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Analyzing The Characterization of Municipal Solid Waste in Da Nang City, Vietnam

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Recently, most cities in Vietnam are facing waste problems that are mainly caused by the rapid increase of municipal solid waste (MSW) amount and the limitations of the MSW management system. This study aims to characterise the waste generation, composition and characteristics of MSW in Da Nang city, which is one of the five biggest cities in Vietnam. The current problems and challenges of MSW system are also analysed. The sampling survey was conducted in the dry and wet seasons in August and November 2018. The MSW was taken directly from trucks at the landfill site with the sample size by 500 kg/waste sources. This study shows that the simultaneous development of production, trade and service activities in the last decade has led to the speedy growth of waste by 9 %/y, and reached 1,073 t/d in 2018. In which, waste generated from industry and the hospitals account inconsiderable proportions by 3.9 % and 1.4 %. This study also indicated that the MSW generation rate from the urban areas is more than that of the coastal and industrial areas. For the composition of MSW, biodegradable waste and recyclables are the main components with the proportion of 54 % and 27 % of the total waste. While the waste composition almost do not differ considerably by seasons, the difference in the characteristics of waste is a consideration for the processing. The current problems and solutions to improve the MSW system toward sustainability are also discussed and suggested.

1. Introduction

The boom in urbanization and urban population growth has led to a considerably negative impact on the environment (Cui and Shi, 2012). Although urbanization and population growth are the main driving force of economic growth in areas such as metropolises, this inevitable increases in natural resource consumption (Song-Toan et al., 2018a). The increase in solid waste generation is inexorable due to the economic development in many areas of the world. As a result, the optimal solid waste management (SWM) system is becoming urgent in many parts of the world, especially in metropolitan cities.

There are several studies on solid waste in Vietnam, but still sporadic in some hot spots. The current situation of municipal solid waste (MSW) in Vietnam has not been thoroughly analyzed and lacked the information for research on strategic development and re-planning of the management system. A study presented waste characterisation, the SWM practice and examined the challenges in the SWM system in the tourism destination of Hoi An City, Vietnam with sampling, questionnaire surveys, and material flow analysis (Song-Toan et al., 2020). This research denoted that restaurants (46 %), hotels (22 %) and households (13 %) are the main waste generation sources of a tourist destination. Also, there were significant rates of kitchen waste (46.8 %), tissue (11.54 %) and recyclable materials (12.58 %), which led to high moisture (46.79 %), and low heating value (16,866 kJ/kg) of waste (Song-Toan et al., 2018b). Also, in Hoi An city, tourism waste was identified and analyse clearly. Notably, the quantity and quality of waste from the accommodation industry was identified and the current practice was analysed (Song-Toan et al., 2018a). Recycling potential and enhancement strategy have been studied to improve SWM activities and reduce waste generation (Hoang et al., 2020). The strategy for developing a recycling system for the whole city has studied and recommended for

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the authorities. It's clearly that study on waste composition and characterization is essential for the process of improving and developing municipal SWM system.
Da Nang city (DNC), which is classified as grade 1, according to Vietnam's urban standards is one of five biggest cities of Vietnam. Over the last decade, there have been dramatic development of economy and population growth in this metropolitan city. This led to a significant increase in the municipal solid waste generation in this area. As a result, optimization of the existing municipal SWM towards sustainability is becoming severe for ensuring the prosperous development of DNC, Vietnam. However, the study on solid waste in DNC is still limited and is not keeping pace with the changes in the city. A study conducted at five bazaars to offer baseline data aimed to enhance bazaar waste management. Notably, the results denoted that vendor clerk had a negative view on source separation, but a reduction in the garbage collection fee can change their attitudes towards waste separation (Kato et al., 2017). The study on municipal solid waste has not been paid attention. The studies, as mentioned above, had no aims to offer comprehensive views on the SWM system in a metropolitan area such as DNC. The waste generation, composition and characteristics of municipal solid waste of research areas have not been examined properly. This study aims to understand the waste generation from 7 districts, identify the composition and characteristics of solid waste, and analyze the current problems and challenges of SWM system in DNC.

2. Material and method

2.1 Studied area

Da Nang, which is located on the central coast of Vietnam, is one of the largest cities in Vietnam. The administrative areas of DNC are 1,283.42 km^2 with six districts and one suburban district. DNC has around 1.134 M people of the population with the average per capita income is 4,098 USD/y. The average estimated GDP in the last five years reaches 13 % (Danang, 2019). With the boom in economy and population over the last decade, the burden from a significantly large amount of municipal solid waste generation is inevitable. As a result, understandings on the existing solid waste composition, characteristics as well as problems and challenges of DNC is considerably needed for sustainable development.

2.2 Waste sampling and analysis

The process of solid waste sampling and analysing is illustrated in Figure 1. The sampling survey was conducted in the dry and wet seasons in August and November 2018. Approximately 500 kg of waste from trucks was collected at the landfill by the rate of samples corresponding to the generation ratio of waste sources. Solid waste was analysed by NT ENVIR 001 standards to determine waste amount and composition (NT Envir 001). The waste was weighted by electronic scale BONSO-393 with a capacity of 50 ± 0.05 kg and DRETEC-KS-221 with a capacity of 2 ± 0.001 kg.
After separating into categories, the density of waste was measured by dividing the weight of waste by the natural volume of waste. The moisture content of solid waste was identified by drying at 105 ± 2°C for 48 h (or until the constant weight was obtained). The moisture content (M) was calculated by Eq(1):

$$Moisture = \frac{m1-m2}{m1} \times 100 \quad (1)$$

where m1 is the weight of the wet waste sample; m2 is the weight of the dry waste sample.

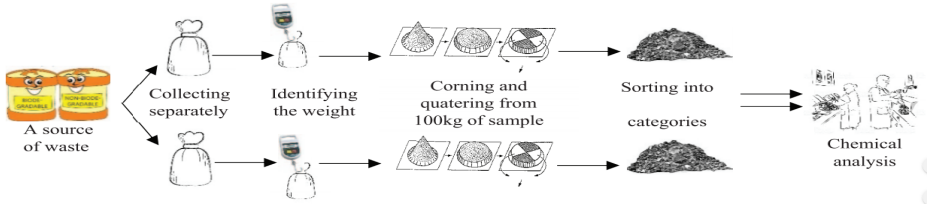

Figure 1: The process of solid waste sampling and analysing (Song-Toan et al., 2019b)

3. Result and discussion

3.1 Municipal solid waste generation

Figure 2 indicated that the MSW amount has been generating rapidly with the increasing rate by 9 %/y. In 2018, the amount of MSW generated daily was approximately 1,073 t. The driving forces behind this phenomenon were population growth and tourism development. Notably, the population of DNC had been growing at a rate between 1.6 % and 2.1 % in the last decade. Tourism arrivals had also increased six times over the same period. There

were negligible proportions in the total amount of waste generated from the industry as well as hospitals and healthcare services, with proportions of 3.9 % and 1.4 % for the former and the latter.

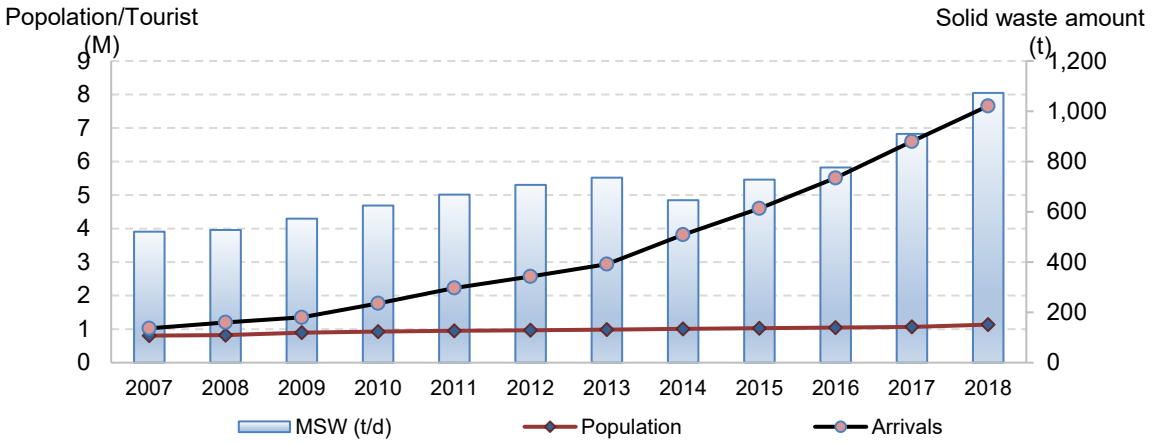

Figure 2: The increase of municipal waste in DNC in the last decade

From waste sources, Table 1 illustrated the information on the area, solid waste generation rate, and density of solid waste by areas of DNC. Notably, Hai Chau and Thanh Khe were account for the significant percentages of waste generation, with 24.9 % and 18.3 %. In which, the density of waste in Thanh Khe was highest by 17.56 t/km^2, comparing to Hai Chau (9.71 t/km^2) and other districts in DNC. These two centered districts had strong urbanization with dynamically economic, social, and cultural activities, especially tourism activities. This inevitably resulted in enormous SW generation and contributed to the total amount of SW generation of DNC.

Table 1: The information related to solid waste generation by areas in DNC

Districts	S (km^2)	The SW generation rate (%)	Density (t/km^2)
Hai Chau	23.29	24.9	9.71
Thanh Khe	9.47	18.3	17.56
Son Tra	63.39	17.6	2.52
Ngu Hanh Son	40.19	9.3	2.10
Cam Le	35.85	10.4	2.65
Lien Chieu	74.52	13.0	1.59
Hoa Vang	733.17	6.6	0.08

On the other hand, Table 1 revealed that Hoa Vang district generated less waste (6.6 %) than the others and the density of waste was lowest (0.08 t/km^2). This information is explained by the rural social form and the large natural area. Most of Hoa Vang's natural area is hills, forests and crops. Agriculture is the primary activity with the significant amounts of organic waste. Naturally, biodegradable waste would be kept for farming, producing compost as an eco-organic fertilizer. Recyclable materials are sorted and saved for selling to get income.

The other districts are the sub-urban area with the bigger square (from 36 km^2 to 75 km^2) and the waste density ranges from 1.59 t/km^2 to 2.65 t/km^2. They have their own strengths and characteristics in the economic structure, and are also the main sources of waste. Notably, Son Tra and Ngu Hanh Son strongly develop tourism industry along the coastline and Han river. While Cam Le and Lien Chieu are the capitals of industry and high-tech activities. Geographic conditions and socio-economic features are the primary factors of the variation in waste generation and composition in districts.

3.2 Waste composition and characterization

Figure 3 showed the waste composition of DNC in (a) wet season and (b) dry season. There were similarities in the waste composition of DNC in two seasons. The vast majority of SW in DNC was biodegradable waste (54 %) and recyclable waste (27 %). Food waste accounted for the significant proportion by 47.64 % and 48.64 % for dry and wet season. Table 2 illustrates in detail the composition of solid waste by districts in DNC. The proportion of food waste from Hoa Vang district to the landfill site was significantly low by 33.2 % comparing to other areas. This would be due to the existing SW generation behaviours of dwellers. With a

largely rural area, dwellers may use food waste for farming or producing compost. Another type of biodegradable waste, garden waste, was illustrated by 6.35 % and 6.75 % in the dry season and wet season (Figure 3). Notably, the figure for garden waste was only 2.1 % of the total amount of Cam Le's SW generation, which was considerably smaller than figures of other districts ranging from 4.5 % to 7.6 % except for Hoa Vang district. This district had the highest proportion of garden waste, which was 13.1 % (Table 2). These phenomena may reflect the strong urbanization of Cam Le district and contrary trend in Hoa Vang district.

Figure 4 showed the moisture of MSW in DNC. The moisture of biodegradable waste was significantly high, especially in the wet season. To be specific, the moisture of food waste ranged between 60 % and 80 % while data of garden waste were from 50 % to 60 % in a year.

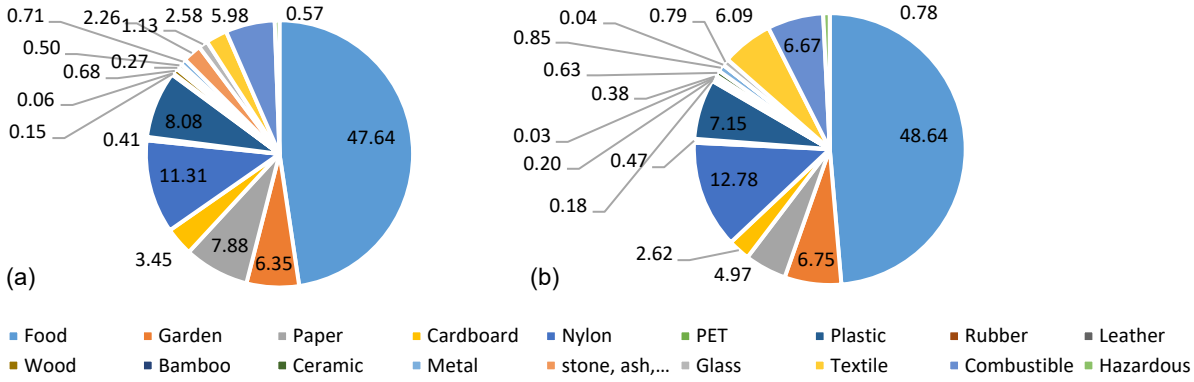

Figure 3: The waste composition of DNC in (a) wet season and (b) dry season.

These characteristics for biodegradable waste could lead to considerable increase in the moisture of waste in DNC. The high moisture contents of MSW leads to several concerns, including complexity associated with the recovery of recyclable items, an increased amount of leachate, and reduction in the net calorific value of the waste when incinerated. Similarly, a larger proportion of biodegradable waste (54 %) in accordance with high moisture (47.7 % - 61.5 %) result in obnoxious odours and leachate during storage, collection and transportation of SW, which negatively affected tourism and landscape.

Table 2: The solid waste composition by districts in Da Nang city

Waste categories		Hai Chau (%)	Thanh Khe (%)	Son Tra (%)	Ngu Hanh Son (%)	Cam Le (%)	Lien Chieu (%)	Hoa Vang (%)
Biodegradable	Food	51.8	40.9	54	45	52.8	42.6	33.2
	Garden	6.9	6	4.5	6.8	2.1	7.6	13.1
Recyclables	Paper	8.9	11.1	6	7.3	4.3	7.2	7.5
	Cardboard	2.5	4.2	3.6	3.4	3	3.6	4.7
	Nylon	9.2	12.3	12.4	6.9	13.3	13.7	12.2
	PET	0.2	0.5	0.3	0.3	0.5	0.7	0.8
	Plastic	6.5	10	7.2	6.8	6.9	8.8	12.5
	Metal	0.7	1.1	0.3	1	0.8	0.9	0.1
	Glass	0.5	1.4	0.5	1.9	1.4	1.4	2
	Rubber	0.3	0	0.1	0	0.1	0.2	0.1
	Leather	0	0.2	0	0	0	0.1	0
Combustible	Wood	0.4	0.5	0.2	0	2.3	0.5	2.1
	Bamboo	0.4	0.5	0.1	0.1	0.1	0.3	0.1
	Textile	1.4	3.9	2.6	3.8	2.2	2.2	2.7
	Combustible	5.8	5.3	4.9	5.3	10	5.6	5.7
Incombustible	Sand, ash	2.3	1.5	2.6	3.1	0.2	3.3	2.8
	Ceramic	1.5	0.1	0	0.1	0	0.6	0.1
Others		0.7	0.5	0.6	0.8	0.2	0.6	0.4
Total		100	100	100	92.6	100	100	100

Recyclable waste accounted for 27 % of the total amount of SW generation in DNC. This denoted the great potential for reducing SW generation due to enhancement in recycling practices (Song-Toan et al., 2018b).

Nylon, plastic, and paper were the three main components of recyclable waste in DNC. The proportions of nylon were highest, at 11.31 % and 12.78 % in the dry season, and the wet season. Despite a slightly lower of data, the figures for plastic were 8.08 % and 7.15 % in the dry, and the wet season. Although plastic and nylon are recyclable waste, there was a limited effort on recycling this waste in DNC. Besides, improper disposal of nylon and plastic waste into the sewers, roadsides caused a negative impact on lot only environment but also the tourism development of DNC.

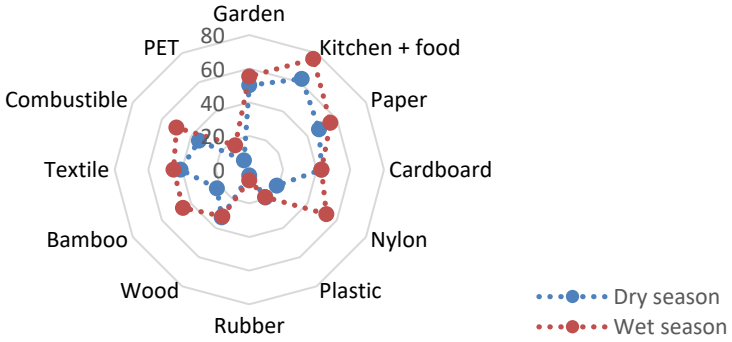

Figure 4: The moisture of MSW in DNC

The proportion of paper was 7.88 % in the dry season and this figure decreased to 4.97 % in wet season. Similarly, the figure for the call board also reduced from 3.45 % (dry season) to only 2.62 % (wet season) (Figure 4). These two components played an important role in the solid waste separation at source as well as the operation of informal sectors due to their economic value. PET, only generated at around 0.4 % of the total amount of SW in DNC, this component was extremely important to the recyclable practices and income of informal sectors. The reason is that the economic value of PET is relatively high compared to other kinds of recyclable waste. Combustible waste, namely rubber, leather, wood, bamboo, and textile accounted for negligible parts in the total amount of SW generation of DNC. Interestingly, the proportion of textile was approximately 2.5 %, which was far more extensive than other kinds of combustible waste (Table 2).
The composition shows that recyclables which are the marketable materials have not recovered for recycling. About one-four of total waste to the landfill site is recyclables. These materials will be collected by waste pickers with low efficiency. On the other hand, about half of the total waste is organic waste which has not reduced at source by animal feeding and composting. In order to minimize waste to landfill, solid waste should be sorted into three types such as organic waste (kitchen waste, tissue and garden waste), recyclable waste (plastics, metals, papers and glasses), and the others. Recyclables waste will be recovered for recycling. Also, residents and commercial sectors can get income from this transaction. Organic should be handle by composting at source. The compost product can be used for farm and garden. The residues will be collected by collection crews and moved to the landfill. The residues may be planned for burning by incineration to get energy. This solution should be considered by the government toward sustainable SWM in DNC.

Table 3: The density, moisture, and high heat value of solid waste in Da Nang city

Districts	D (kg/m3)	Moisture (%)		HHV (kJ/kg)	
		Dry season	Wet season	Dry season	Wet season
Hai Chau	216	52.9	67.4	15,000	14,636
Thanh Khe	154	46.7	60.2	16,275	15,936
Son Tra	228	48.3	62.8	16,515	16,151
Cam Le	211	42.0	55.4	17,383	17,047
Hoa Vang	157	44.0	58.4	17,105	16,744
Lien Chieu	262	46.3	60.9	16,768	16,403
Ngu Hanh Son	273	45.6	56.8	14,582	14,302

The moisture of SW in the wet season was higher than that of the dry season while the opposite phenomenon found in HHV. The higher heating value of SW in DNC was 16,510 $kJkg^{-1}$ in the dry season and 15,159 $kJkg^{-1}$ in the wet season. The moisture of MSW was 47.7 % and 61.5 % in the dry and wet season (Table 3). These conditions seem unfavourable for incineration. This situation can be boosted by holistic SW separation at source, distinct solid waste collection systems, and proper technologies. If the feedstock of solid waste management process is well-separated, the effectiveness of treatment of SW will be significantly enhanced whether they are

incineration, compost, or anaerobic digestion. Solid waste separation at source is needed in order to optimization the solid waste management system towards sustainability as the regulation proposed of DNC. As a result, integrated planning of solid waste management should be developed for the optimization of the SWM system. Notably, SW generation of DNC had a tiny amount of incombustible waste such as ceramic, sand, and ash, which accounted for less than 3 % of the total amount of SW generation (Table 2). The treatment method for these kinds of incombustible waste was only dumping in a landfill.

3.3. Problems and challenges in the solid waste management system

There was no integrated system of waste separation at source in DNC. Although there were some projects and programs on waste separation at source in DNC, the results have been limited. Due to the low awareness of the community about SWM and environment, the classification of waste at source has become a radical challenge. The lack of knowledge and skills for waste separation at source. SW separation at source plays a fundamental role in the integrated SWM system. The efficiency of treatment methods and solid waste collection system is heavily dependent on the implementation of waste separation at source.

The waste collection rate in DNC was 90 % (Da Nang, 2019). The collection rate must be enhanced due to the economic and tourism development in the near future. The proper solid waste collection system is becoming urgent when waste separation at source is implemented in DNC.

These problems have been intractable recently. All amounts of SW of DNC were transported to Khanh Son landfill, which will be full in the near future. The projects on the extension of Khanh Son landfill or making enhancements on the treatment of SW have experienced the delay. The negative environmental impacts of Khanh Son landfill on the surroundings have ben urgent. The nearby citizens have combatted with environmental pollution due to the leachate and odour of Khanh Son landfill. As a result, the boost in treatment technologies or extension the areas of SW disposal are vital to confronting the existing problems in waste treatment and disposal of DNC.

4. Conclusions

This study presents the solid waste generation, composition and characteristics of the MSW in DNC. This study indicated that the daily SW amount of DNC was approximately 1,073 t/d, with a growth rate of 9 %/y in the last ten years. Urban areas accounted for a significant solid waste generation rate compared to coastal and industrial areas. Also, the main component of MSW in DNC were biodegradable waste and recyclables, which accounted for 54 % and 27 % of the total waste. Despite similarities in waste composition by season, variety in characteristics of waste is an important factor for processing. The overload of waste at Khanh Son landfill site, the low rate of waste management at source, the disruption of the collection system and the degradation of treatment plants are the current problems of MSW system in DNC. Also, improvement of waste management practice by waste separation at source for enhancing recycling and composting practice is suggested as the solution to reduce these problems and minimizing waste to the landfill, toward sustainable SWM in DNC.

Acknowledgments

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