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Practical Solid Waste Management System in a Campus in Danang city, Vietnam

Duy Bao Nguyen[a], Song Toan Pham Phu[b,*], Cuong Le Dinh[a], Makoto Usami[c]

[a] Graduate School of Environmental and Life Science, Okayama University, 3-1-1 Tsushima, Kita, Okayama, 700-8530, Japan.
[b] The University of Danang - University of Technology and Education, 48 Cao Thang, Hai Chau, Danang 55100, Vietnam
[c] Graduate School of Global Environmental Studies, Kyoto University, Japan.
ppstoan@gmail.com

Da Nang is a city with rapid growth and expansion, along with it is pressure for municipal solid waste treatment. Within a decade, waste generation from commercial and service activities increased significantly at a rate of 9 %/y and reached 1.073 t/d in 2018. This study aims at developing municipal solid waste management toward sustainability in the campus of Danang University. A waste audit was performed to evaluate the total emission and characteristics of the solid waste generated by the campus. Simultaneously, the 3R program was applied for assessing the current status of the waste management practice (WMP) system. This study analyzes the total amount and characteristics of campus waste, in which, recycling (25 %) and organic waste (28 %) took up a great proportion. It also reveals that even though a big part has shown disinterest in waste management, the awareness of students toward environmental protection was raised during the process of this research. Therefore, the improvement of WMP at source and formal environmental education at a younger age can reduce a significant amount of waste-to-landfill, as well as enhancing environmental awareness.

1. Introduction

According to a World Bank report, it is estimated that the world generates around 2.01 x 10^9 t/y of waste in 2016. With increasing urbanization, it is expected to reach 3.4 x 10^9 t/y by 2050 - an increase of 70 % (Kaza et al., 2018). In developed countries, combing recycling, with digestion, composting, and biogas generation, the material and energetic recycling potential of the different municipal solid waste (MSW) fractions can be exploited optimally. Stimulated by the landfill legislation and segregated waste collection, anaerobic digestion and composting of organic waste are already well-proven and mature technologies in Europe (Tock and Schummer, 2017). In middle-income countries, such as Vietnam have experienced significant challenges in solid waste management. Not only in the collection, transfer, and final disposal of waste, but also a lack of public awareness of the solid waste system, haphazard urbanization, the introduction of environmentally unfriendly materials, and changing consumption patterns (Phan Hoang and Kato, 2016).
Sustainability is a goal of a long-term process that the MSW system, which has to be implemented and upgraded gradually. Planning an oriented strategy for the MSW system is important (Pham Phu et al., 2020). The current situation of municipal solid waste in Vietnam has not been thoroughly analyzed and lacked the information for research on strategic development and re-planning of the management system (Pham Phu et al., 2021).
The rapid growth of MSW, inefficiency in waste management, and low waste collection performance caused the overload of waste in urban areas and at the disposals (Hoang et al., 2017b). Leading to the unsustainability of the solid waste treatment system in Vietnam in general and Da Nang in particular.
Da Nang city (DNC), which is classified as grade 1, according to Vietnam's urban standards, is one of the five biggest cities of Vietnam. Over the last decade, there has been a dramatic development of economy and population growth in this metropolitan city. Danang city in general, and Danang University in particular, are facing inadequacies in the current state of solid waste management. The waste is not classified but gathered at the collection area and sent directly to the landfill. This leads to an unsustainable waste management system. Optimization of the existing municipal SWM towards sustainability is becoming essential for ensuring the

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prosperous development of DNC, Vietnam. This study focuses on the analysis of components and assessment of the management of solid waste in the dormitory of Danang University, which is an accommodation for students – the owners of society in the future. The study established a suitable 3R (Reduce – Reuse – Recycle) model and contributed to change in thinking and improving the awareness of students about waste separation at source for more effective management and disposal of solid waste.

2. Methodology

2.1 Sampling and classifying methods

Solid waste of the campus of Da Nang University (DNU) was collected, sampled, classified, and analyzed by Nordtest methods on solid waste (Nord Test methods – NT – ENVIR 001, Finland)

- The sampling frequency: 14 consecutive days
- Numbers of sample: all student's rooms (100 rooms), five kiosks, one canteen, and one cafeteria.

All of the samples, which were collected to a gathering point at the yard were determined by the weight and the volume by tanks. After that, solid waste was classified into 10 kinds of waste (as table 1 shows) and determined the characteristic. Waste classification base on gender was also performed since the dormitory is divided into male and female areas. This helps to understand how differences in lifestyle and gender affect the amount of waste generated.

Table 1: Classification of solid waste

No.	Types	Describe
1	Degradable solid waste	Kitchen waste, animal waste, garden waste
2	Paper	Newspaper, magazine, book, notebook, etc.
3	Cardboard	Box etc.
4	Combustible waste	Textile, wood, leather, rubber, etc.
5	Glass	All kinds
6	Nappies	
7	Plastic	All kinds
8	Nylon	Nylon bags
9	Metal	All kinds
10	Incombustible waste	Ceramic, ash, etc.

2.2 Environmental education and 3R methods

To sustain solid waste or environmental issues in developing countries, formal education for sustainable development is essential at all levels of education (Debrah et al., 2021). Image communication (poster) was the way environmental education was applied in this study. Posters were hung at the dedicated recyclable locations and garbage collection points (Figure 1a).
Simultaneously, the 3R program was applied for reducing the total amount of solid waste, gradable waste (for composting), non-gradable waste (dumping to the landfill), and recycling waste was the three types of waste collected at the gathering point (Figure 1b and 1c).

Figure 1: (a) Environmental communication at the campus; (b) Collection points; (c) Gathering points.

3. Results and discussion

3.1 The weight and volume of solid waste generation

The challenges of sustainable development and waste management are complicated by increases in the types and quantity of waste materials in large cities, differentiation of waste content according to space and timeframe (Kayihan and Tönük, 2012). To determine the amount and the volume of solid waste generation from different sources in the campus, solid waste was collected for 14 d from the rooms of students, canteen, and shops. The results are shown in Figure 2.

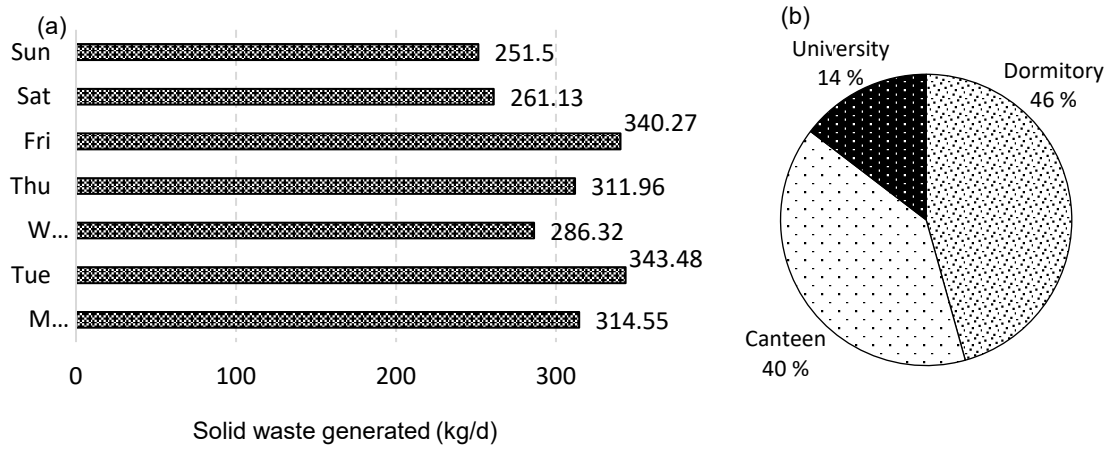

Figure 2: (a) The amount of solid waste generated daily and (b) Ratio of solid waste generated by the campus

The bar chart shows clearly the fluctuation in the amount of solid waste per week. Sunday and Saturdays have the least amount of waste because many students go home for the weekend. Most of the waste was generated from the dormitory and canteen. Through the process of determining waste characteristics, we found that the canteen and university have a non-diversified waste composition. Specifically, at canteens and kiosks, mainly biodegradable organic waste, and were used as fodder on farms, with an average of 120 kg/d. At the university, the main waste is stationery, school supplies, and plastic with a quantity of 40 kg/d. In student rooms, as household waste, the amount and composition of waste are more diverse, with an average of 140 kg generated daily. Controlling waste generation from student's rooms by raising their awareness about environmental protection, as well as waste classifying at source, would be a good method for solid waste management in the campus. The living habits of male and female students are different, so the amount of waste generation also shows disparities. Depend on the number of students we can also estimate the amount of waste per capita (student, male, female). Figure 3 shown the total solid waste generated by block A and block B&C. Females generated more waste than males. The most waste generated was on Friday with 74.57 kg by the females and 50.70 kg by males

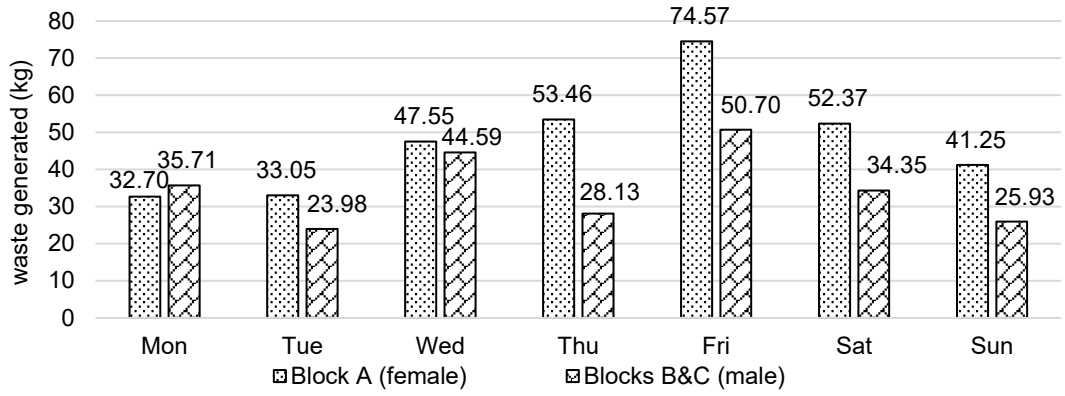

Figure 3: The amount of waste generated by the dormitory (block A and B&C)

Table 2: The amount of waste generated per capita.

	Per student	Per male (B+C)	Per Female (A)
Number (student)	780	452	328
Waste (kg/d)	82.62	34.77	47.85
Solid waste per capita (kg/d)	0.11	0.08	0.15

Table 2 revealed the difference in the amount of solid waste generated by male and female students. It can be seen that the average amount of solid waste per capita was 0.11 kg/d, in which the amount of waste generated by the females (0.15 kg/d) was double that of the males (0.07 kg/d). Through surveying using questionnaires, we found that females cooking in the room more often than males, and base on their lifestyle, personal belongings are also more than male. This is conducted to the difference in waste generated base on gender. This data can be used in further studies related to estimating solid waste management and designing a suitable model of solid waste management.

3.2 The components of solid waste

Waste characteristic determination is one of the most important elements for designing suitable solid waste management (Starovoytova, 2018). The solid waste components of student's rooms are shown in the chart of Figures 4 and 5.

It can be seen that organic, nylon, and paper are the main components of waste from student's rooms, with an average amount of 16 kg/d, 4.8 kg/d, and 4.2 kg/d. A large amount of organic waste is the potential raw material for composting with a ratio of 25 % (Manu et al., 2019). 28 % of recycled waste can be separated at source to reuse as raw material for recycling, instead of being considered as garbage and going directly to the landfill. By using a suitable waste management method, the amount of campus waste can be reduced by 53 %, a significant amount that will contribute to the close-the-loop process (Pham, 2014)

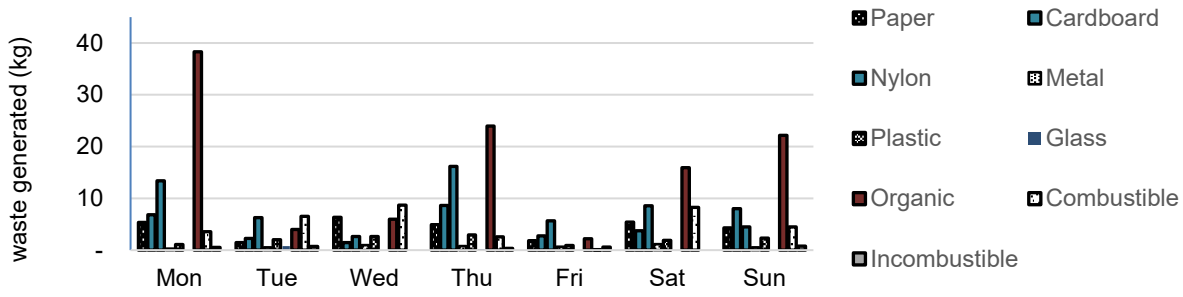

Figure 4:Solid waste generated from student's rooms

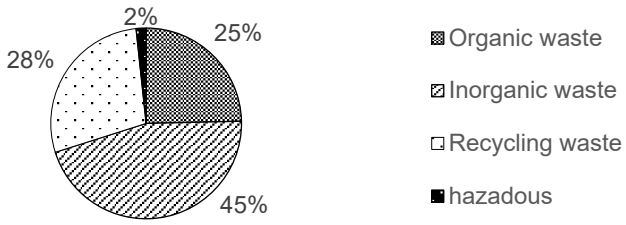

Figure 5:The components of waste from student's rooms

3.3 The 3R model

At the gathering point, the total solid was separated into three bins as organic waste, inorganic waste, and nylon. The components of waste in three bins are shown in Figure 6. This chart partially assesses the awareness of students in the dormitory. It can be seen that the components of waste are almost the same in those bins especially for metal, PET, paper, and inorganic waste. A significant amount of nylon and organic waste are properly classified. In the inorganic and nylon bins, there were 5.6 kg/d and 2.5 kg/d, while 13 kg/d were found in the organics bin. Nylon in the nylon bin was 18 kg/d, 8 times greater than the quantity in organic and inorganic waste. A significant proportion of students still thought it was an inconvenience to separated garbage at source and were not interested in waste and environmental protection. These views are most likely the result of their

upbringing and their families' habits in garbage disposable at home (Matsumoto et al., 2020); this is why moving towards formal environmental education is so important.
At the collecting point for recycling, plastic, PET bottles, and paper were collected every day with the amount of 1 kg/d and 1.5 kg/d.

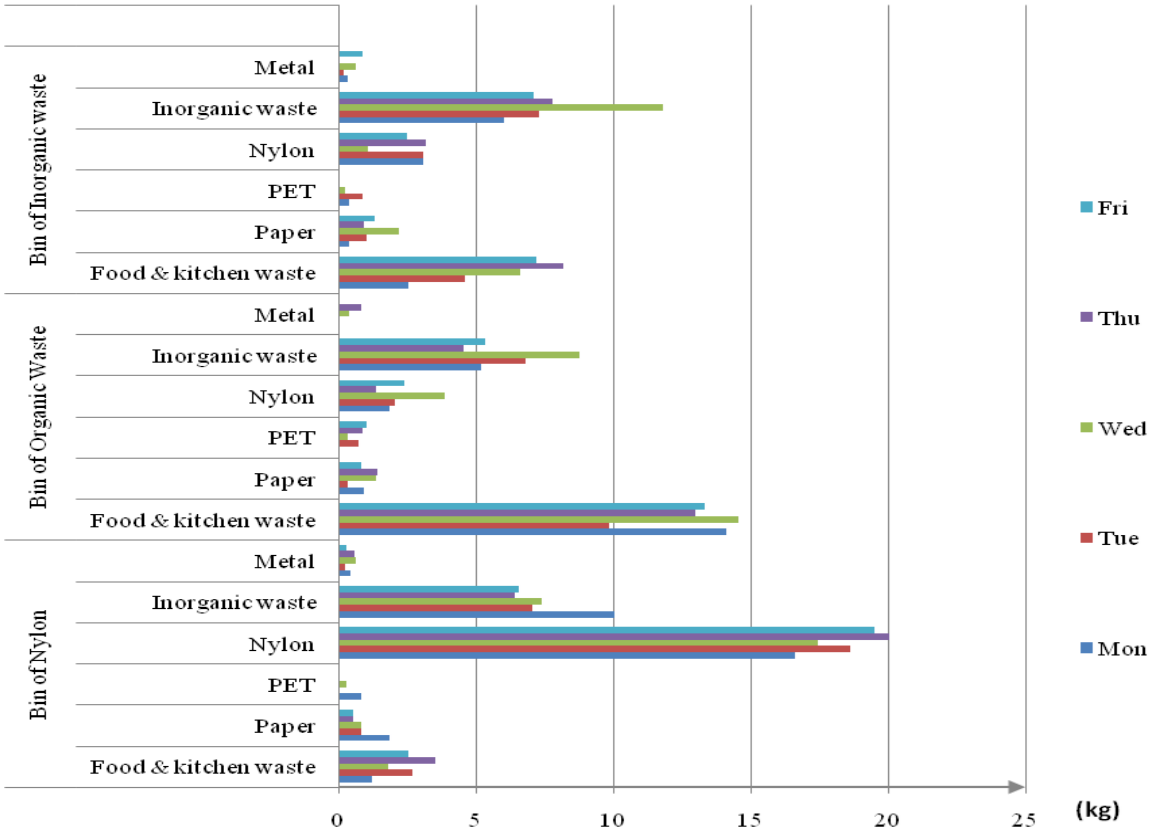

Figure 6: Components of waste in three bins at the gathering point

According to the obtained results in the specific models, we suggest sustainable integrated management for solid waste in the dorm is as Figure 7.

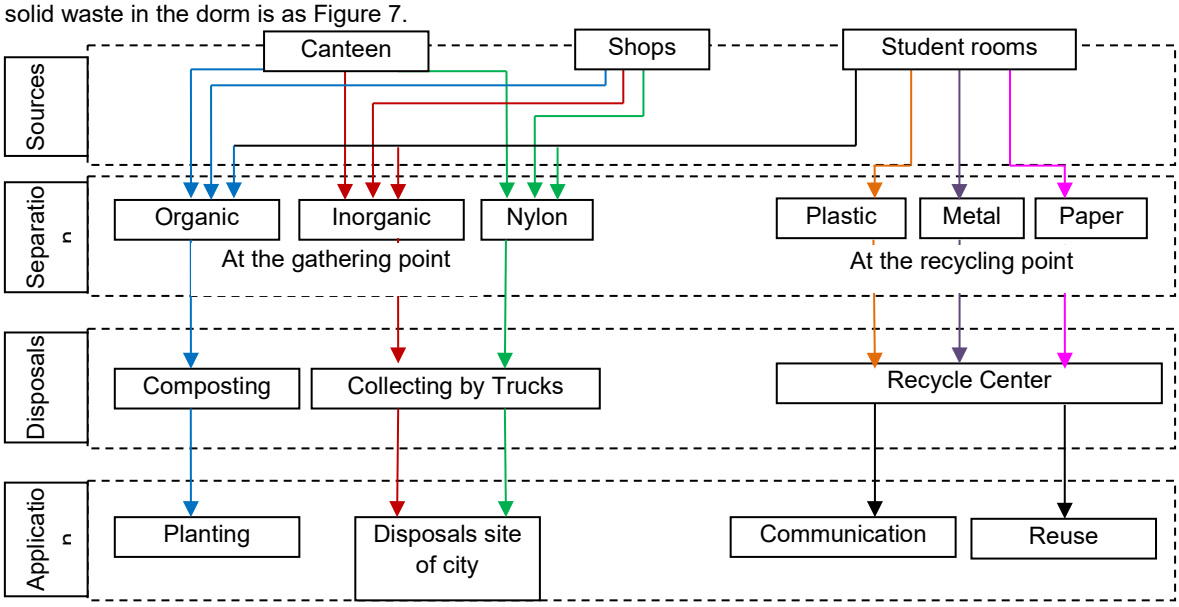

Figure 7: The flow of waste in the dorm of Danang University, Vietnam.

4. Conclusions

This study analyzed and assessed the characteristic of solid waste and the status of solid waste management in the dorm of Danang University. The estimated quantity of waste generated by the campus was 300 kg/d, and there was a significant difference in the amount between genders. In which biodegradable waste took up a proportion of 25 %, and recycle waste was 28 %. This waste has great potential for composting and raw material for recycling. This study also contributed to the evaluating of student knowledge and awareness toward waste and environmental protection. Vietnam in general and DNC, in particular, is lacking formal environmental education, aside from programs hosted by universities. MSW education should be done at a younger age, such as in elementary schools. Plus, there should be uniformity and continuity of programs organized by universities and social organizations. This study also suggests an integrated management system for campus solid waste toward sustainability.

Acknowledgments

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