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Determination of municipal solid waste characteristics and proposal of a household-scale management model in Sam Son ward, Thanh Hoa province

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KEYWORDS

Municipal Solid Waste (MSW) in Sam Son
Coastal tourism
Organic waste
At-source composting

ABSTRACT

Sam Son Ward, Thanh Hoa Province is an area where Municipal Solid Waste (MSW) management is under significant pressure from seasonal tourism activities. The survey results show that the volume of generated MSW exhibits a significant seasonal fluctuation (increasing from 117.42m3 per day to 144m3 per day during the peak season), and the waste composition is predominantly organic matter (60%–70%) with high moisture content (52.15%). Current management efforts still face many shortcomings, particularly severe overload at the Trung Son Landfill and an absence of effective solutions for organic waste resource utilization. Therefore, the study proposes the core solution of implementing an at-source composting model (at the household/residential group scale) to alleviate the landfill burden, utilize resources, and enhance the effectiveness of sustainable tourism environmental management.

1. Overview

1.1. Global challenges and urbanization context in Vietnam

In the context of globalization and urbanization, the issue of Municipal Solid Waste (MSW) management has become a critical challenge to every country, especially developing countries like Vietnam. The rapid population growth and the substantial volume of waste generation are exceeding the processing capacity of existing infrastructure and technologies. MSW management is not simply a matter of collection and final disposal, but also a crucial component in the circular economy development strategy, contributing to the goal of sustainable development.

In Vietnam, with the estimated urbanization rate reaching nearly 40% and stable GDP growth, the volume of MSW generated is increasing at a rate of 10–16 % per year. Despite significant efforts to improve treatment technology, landfilling remains the prevalent method, particularly in localities that lack the conditions to invest in modern technology. Based on available data, the proportion of landfilled waste in Thanh Hoa province accounts for approximately 90% of the total generated waste volume. This disposal method not only wastes valuable land resources but also causes serious environmental consequences such as leachate pollution, the emission of greenhouse gases (primarily Methane), and negatively affects public health and the urban landscape.

Recognizing the limitations of the traditional linear management model (collection – transportation – landfill), the Vietnamese Government has issued important legal documents to promote the transition to a more sustainable waste management model. Notably, the 2020 Environmental Protection Law and the Resolutions and National Strategy on Solid Waste Management have set mandatory requirements for the classification of MSW at source. This shift emphasizes the role of recycling, reuse and treatment of organic waste through biological technologies such as composting, to minimize the amount of waste that must be sent to landfills.

1.2. Pressure from seasonal tourism activities

Sam Son Ward (formerly a part of Sam Son City) in Thanh Hoa Province is one of the most famous coastal tourist destinations in Vietnam and is classified as a grade III urban area. With its advantageous coastal geographical location, Sam Son annually attracts millions of domestic and foreign tourists, making the tourism and service industry the main economic sector. However, this economic development based on seasonal tourism puts considerable and cyclical pressure on the local solid waste management system.

During the off-peak season, the average volume of MSW generated is around 60–70 tons per day. However, during the peak tourist season (May to September), the amount of waste surges to about 144 tons per day. This rapid increase in waste volume, reaching nearly 70% in just a few months, has resulted in a severe overload of the entire collection, transportation, and treatment system. Planning and allocating resources (labor, vehicles, costs) to meet the high-peak demand without causing wastefulness during the low season is a daunting socio-economic and technical challenge for the local authorities. The current MSW management in Sam Son is facing a serious overload issue at the Trung Son Landfill. Although the landfill's designed capacity is only 90 tons per day, it is currently receiving up to 143 tons daily, significantly exceeding its limit.

Since 2010, this landfill has been included in the list of sites that cause serious environmental pollution by the Thanh Hoa Provincial People's Committee. The proximity of the landfill to residential areas negatively impacts public health and local quality of life, diminishing the city’s appeal as a tourist destination.

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To address this challenge, the Sam Son Solid Waste Treatment Plant Project in Quang Minh Ward with an expected capacity of 300 tons per day was approved. Due to the delay in project implementation and failure to commence construction, Sam Son must maintain its dependence on Trung Son Landfill, thereby exacerbating the existing environmental degradation.

2. Research Methodology

2.1. Literature Review and Secondary Data Collection

This method involves the collection of data concerning the following areas:

- Gathering data on the natural and socio-economic conditions in Sam Son Ward, Thanh Hoa Province.
- Collecting information regarding the current status of MSW generation, collection, transportation, and treatment in Sam Son Ward, Thanh Hoa Province.

2.2. Social Survey Method

A field survey was conducted using direct interview with 50 subjects to collect both qualitative and quantitative data on their behavior, awareness, and satisfaction. The subjects are divided into 03 main groups:

- Households (40 questionnaires): Surveying the number of residents, collection frequency, fees, and most importantly, the level of source-waste segregation and their opinions on environmental protection solutions.
- Waste Collection Workers (8 questionnaires): Recording actual difficulties encountered, the public's awareness, and the current status of transportation.
- Environmental Officials (2 questionnaires): Gathering general information on the volume of waste generated and the Ward's orientation for MSW management.

2.3. Experimental Method for Determining MSW Characteristics

To obtain scientific data on the composition and properties of the waste, the study conducted experiments on a representative sample from 20 households over 3 consecutive days.

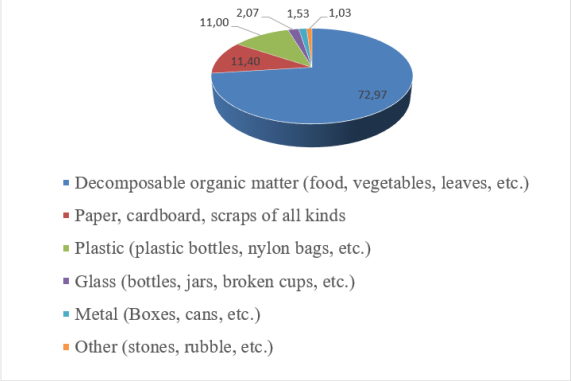
2.4. Data Processing Method

The collected data will be compiled and processed using the Excel tool to create charts, tables, and comparisons. Based on the compiled statistics, specific calculations and evaluations for each research objective will be performed.

3. Results and discussion

3.1. Composition of MSW in Sam Son ward

The organic fraction of MSW in Sam Son represents approximately 73 % of the total. As the main components are food scraps and yard waste from households and food services, this composition is highly favorable for composting.



Unit: %

Figure 1. Composition of MSW in Sam Son ward.

3.2. Average MSW generation volume and rate

From the experimental results, we have the average amount of waste per household is 1.43 kg, the average waste disposal standard is 0.36 kg/capita/day.

3.3. The moisture content and mass percentage of each MSW component

This composition and properties exacerbate the difficulties in handling waste by traditional landfill methods. MSW with a high moisture and organic content results in the following impacts:

+ Increased operating costs: Wet waste is heavier, thereby increasing its volume and transportation costs.

+ Increased risk of pollution: Anaerobic decomposition of organic matter produces large amounts of highly polluted leachate and methane (CH_4). a greenhouse gas 25 times more potent than carbon dioxide (CO_2).

+ Wasted resources: The 60 − 70 % of the waste mass that could be converted into high-quality organic fertilizer is wasted in landfills.

Although organic waste is dominant (60-70 %) and represents a valuable resource, the current management system lacks effective solutions. All efforts to sort waste at source mainly revolve around individuals sorting it by themselves to sell recyclable scrap, while organic waste is still collected together and transported to landfills. This creates a vicious cycle:

+ Pressure on landfills does not decrease.

+ Localities have to pay high costs for collecting, transporting and disposing of (burying) a large volume of waste. while 40-60% of this volume can be processed at source.

4. Proposed solutions for improved management efficiency

Given the nature of a mixed residential area (type 3 urban area), it exhibits characteristics of both urban (increased population density,

developed services) and rural areas (available land, a part of the population is engaged in agriculture). The choice of a solid waste treatment model must be flexible.

Areas with high population density, limited land, and dominant service activities will tend to apply urban-like solutions (source separation, separate collection of waste streams, centralized/semi-centralized treatment).

Areas that still have large land areas and closely linked to agriculture will prioritize promoting the bio-composting model at the household and household clusters level.

Although residents participate in the informal recovery of recyclables, this behavior must be integrated into a system of organized separation and collection of specific waste streams to achieve higher efficiency. Consequently, innovative models, such as “recycling for rewards” programs (exchanging recyclables for gifts or greenery) are proposed as effective urban and community-level solutions to encourage the recovery of recyclable materials.

To effectively manage recyclable waste stream at the community and municipal level, numerous studies propose innovative models that promote the segregation of the inorganic waste fraction at the source.

Table 1. Methods for determining the properties of MSW.

MSW Characteristic	Experimental Method
Waste Generation Rate (kg/capita/day)	Weighing the amount of waste collected from each household to determine the daily per capita generation rate.
Component Classification (Sorting)	The sample is manually sorted to determine the percentage ratio (by weight) of different waste components.
Moisture Content	The waste sample is dried at 105^{o}C until it reaches a constant weight.

Table 2. Composition of MSW in Sam Son ward.

Waste composition	Unit	Value
Decomposable organic matter (food, vegetables, leaves, etc.)	%	72.97
Paper, cardboard, scraps of all kinds	%	11.40
Plastic (plastic bottles, nylon bags, etc.)	%	11.00
Glass (bottles, jars, broken cups, etc.)	%	2.07
Metal (Boxes, cans, etc.)	%	1.53
Other (stones, rubble, etc.)	%	1.03
Total	%	100

Table 3. Mass of MSW generated by residential Sources in Sam Son Ward.

No.	Number of people	Weight (kg)			Average (kg/household)	Waste Generation Rate (kg/capita/day)	Job
		Day 1	Day 2	Day 3			
1	4	1.3	1.3	1.4	1.33	0.33	BO
2	4	1.6	1.7	1.2	1.50	0.38	BO
3	3	1.1	1.2	1.0	1.10	0.37	AL
4	4	1.3	1.5	1.2	1.33	0.33	BO
5	5	1.3	1.6	1.4	1.43	0.29	AL
6	3	1.1	1.3	1.2	1.20	0.40	AL
7	4	1.3	1.3	1.2	1.27	0.32	BO
8	4	1.6	1.4	1.3	1.43	0.36	CS
9	6	1.7	2.0	1.9	1.87	0.31	CS
10	3	1.5	1.7	1.4	1.53	0.51	AL
11	5	1.6	1.3	1.5	1.47	0.29	BO
12	4	1.7	1.7	2.2	1.87	0.47	BO
13	4	1.8	1.7	1.7	1.73	0.43	AL
14	6	1.7	1.8	1.4	1.63	0.27	CS
15	2	0.8	0.8	0.7	0.77	0.38	CS
16	4	1.4	1.2	1.5	1.37	0.34	AL

No.	Number of people	Weight (kg)			Average (kg/household)	Waste Generation Rate (kg/capita/day)	Job
		Day 1	Day 2	Day 3			
17	4	1.3	1.7	1.4	1.47	0.37	BO
18	4	2.3	1.2	1.0	1.50	0.38	BO
19	3	1.3	1.4	1.5	1.40	0.47	BO
20	5	1.2	1.4	1.2	1.27	0.25	BO
Total	81	28.9	29.2	27.3			
Average					1.43	0.36	

Note: BO – Business Operators, AL – Agricultural Laborers, CS – Civil Servants

Table 4. Components of MSW in Sam Son Ward.

Composition	Humidity (%)	Dry matter (%)	Dry matter					
			Carbon (%)	Hydrogen (%)	Oxygen (%)	Nitrogen (%)	Sulfur (%)	Ash (%)
Decomposable organic matter (food, vegetables, leaves, etc.)	70.0	30.0	48.0	6.4	37.6	2.6	0.4	5.0
Paper, cardboard, scraps of all kinds	6.0	94.0	43.5	6.0	44.0	0.3	0.2	6.0
Plastic (plastic bottles, nylon bags, etc.)	2.0	98.0	60.0	7.2	22.8	0.0	0.0	10.0
Glass (bottles, jars, broken cups, etc.)	2.0	98.0	0.5	0.1	0.4	0.1	0.0	98.9
Metal (Boxes, cans, etc.)	3.0	97.0	4.5	0.6	4.3	0.1	0.0	90.5
Other (stones, rubble, etc.)	8.0	92.0	26.3	3.0	2.0	0.5	0.2	68.0

Table 5. Summary of waste mass by component.

Composition	Mass, %	Moisture mass, kg	Dry matter mass, kg	m_C, kg	m_H, kg	m_O, kg	m_N, kg	m_S, kg	m_A, kg
Decomposable organic matter (food, vegetables, leaves, etc.)	72.97	51.08	21.89	10.51	1.40	8.23	0.57	0.09	1.09
Paper, cardboard, scraps of all kinds	11.40	0.68	10.72	4.66	0.64	4.72	0.03	0.02	0.64
Plastic (plastic bottles, nylon bags, etc.)	11.00	0.22	10.78	6.47	0.78	2.46	0.00	0.00	1.08
Glass (bottles, jars, broken cups, etc.)	2.07	0.04	2.03	0.01	0.00	0.01	0.00	0.00	2.00
Metal (Boxes, cans, etc.)	1.53	0.05	1.49	0.07	0.01	0.06	0.00	0.00	1.35
Other (stones, rubble, etc.)	1.03	0.08	0.95	0.25	0.03	0.02	0.00	0.00	0.65

Table 6. Moisture content and mass percentage by component.

Humidity	% Dry matter	Carbon	Hydrogen	Oxygen	Nitrogen	Sulfur	Ash
52.15	47.85	45.90	5.98	32.38	1.27	0.23	14.23

5. Conclusion and recommendations

The volume of waste generated is large and seasonal. As a famous coastal tourist city, Sam Son is under great pressure from waste, especially during the peak season (May to September), when the amount of solid waste generated increases dramatically from 60–70 tons per day to 100–150 tons per day. The average waste generation of Sam Son is 117.42 m^3 per day, increasing to 144 m^3 per day during the peak season.

Organic components are dominant. The results of determining the composition show that the proportion of organic waste in MSW in Sam Son accounts for 60–70 %. This key finding indicates that the majority of waste originates from food scraps and yard waste. Detailed analysis shows that MSW has a high moisture content of up to 52.15 %, reflecting a large content of easily biodegradable organic matter, making it highly suitable and optimal for the composting process.

The current challenges in MSW management in Sam Son are enormous, but the potential to convert most of the organic waste into resources (compost) is also very clear. The synchronous implementation of technological, infrastructure and community management solutions, focusing on source separation and composting, will be the key for Sam

Son to address the waste crisis, protect the marine environment and successfully implement the goal of sustainable development.

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