste management (World Bank, 2022). Other incentives may included fee reduction or fee waiver for HHs who implement well waste sorting at the source.

Waste collection and treatment in rural areas could apply the following models: (1) collection by individuals; (2) collection by communes and villages; (3) waste management services provided by small state-owned cooperatives; (4) waste management services provided by private limited liability company (LLC) or joint stock company; or (5) waste management services provided by a big state-owned urban environment company. The appropriate model for rural areas would probably involve more than one of the models mentioned above. Waste management must be given priority regardless of the selected model(s), with special attention to recycling and reuse. These activities shall mitigate waste impacts and bring back the following benefits:

- reduction of the quantity of solid waste being transferred to landfills;
- increase of waste components that can be reused; and
- minimization of pollution during and after the treatment process.

The study proposes that the SWM model for rural areas of Ha Nam province should be a combination of activities at household and community levels (*Fig. 8*).

Fig. 8. *Proposed waste management for a rural district*



Specifically, it should include (i) activities at households (i.e., separation at source) and (ii) collection and transportation of solid waste at the community level to the concentrated treatment area of each village and commune. During this process, the initially sorted solid household waste is collected by trolleys to the common gathering place of the residential area or village/commune. Then, the waste is sorted manually by collectors for recyclable parts (glass, nylon, steel, etc). Unrecyclable components (cloths, bricks, shells, etc.) are buried in a small landfill of 500–1 000 $m^{2.}$ which is located far from residential areas.

In fact, the separation of organic waste has been implemented to some certain extent in rural areas for animal feed or composting at the household level; it is even more efficient than in urban areas. In this aspect, people living in rural areas are more energy-saving and have already obtained a more sustainable life than those residing in cities. This happened thanks to their constrained budget for fertilizers and the "saving" attitudes of low-income people in Vietnam.

This study still has some constraints in the survey size. A larger-scale survey would be designed for future research. In addition, the research group would evaluate some best practices in waste management in other low-income rural areas of Vietnam and in some other Asian countries. Specifically, the technical guidelines in waste management and incentive policies shall be focused on and highlighted.

Conclusion

The initial survey on household solid waste management in a low-income province of Vietnam revealed the following findings.

- The waste generation in Ha Nam province was 0.33 kg/person/day, lower than the average waste generation rate in rural areas of Vietnam (0.51 kg/person/day). This was logical as Ha Nam province remained a low-income province.
- The waste generation rates of people living in the provincial city, town, and communes were 0.62 kg/person/day, 0.49 kg/person/day, and 0.25 kg/person/day, respectively. These figures reconfirm the close relationship between waste generation and socio-economic conditions.
- The local government has not paid due attention to proper solid waste collection, storage, treatment, or recycling in rural areas since SWM fell beyond their priorities. This resulted in limited public awareness of proper waste management and a low willingness to pay at about US$0.25/HH/month (accounting for 0.16% of the household's monthly expenses).
- The appropriate model for waste management in rural areas would probably combine several management models depending on their economic conditions, which involve the collection by individuals and/or by communes and villages, and the treatment by small state-owned cooperatives or by private companies or even big state-owned urban environment company. Future research could assess the cost and benefits and application scopes for each of these combinations.

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