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Commercial and institutional solid waste generation and relevant factors: Case study in tourism city - Hue, Vietnam

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ABSTRACT

This study was undertaken to evaluate the waste generation rate and composition generated from commercial and institutional sectors to identify the potential for recycling, discharge, and treatment in a tourism city—Hue city, central of Vietnam. Waste generation rate (kg/unit/day) was calculated and discussed in various units of dischargers. The waste compositions were analyzed in 10 physical categories for each component of institutional and commercial sectors. The relevant factors influencing generation rates were analyzed. The authors also explored the putative correlations between the waste generation rate and the examined factors. The outcomes of this study clarified the total and detail figures of waste generation and composition and relevant factors influencing waste generation rates from commercial and institutional sectors. These are indispensable to develop reliable predictive models and master plans towards integrated waste management and sustainable development.

Keywords: Commercial waste, institutional waste, waste generation rate, waste composition, ANOVA, Correlation analysis

INTRODUCTION

To develop an effective solid waste management (SWM) strategy for a given region, it is important to know the amount of waste generated and the composition of the waste stream. The waste generation rate (kg/unit/day) is essential to estimate future waste generation and to evaluate the waste generation trend [1]. Data on waste composition is required for the planning of collection, transportation, and treatment of municipal solid waste (MSW). Reliable data is the foundation of effective integrated waste management system [2]. Furthermore, the evaluation on waste generation for disposal habit, changes and trends are indispensable [3]. However, it must be noted that cities in Vietnam lack reliable database on SWM.

Many studies have examined waste generation and physical waste composition for MSW or different sectors of MSW in Vietnam. Among them, Thanh *et al.* ^[4] analyzed household (HH) solid waste to assess the waste generation rate and the detailed waste composition separated into 83 sub-categories in order to identify the potential for recyclables and mitigating greenhouse gas emissions; and developed predictive models for waste generation. Trung and Kumar ^[5] assessed the resource use and management in the hotel industry in Vietnam; in which, the energy and water use, as well as the waste generated in the various hotel categories have been estimated. Byer *et al.* ^[6] conducted surveys on waste generation rate and waste composition for households, hotels and markets to identify the possibility of composting of organic solid waste in Vietnam and Laos.

Annually, Vietnam publishes a report on the current status of environment situation focusing on the year's prominent issue. In 2004, SWM became the main topic. However, the report ^[7] presented the information on physical composition of MSW around Vietnam, and didn't introduce in-depth data of waste stream and various sources of MSW.

The rapid economic growth and expanding urbanization in cities in Vietnam have caused the increase of the waste generation and the diversification of waste composition. Commercial and institutional solid waste accounted for high proportion of total MSW, especially in tourism cities. Therefore, the evaluation and understanding for waste generation and characteristic from these sources are indispensable for the effective SWM planning.

In this paper, the authors intended to evaluate the waste generation rate and the detailed waste composition on commercial and institutional sectors in a tourism city—Hue city, located in the central of Vietnam. The authors also explored the interrelationships between the waste generation rate and the examined relevant factors such as business scale indicators.

METHODOLOGY

Research area

In this study, Hue city was selected as the research area. Hue is located in the Central of Vietnam (see Fig. 1); it was also the capital of Vietnam in the old times. Hue city is the capital city of Thua Thien Hue province with an area of 83.3 km² and a population of 337,506 persons (by 31 December 2009) [8]. Hue city has been known as one of World Heritage sites in Vietnam. Nowadays, Hue is becoming famous for visitors around the world.

The collected MSW amount in Hue city was approximately 200 tons/day, and the waste collection efficiency was estimated about 90–95%, collected by the Hue Urban Environment and Public Works State Company (HEPCO) [9].

Sampling method

The major components (main categories and sub-categories) of commercial and institutional sectors in this study were presented in Table 2. This table also presented the total number in Hue city, sample size in this study, and sample selection method of each category and sub-category applied in this study.

Generally, the sample selection in this study was mainly based on the total list according to the system of economic branches of Vietnam, which was accumulated by the statistical office of Hue city.



Fig. 1 Map of location of the target research area

According to "*The System of Economic Branches of Vietnam*" (Decision No. 10/2007/QD-TTG dated January 23, 2007) issued by Prime Minister of the Government of Vietnam^[10]; This system comprises five levels as follows: Level 1 comprises 21 branches coded by the letters of the alphabet in alphabetical order from A to U; Level 2 comprises 88 branches; Level 3 comprises 242 branches; Level 4 comprises 437 branches; and Level 5 comprises 642 branches. The structure and components were presented in Table 1. Table 1 also presented the target categories in this study.

BRANCH Level Target category Agriculture, Forestry and Aquaculture 1-3 Mining Minerals В 5-9 numbers after those of the branches, each branch coded by four numbers after those of the five numbers after those of the HH with business C 10-33 Manufacturing and Processing Industries Production and Distribution of Electricity, Natural Gas. D 35 Hot Water, Steam and Air-Conditioning 36-39 Water Supply, Waste and Sewage Management \mathbf{E} F 41-43 Construction Sale and repair of automobiles, motors, motorbikes, etc. HH with business & G 45-47 Wholesale and retail Market & supermarket evel 4 Н 49-53 Transport and Warehouse Office corresponding Level three Ι 55-56 Accommodation and Restaurant Services Restaurant & Hotel 58-63 Information and Communication HH with business & Office J branch coded by 1 coded by K 64-66 Finance, Banking and Insurance Office 68 Real-Estate Business Office M 69-75 Professional Practice, Science and Technology Office each branch 77-82 HH with business & Office N Administrative Services and Assistant Services The Communist Party, Civil society, State administration, Office O 84 642 branches, each National defense security, etc. P 85 Education and Training School & education services branches, O 86-88 Health and social support activities Hospital & healthcare services 90-93 HH with business & Office R Artistic, recreational activities S 94-96 Other Services HH with business & Office 437 242 Hired Labor services for Households, Producing Home Т 97-98 HH with business Consumption Material Products U 99 Operation of International Organizations and Agencies Office

Table 1 The system of economic branches of Vietnam [10]

Table 2 Target categories of commercial and institutional sectors and sample selection methods

Cate	egory	Sub-category	Total size	Sample size	Sample selection methods	Remarks		
		(1) Kindergarten	49	9	Based on the total list, excluding sub-category (4).			
	vice	(2) Primary education	37	5	The total list of each sub-category was prepared			
	Schools/ Education service	(3) Secondary education	36	9	and sorted by the number of students. The target samples were selected systematically from the			
	Schools/ ation ser	(4) Post-graduate education	8	2	list.	-		
	S	(5) Other education services	181	6				
	Ĕ	(6) Education assistant services	0	0				
		(1) Hospitals	12	3	- Random selection	_		
Institutional waste	Hospital/Healthcare services	(2) Healthcare stations	27	3	The total list of each sub-category was prepared and sorted by the number of beds. The target samples were selected systematically from the list.	-		
itutions	althcare	(3) General and specialized medical establishments 256		6	The total list of each sub-category was prepared and sorted by the number of staff. The target	– 50% samples is family scale		
Insti	ital/He	(4) Dental establishments	92	6	samples were selected systematically from the list.	– 50% samples is medium scale		
	dsoj	(5) Standby [reserve] medical	5	1	Random selection	-		
	Н	(6) Orthopedic and rehabilitation centers	2	1	- Random selection	-		
	Offices	(1) Government offices - Professional management services - People committee (PC)	18 27+2	3 3+2	Random selection (Departments/Bureaus/Institutions/Agencies) Random selection (27 Wards' PC,2 City/Province's PC)	-		
		(2) Other offices	365	32	Random selection (2) wards PC,2 City/Province s PC) Random selection from the total list	_		
-		(1) Guest house				Total hotels in Hue also		
		()	101	10	- Based on the total list: The total list of each sub- category was prepared and sorted by the number	consist of:		
	_	(2) 1-star hotel		7	of beds. The target samples were selected	 45: Non-rated hotels have 		
	Hotel	(3) 2-star hotel	18	6	systematically from the list.	registered		
		(4) 3-star hotel				 76: Non-rated hotels have not registered yet 		
		(5) 4-star hotel	7	5		not registered yet		
		(6) 5-star hotel				68 restaurants in 5 zones		
	Restaurant	(1) Restaurant (large scale) (2) Family-restaurant and pub/bar - I worker - 2 workers - 3 workers - 4 workers or more (3) Beverage shops	131 1068 836 212 190	30 22 7 6	 5 target zones were selected according to the urbanization level^[11] Based on the total list of each target zone: The total list of each sub-category was prepared and sorted by the number of workers. The target samples were selected systematically from the list. Sample size was decided according to the 	Total number in 5 zones: - 1 worker: 565 - 2 workers: 425 - 3 workers: 114 - 4 workers or more: 92 Total number in 5 zones:		
4)		– 1 worker – 2 workers	921 793	11 7	proportion by the number of workers in each zone.	– 1 worker: 564 – 2 workers: 416		
waste		- 3 workers or more	211	2		- 3 workers or more: 149		
ial w		(4) Vendor	NA	5	- Random selection	1 sample for each zone		
Commercial	Market and supermarket	(1) Market (kiosks in market)	460	64	- Kiosks are classified into 12 categories and 31 subcategories based on the "The system of economic branches of Vietnam" (level 5) - The total list of each sub-category was prepared. The target samples were selected systematically from the list.	1 st class market		
	L	(2) Supermarket	8	1	- Random selection			
	iness	(1) Manufacturing and Processing Industries (C)*	3247	45	- 5 target zones were selected according to the urbanization level [11] - Based on the total list of each target zone: The total list of each sub-category was prepared	- 17 categories from 25 total categories in the 2 nd level of the "System of Economic Branches"		
	Household with business	(2) Sale, repair of automobiles, motors, motorbikes etc. Wholesale and retail (G)*	7375	82	and selected systematically from the list. The sub-categories with less than 5 facilities were not surveyed (only 55 in total 85 sub-categories were considered and surveyed).	 31 categories from 53 total categories in the combination both 4th and 5th levels of the "System of Economic Branches" 		
	, ,	(3) Other Services (Level 1 of the "System of Economic Branches": J, N, R, S, T)*	2250	17		- 7 categories in the 2 nd level of the "System of Economic Branches"		

^(*) Industrial code according Level 1 of the "System of Economic Branches"

Outline of surveys

The authors surveyed the target samples for each component of commercial and institutional sectors composed of three surveys; a waste generation survey by actual measurement, a waste composition survey, and a questionnaire survey. All surveys were carried out simultaneously in rainy season (from September to December 2011).

- (1) Waste generation survey: a waste generation survey was conducted to acquire data on discharge amount of waste generated for 7 consecutive days. The target samples were requested to keep and separate their waste into 4 categories; "General waste," "Recyclables," "Food residues," and "Garden waste." The waste was daily collected and measured by wet weight.
- (2) Waste composition survey: During the waste generation survey, a waste composition survey was conducted. The representative samples were selected. The waste was classified into 10 physical categories and 54 sub-categories and recorded the weight with a digital scale measuring a minimum of one gram (g).
- (3) Questionnaire survey: A questionnaire survey was conducted by a face-to-face interview at the targets to obtain data on relevant factors influencing waste generation such as business scale indicators, and the current status of recycling activities.

RESULTS AND DISCUSSION

Waste generation rate

Table 3 presented the waste generation rate (kg/unit/day) for commercial and institutional sectors in Hue city, the average and standard deviation (Ave \pm SD) of waste generation rate by the category of the commercial and institutional sectors were summarized. The waste generation rate was separately measured and calculated by 4 waste types; general waste, recyclable waste, food residues, and garden waste. The waste generation rate (g/unit/day) was calculated by dividing the waste generation amount per day (g/day) by business scale indicators such as the number of workers, the number of beds. The estimated waste generation rate by the category is indispensable basic data for the rational planning on waste management and 3Rs promotion.

The details and discussion are presented as follows:

School, university, and education services: The waste generation rate was calculated by the following 3 business scale indicators; g/class/day, g/pupil (student)/day, and g/classroom/day. Each category of this section was separately measured and estimated by two sources: canteen and class. Regarding waste from class activities, "Kindergarten" was identified as the highest generation category for the unit (g/class/day and g/classroom/day), while the generation rate (g/pupil/day) of "other education (baby-keeping house)" category was the highest.

Healthcare services: The waste generation rate was calculated by the following 3 business scale indicators; g/patient/day, g/worker/day, and g/bed/day. Among various categories of healthcare services, the waste generation rate (g/patient/day) of "hospital" category was the highest, followed by "dental establishment" category. While "dental establishment" was the highest category in the generation rate by worker (g/worker/day), followed by "hospital." Among waste proportions, general waste accounted for the highest generation part, followed by food residues, garden waste, and recyclable waste. (Hazardous healthcare waste was not covered in this study.)

Offices: The waste generation rate was calculated by the following 3 business scale indicators; g/room/day, g/worker/day, and $g/m^2/day$. Among three categories of office sector, the waste generation rate (g/unit/day) of "professional management services" category was smaller than those of others; while "other offices" category was the highest in the waste generation rates by staff (g/worker/day) and area ($g/m^2/day$). Among 4 waste types, recyclable waste accounted for the highest part, followed by general waste and garden waste. Food residues weren't discharged for collection by users such as pig farmers.

Hotels: The waste generation rate was discussed by the following 3 business scale indicators; kg/room/day, kg/bed/day, and kg/guest/day. Among the hotel categories, the waste generation rate (kg/unit/day) of "5-star hotel" category was larger than those of others; while "guesthouse" was the smallest in most cases. Among 4 waste types, general waste accounted for the highest part, followed by food residues, recyclable, and garden waste.

Restaurants: Waste generation rate was considered by the following 3 business scale indicators; kg/worker/day, g/chair/day, and g/table/day. Among the restaurant categories, the waste generation rate (kg/unit/day) of "vendor" category was smaller than those of others, followed by "beverage shops" category; while "restaurants" (large and family scale) was the highest in most cases. The waste generation rate (kg/worker/day) of "1-worker restaurant" category was the highest generation rate, while "3-workers restaurant" was the highest for the generation rates by table (g/table/day) and chair (g/chair/day). Among 4 waste types, food residues accounted for the highest part, followed by general waste, recyclable, and garden waste.

Market and supermarket: Kiosks in market were classified into 12 categories. The waste generation rate of kiosks in market was considered by the following 3 business scale indicators; kg/kiosk/day, $kg/m^2/day$, and $g/m^2/hour$. The waste generation rate of supermarket was considered by the following 2 business scale indicators: $g/m^2/day$ and kg/worker/day.

Table 3 Waste generation rate (g/unit/day) of commercial and institutional sectors

	CATEGORY	General	Recyclable	Food residues	Garden	Total	General	Recyclable	Food residues	Garden	Total	General	Recyclable	Food residues	Garden	Total
П		I		g/class/day					g/pupil/day					g/classroom/day		
	(1) Kindergarten - Classes Kindergarten - Canteen	1152.53 + 925.88		0	473.8 + 764.86	1559.04 + 911.98	31.04 + 22.14	0.46 + 0.94	0	13.48 + 23.53	42.61 + 22.88	1114.57 + 935.57	15.01 + 30.89	0	460.46 + 767.71	1506.67 + 928.56
,	,	432.33 + 220.83 861.67 ± 184.57	20.6 + 35.18	3416.74 + 1357.53	0 119.14 ± 202.17	3953.04 + 1446.9 980.82 ± 124.45	12.01 + 4.84 25.61 ± 3.01	0.55 + 0.95 0	96.21 + 37.16 0	0 5.01 ± 8.97	111.14 + 37.85 30.62 ± 11.3	400.73 + 149.64 842.9 ± 162.36	18 + 31.12 0	3255.02 + 1267.5	0 136.63 ± 236.88	3757.12 + 1289.01 979.53 ± 237.65
	(2) Primary education - Classes Primary education - Canteen	861.67 ± 184.57 112.18 ± 66.65	0	1537.02 ± 635.06	119.14 ± 202.17	980.82 ± 124.45 1649.2 ± 588.62	25.61 ± 3.01 3.21 ± 1.22	0	51.81 ± 28.73	5.01 ± 8.97 0	30.62 ± 11.3 55.03 ± 27.54	842.9 ± 162.36 114.69 ± 62.9	0	1634.23 ± 702.62	136.63 ± 236.88	1748.91 ± 647.99
3	(3) Secondary education - Classes	475.57 ± 205.31	16.1 ± 47.42	0	685.45 ± 486.59	1177.12 + 583.43	12.66 ± 5.86	0.39 ± 1.13	0	18.35 ± 15.7	31.39 + 19.41	592.01 ± 269.84	19.4 ± 57.52	0	888.43 ± 701.51	
5	Secondary education - Canteen	126.82 ± 48.33	18.46 ± 22.68	117.35 ± 133.07	0	262.62 + 180.03	2.88 ± 1.04	0.42 ± 0.52	2.69 ± 3.04	0	5.99 + 4.09	182.5 ± 121.58	21.56 ± 21.66	154.22 ± 180.06	0	358.28 + 292.03
È	(4) Post-graduate education-Classes	488.24 + 122.17	50.96 ± 25.73	0	474.33 ± 670.81	1013.53 + 818.71	7.3 + 2.62	0.7 ± 0.06	0	4.5 ± 6.36	12.5 + 3.67	568.03 + 317.5	52.98 ± 16.46	0	283.57 ± 401.02	904.59 + 67.06
1 2	Post-graduate education- Canteen	212.24 + 52.33	31.24 ± 3.09	291.48 ± 21.15	0	534.96 + 34.27	3.67 + 2.84	0.52 ± 0.34	4.6 ± 2.4	-	8.79 + 5.58	298.16 + 273.51	41.65 ± 34.33	364.28 ± 256.1	0	704.09 + 563.94
3	(5) Other education											<u> </u>	<u> </u>			
STE	- Private teaching classes	21.06 ± 1.78 1050.96 ± 486.58	0	0 1592.27 ± 1797.64	0	21.06 ± 1.78 2643.23 ± 1318.2	2.58 ± 0.04 79.31 ± 63.23	0	0 143.14 ± 129.74	0	2.58 ± 0.04 222.46 ± 153.95	138.75 ± 56.21 780.48 ± 661.44	0	796.13 ± 898.82	0	138.75 ± 56.21 1576.62 ± 451.3
×	Baby-keeping house ANOVA (F) [Among Classes of sub-categories]	2.662	0.766	1592.27 ± 1797.04	1.07	2.433	79.31 ± 63.23 3.525*	3.26	143.14 ± 129.74	8.29	2.452	1.609	0.641	/90.13 ± 898.82	1.513	1.706
O	ANOVA (F) [Among Canteens of sub-categories]	5.665**	0.638	15.489***	-	16.337***	10.090**	0.453	15.131***	- 0.25	17.956***	3.841*	1.077	14.943***	-	15.986***
15		1		g/patient/day					g/worker/day					g/bed/day		
STL	(1) Hospitals	448.16 ± 565.2	40.83 ± 55.98	211.72 ± 423.43	88.19 ± 102.73	788.89 ± 1036.53	188.29 ± 112.64	30.53 ± 55.77	38.52 ± 77.03	70.63 ± 122.65	327.96 ± 160.19	186.51 ± 109.27	31.41 ± 58.67	30.04 ± 60.09	79.17 ± 143.62	327.13 ± 155.99
_ ≥ 3	(2) Healthcare stations	91.37 ± 143.24	0	0	20.73 ± 26.67	112.09 ± 126.91	99.78 ± 57.02	0	0	181.66 ± 255.37	281.43 ± 241.22	178.67 ± 207.28	0	0	22.29 ± 31.52	200.95 ± 175.76
9	(3) General/specialized medical establishments	96.22 ± 100.72	13.31 ± 26.62	44.09 ± 88.17	0	153.62 ± 211.07	183.47 ± 147.76	17.45 ± 34.89	57.79 ± 115.59	0	258.71 ± 263.54	374.05 ± 300.9	14.83 ± 29.66	49.13 ± 98.25	0	438.01 ± 296.23
1 5	(4) Dental establishments (5) Standby [reserve] medical activities	570.9 ± 517.06 65.93	0	0	0 24.25	570.9 ± 517.06 90.18	621.66 ± 413.17 87.68	0	0	0 32.25	621.66 ± 413.17 119.94	1201.95 ± 309.17	0	0	0	1201.95 ± 309.17
100	(6) Orthopedic and rehabilitation centers	251.51	14	162.05	292.29	719.84	57.72	3.21	37.19	67.08	165.21	50.3	2.8	32.41	58.46	143.97
	ANOVA (F)	0.838	0.737	0.447	5.137*	0.703	2.551	0.397	0.329	0.807	0.952	7.578**	0.327	0.248	0.507	6.084
	(1) Government offices	1		g/room/day					g/worker/day	-	-			g/m2/day		*
1	- Professional management services	168.29 ± 166.52	9.58 ± 16.59		154.45 ± 131.43	332.33 ± 233.37	35.34 ± 43.63	1.17 ± 2.02		28.98 ± 24.58	65.49 ± 61.51	1.51 ± 1.94	0.06 ± 0.1		1.14 ± 1.01	2.7 ± 2.74
i i	- People committee (PC)	280.97 ± 58.2	370.99 ± 197.54		960.49 ± 678.44	1612.44 ± 471.41	39.32 ± 17.6	45.76 ± 32.01		87.21 ± 14.33	172.29 ± 45.84	1.86 ± 0.23	2.66 ± 0.24		3.74 ± 0.39	8.26 ± 0.2
	(2) Other offices (10 detailed sub-categories)	250.22 ± 194.77	509.35 ± 781.28		89.71 ± 158.12	849.28 ± 1035.31	51.07 ± 39.53	212.67 ± 316.34		9.6 ± 17.07	273.33 ± 355.38	8.14 ± 7.49	10.61 ± 17.33		0.62 ± 1.05	19.37 ± 23.77
+	ANOVA (F) [Among 13 sub-categories]	1.259	1.622	kg/room/day	3.487**	1.622	1.134	1.901	kg/bed/day	3.550**	1.727	0.888	0.818	kg/guest/day	1.208	0.594
	(1) Guest house	0.19 + 0.11	0.02 + 0.01	0.09 + 0.2	0.01 + 0.03	0.3 + 0.24	0.13 + 0.08	0.01 + 0.01	0.06 + 0.13	0.01 + 0.02	0.21 + 0.16	0.39 ± 0.29	0.08 ± 0.11	0.07 ± 0.14	0.02 ± 0.06	0.55 ± 0.4
	(2) 1-star hotel	0.31 + 0.15	0.02 + 0.01	0.07 + 0.12	0.01 + 0.04	0.42 + 0.22	0.18 + 0.09	0.02 + 0.01	0.04 + 0.07	0.01 + 0.02	0.25 + 0.13	0.59 ± 0.55	0.05 ± 0.08	0.07 ± 0.14 0.08 ± 0.21	0.02 ± 0.00	0.75 ± 0.66
3	(3) 2-star hotel	0.29 + 0.31	0.02 + 0.02	0.12 + 0.16	0.01 1 0.04	0.42 + 0.4	0.17 + 0.17	0.01 + 0.01	0.07 + 0.09	0.01 1 0.03	0.24 + 0.22	0.82 ± 0.85	0.05 ± 0.08	0.14 ± 0.2	0	1.01 ± 1
3	(4) 3-star hotel	0.55 + 0.37	0.06 + 0.05	0.29 + 0.07	0	0.9 + 0.4	0.29 + 0.18	0.03 + 0.03	0.16 + 0.04	0	0.48 + 0.19	1.43 ± 1.29	0.19 ± 0.28	1.01 ± 1.5	0	2.63 ± 2.63
	(5) 4-star hotel	0.65 + 0.45	0.06 + 0.04	0.42 + 0.26	0	1.12 + 0.73	0.45 + 0.19	0.04 + 0.03	0.31 + 0.12	0.01 + 0.02	0.82 + 0.31	1.18 ± 1.21	0.22 ± 0.58	0.85 ± 0.85	0.03 ± 0.12	2.28 ± 2
	(6) 5-star hotel	0.79 + 0.24	0.1 + 0.07	0.51 + 0.02	0.11 + 0.17	1.5 + 0.25	0.58 + 0.25	0.07 + 0.06	0.37 + 0.03	0.08 + 0.12	1.1 + 0.31	1.73 ± 1.05	0.21 ± 0.18	1.13 ± 0.42	0.08 ± 0.19	3.15 ± 1.38
- 1 ⊢	ANOVA (F)	3.993**	3.979**	6.971***	2.619*	7.8004***	7.225***	4.968**	11.698***	2.496*	15.011***	7.207***	2.611*	10.257***	3.372**	11.529***
				kg/workerday		T	<u> </u>	T	g/chair/day			L	T	g/table/day		
	(1) Restaurant (large scale)	1.41 ± 0.82	0.15 ± 0.18	1.86 ± 1.59	0	3.42 ± 2.32	134.5 ± 65.55	10.49 ± 9.29	174.26 ± 123.13	0.52 ± 1.54	319.76 ± 175.8	611.5 ± 311.02	61.49 ± 93.92	795.65 ± 598.81	2.85 ± 8.91	1502.38 ± 874.94
	(2) Family-restaurant and pub/bar - 1 worker	2.75 ± 2.1	0.05 ± 0.12	4.44 ± 4.24	0	7.25 ± 5.68	160.38 ± 104.88	3.02 ± 8.02	232.59 ± 165.93	0	395.98 ± 231.15	586.3 ± 439.4	12.06 ± 32.09	883.67 ± 682.75	0	1482.04 ± 973.35
11.	- 2 workers	1.51 ± 0.77	0.08 ± 0.12	3.08 ± 2.46	0.05 ± 0.16	4.72 ± 2.75	132.31 ± 71.46	4.57 ± 6.42	222.71 ± 189.47	3.58 ± 10.52	363.16 ± 227.17	568.37 ± 337.3	18.08 ± 25.39	996.51 ± 860.55	14.68 ± 42.38	1597.64 ± 992.37
-	- 3 workers	1.74 ± 1.04	0.05 ± 0.09	3.87 ± 4.88	0	5.66 ± 5.55	169.17 ± 123.9	3.28 ± 6.56	459.65 ± 657.56	0.52 ± 1.57	632.63 ± 770.47	675.99 ± 494.86	15.58 ± 32.58	1796.34 ± 2628.07	1.84 ± 5.51	2489.74 ± 3071.9
1	- 4 or more than 4 workers	2.1 ± 2.22	0.22 ± 0.54	2.4 ± 2.22	0.01 ± 0.03	4.73 ± 4.18	210.42 ± 161.32	4.64 ± 7.06	317.99 ± 377.27	0	533.05 ± 371.61	829.28 ± 657.46	18.58 ± 28.24	1251.35 ± 1520.08	0	2099.21 ± 1520.67
å	(3) Beverage shops	2.08 ± 0.93	0.01 ± 0.01	0	0	2.09 ± 0.94	101.04 ± 52.27	0.32 ± 0.28	0	0	101.36 ± 52.34	330.9 ± 131.1	1.14 ± 1.05	0	0	332.04 ± 131.28
	- 1 worker - 2 workers	1.7 ± 1.4	0.07 ± 0.01	0	0.13 ± 0.32	1.9 ± 1.51	76.16 ± 38.86	2.47 ± 3.17	0	9.76 ± 26.46	88.39 ± 54.35	278.62 ± 133.64	8.84 ± 11.41	0	38.48 ± 106.04	325.94 ± 204.55
	- 3 or more than 3 workers	1.95 ± 1.88	0.79 ± 1.36	0	0.1 ± 0.13	2.85 ± 2.04	126.32 ± 44.77	8.91 ± 11.76	0	1.87 ± 3.23	137.09 ± 45.75	504.74 ± 204.17	28.21 ± 34.53	0	7.46 ± 12.93	540.42 ± 194.33
2	(4) Vendor	1.52 ± 1.06	0.02 ± 0.03	0.33 ± 0.05	0	1.87 ± 1.04	0	0	0	0	0	0	0	0	0	0
WAS	ANOVA (F)	0.913	2.106*	2.910**	1.059	2.023	1.566	1.586	2.121	0.831	2.330*	1.599	1.694	2.278*	0.849	2.460*
A.	(1) Market (kiosk in market)			kg/kiosk/day			<u> </u>		kg/m2/day			<u> </u>		g/m2/hour		
ISCI	- Food (rice, cereal, etc.)	1.58 ± 1.72	0.43 ± 0.18	0		2.01 ± 1.53	0.84 ± 0.87	0.24 ± 0.12	0		1.08 ± 0.75	143.7 ± 155.98	22.07 ± 11.31	0		98.16 ± 68.17
Ž	Meat and meat products Fish and fish products	0.4 ± 0.09 0.29 ± 0.31	0.05 ± 0.08	5.21 1.57 ± 1.12		3.05 ± 3.64 1.85 ± 0.96	0.57 ± 0.41 0.33 ± 0.34	0.06 ± 0.12	1.74 ± 3.68 1.53 ± 1.3	+	2.36 ± 4.12 1.86 ± 1.11	39.42 ± 16.62 39.68 ± 48.74	9.39 ± 13.29	289.31 ± 409.15 165.21 ± 164.48		344.37 ± 431.06 201.68 ± 153.12
g ,	- Fish and fish products - Vegetables	0.29 ± 0.31 4.21 ± 1.16	0	1.57 ± 1.12 0	\vdash	1.85 ± 0.96 4.21 ± 1.16	0.33 ± 0.34 2.85	0	1.53 ± 1.3	+	1.86 ± 1.11 2.85	39.68 ± 48.74 480.86 ± 117.47	0	165.21 ± 164.48		201.68 ± 153.12 265.78 ± 266.42
1	- Fruits	11.2 ± 4.65	3.53 ± 3.6	0		14.73 ± 8.25	4.35 ± 0.41	1.05 ± 1.59	0		5.41 ± 2.41	1135.52 ± 262.54	111.52 ± 70.97	0		551.92 ± 95.95
1 8	- Other foodstuffs	0.22 ± 0.1	0	0		0.22 ± 0.1	0.17 ± 0.02	0	0		0.17 ± 0.03	18.31 ± 7.71	0	0		10.4 ± 6.71
1	- Food stalls	1.29 ± 1.62	0.1 ± 0.23	5.84 ± 3.6		7.23 ± 4.84	0.77 ± 0.96	0.06 ± 0.14	3.47 ± 2.14		4.3 ± 2.88	150.61 ± 122.4	10.15 ± 22.7	523.57 ± 251.07	\vdash	623.37 ± 250.65
g	- Beverages	0.35	0.03	0	 	0.35 0.22	0.09	0.03	0	+	0.09 0.17	63 16.21	0 2.18	0		15.75 14.46
100	Cigarettes, rustic tobacco Textiles, apparel, footwear	0.19 0.68 ± 0.19	0.03	0		0.22 0.68 ± 0.19	0.14 0.32 ± 0.03	0.03	0	+	0.17 0.32 ± 0.03	16.21 52.64 ± 12.23	2.18 0.21	0		14.46 24.15 ± 3.47
2	- Fresh flowers, ornamental plants	20.82 ± 19.33	0.01	0	t	20.82 ± 19.33	5.30 ± 2.62	0	0	+	5.30 ± 2.62	52.64 ± 12.23 1530 ± 1320	0.21	0		1530 ± 1320
	- Other commodities	0.33 ± 0.14	0.01 ± 0.01	0		0.34 ± 0.14	0.12 ± 0.07	0	0		0.12 ± 0.07	28.23 ± 13.57	0.22 ± 0.26	0		9.9 ± 5.49
11	ANOVA (F)	9.363***	2.485**	1.826*		4.261***	3.694**	2.817**	1.22		2.739**	20.733***	4.778***	1.685		3.078**
11	(2) Supermarket			g/m2/day					kg/worker/day							
L		12.34 ± 4	9.15	20.15 ± 4.43		41.64 ± 3.46	0.25 ± 0.08				0.83 ± 0.07					
1 [Bu	usiness source: g/worke	er/day			Hou	usehold source: g/capit	ta/day		1	Garden	source: calculated in two aspects		
1 3	(1) Manufacturing Industries (C)	715.23 ± 1007.75	910.22 ± 1197.22	283.52 ± 426.02		1908.97 ± 1598.62	259.73 ± 141.98	1.97 ± 2.29	87.39 ± 93.51		349.09 ± 189.54			80.61 ± 130.7		14.75 ± 24.55
1 1	(2) Sale, repair of automobiles etc.	294.49 ± 422.15	55.54 ± 153.68	0		350.03 ± 570.87	193.58 + 86.03	1.91 ± 8.14	27.65 ± 82.45		223.15 ± 138.81		1	3.03 ± 10.58	1	1.21 ± 4.23
4	Wholesale and retail (G)	321.27 ± 246.68	128.53 ± 190.5	6.23 ± 9.52	 	456.03 ± 337.89		7.49 ± 12.69	71.68 ± 103.62	+	309.83 ± 184.9		g/worker/day		g/household	1.21 ± 4.23 13 ± 20.99
1 13			128.53 ± 190.5 38.44 ± 38.71	6.23 ± 9.52 111.4 ± 298.92	 	456.03 ± 337.89 316.45 ± 450.94	230.66 ± 128.21 209.91 ± 116.52	7.49 ± 12.69 4 ± 5.2	71.68 ± 103.62 67.91 ± 108.72	+	309.83 ± 184.9 281.82 ± 136.02		- 3,,,	29.08 ± 46.91 0.86 ± 1.21	member/day	
11.5											2×1 ×2 + 136 02					0.29 ± 0.4
Š	(3) Other Services (Level 1: J,N,R,S,T)	166.61 ± 186.77			 					 		 	1		1	
3	ANOVA (F) [Among 55 sub-categories]	1.637*	1.590*	1.455		3.059***	1.043	0.661	1.454		1.545*			1.596*		1.494*

Table 4 Waste composition (in percentage, %) of commercial and institutional sectors

Ca	ategory	Sub-category	Plastic	Paper	Food waste	Rubber & Ieather	Grass & wood	Textile	Metal	Glass	Ceramic	Miscella- neous	Total	Boundary
	uo	(1) Kindergarten	14.87	20.04	51.01	1.47	4.05	1.55	0.65	0.14	0.88	5.33	100	
	cati	(2) Primary education	21.74	23.77	22.81	0.60	7.50	6.86	0.13	0.12	3.99	12.48	100	General
ره ا	Schools/Education service	(3) Secondary education	22.74	28.76	32.06	0.17	8.21	0.38	0.32	1.14	0.46	5.76	100	waste (class and
ast	ls/F	(4) Post-graduate education	27.42	11.64	21.29	0.21	13.32	1.66	0.51	-	-	23.96	100	canteen)
<u>-</u>	hoo	(5) Other education services	15.21	22.36	32.47	0.06	23.78	0.19	1.16	-	-	4.77	100	canteen
ous	Sc	Garden of school	1.48	6.82	0.25	0.07	90.10	0.76	0.03	-	-	0.50	100	
Institutional waste	Hospita	l/Healthcare services	-	-	-	-	-	-	-	-	-	-	-	
nsti		(1) Government offices	15.66	38.57	31.39	0.58	4.69	0.78	1.90	0.18	0.14	6.13	100	
1	seo	- Professional management	11.56	43.67	30.80	0.23	9.73	0.55	0.52	-	-	2.94	100	General
	Offices	- People committee (PC)	14.07	35.61	39.45	0.01	0.20	0.26	1.75	-	-	8.64	100	waste
		(2) Other offices	21.34	36.42	23.90	1.49	4.12	1.53	3.42	0.54	0.42	6.80	100	
		(1) Guest house	11.52	10.24	28.80	0.03	3.73	0.04	1.70	31.90	0.01	12.05	100	
		(2) 1-star hotel	28.29	23.39	28.75	0.14	10.29	0.05	3.01	-	-	6.09	100	General
	tel	(3) 2-star hotel	25.15	8.99	52.15	0.05	2.92	0.85	0.42	-	-	9.46	100	waste and
	Hotel	(4) 3-star hotel	9.48	9.69	63.11	0.77	7.56	1.17	2.74	-	-	5.48	100	recyclable
		(5) 4-star hotel	13.86	18.93	47.37	0.38	3.64	1.77	1.67	3.52	0.01	8.86	100	waste
		(6) 5-star hotel	15.52	13.84	55.81	0.09	1.46	2.89	1.50	3.77	0.18	4.95	100	
	ıt	(1) Restaurant (large scale)	12.80	9.04	57.63	0.08	4.69	2.82	1.18	0.99	0.17	10.61	100	
	Restaurant	(2) Family-restaurant and pub/bar	11.66	9.64	53.43	0.04	7.47	1.19	1.76	0.50	0.42	13.90	100	General
	sta	(3) Beverage shops	4.62	5.46	78.48	0.02	3.30	0.22	1.17	0.04	0.05	6.64	100	waste
	Re	(4) Vendor	12.90	-	76.10	-	10.16	-	-	-	-	0.84	100	
		(1) Market (kiosk in market)	18.19	10.50	51.76	0.67	13.13	0.28	0.19	0.40	0.20	4.68	100	
e		- Food (rice, cereal, etc.)	2.65	0.94	71.33	0.17	-	-	-	-	-	24.91	100	
ast		- Meat and meat products	26.11	15.62	55.88	0.09	1	-	-	2.29		-	100	
<u>-</u>		- Fish and fish products	4.74	-	95.04	1	-	-	-	-	-	0.22	100	
Commercial waste	Market and supermarket	- Vegetables	4.80	0.69	91.15	-	3.07	-	-	-	-	0.29	100	
l ä	maı	- Fruits	8.51	14.48	62.02	0.03	0.19	-	-	-		14.76	100	
J	ıper	- Other foodstuffs	55.14	27.09	14.94	0.15	2.19	0.25	-	-	-	0.25	100	General
1	ns p	- Food stalls	3.67	2.98	46.61	0.03	38.45	0.02	0.03	0.43	-	7.77	100	waste
	t an	- Beverages	-	-	-	-	-	-	-	-	-	-	-	
	rke	- Cigarettes, rustic tobacco	19.87	4.10	66.56	0.95	7.26	-	1.26	-	-	-	100	
	Ma	- Textiles, apparel, footwear	51.46	15.79	22.53	4.92	2.75	2.19	0.24	-	-	0.11	100	
		- Fresh flowers, ornamental	6.90	4.32	5.34	0.10	83.22		0.09	-	-	0.03	100	
		- Other commodities	16.27	29.49	37.94	0.93	7.28	0.62	0.41	1.69	2.23	3.14	100	
		(2) Supermarket	23.58	22.15	42.42	0.08	1.77	3.48	1.06	-	-	5.48	100	General waste
	p p	(1) Manufacturing Industries (C)	20.88	8.21	37.13	2.63	7.64	16.84	4.15	0.31	-	2.20	100	General
	hole	(2) Sale, repair of automobiles, etc.	17.39	25.43	18.84	20.21	0.48	10.54	1.84	-	-	5.29	100	waste of
	Household with business	Wholesale and retail (G)	20.32	11.37	48.52	0.54	10.99	3.27	0.69	2.51	0.46	1.32	100	business
1	Hc	(3) Other Services	17.30	13.32	40.70	6.53	1.76	0.45	2.74	1.87	0.92	14.41	100	facilities

Household with business: Households with business facilities were classified in four types of business: manufacturing industries, sale/repair of automobiles, wholesale/retail, and other services. The waste generation rate of business facilities was calculated by g/worker/day, and the waste generation rate of household was separately estimated by g/capita/day. Besides, garden waste was calculated by 2 indicators for households and business scales.

ANOVA results showed that the significant average differences were found among the generation rates of categories and sub-categories of the commercial and institutional sectors by business category. The business category was identified as the appropriate factor influencing waste generation for "Hotel" category, "Education" category and "Market" category.

Waste composition

Table 4 presented the average proportion of waste composition of commercial and institutional waste by 10 physical categories.

School, university, and education services: The waste compositions of education service were calculated by 5 categories of education service and garden waste. Food waste accounted for the largest part in the total

general waste, followed by paper and plastic (excluding "post-graduate education" category). Regarding "post-graduate education" category, plastic accounted for the largest part in the total general waste (27.42%), followed by miscellaneous (23.96%), food waste (21.29%), grass and wood (13.32%), and paper (11.64%).

Offices: Paper and food waste accounted for the largest parts, followed by plastic, miscellaneous, grass and wood, metals, textile, rubber and leather, ceramic, and glass. The large generation rate of food waste was partly caused by the discharge from residents (security staff, drivers) living in the office. Paper and plastic have high potential for recycling and reducing of total waste generated from these sources.

Hotels: Food waste accounted for the largest part in the total general waste and recyclable waste, followed by plastic and paper (excluding "guest house" category). These large components have high potential for recycling and reducing by composting and recycling options for paper and plastic waste.

Restaurants: Food waste accounted for high proportion in total general waste (more than 50%), especially more than 75% in "beverage" and "vendor" categories. Paper and plastic were the second largest components. However, miscellaneous accounted for large part in "restaurants" (for large scale and family scale); the possible reason was the fossil coal used for cooking in these restaurants; this coal caused large discharge amount by coal ash with high density.

Market and supermarket: Kiosks in market were also classified into 12 categories. The average composition of market showed that food waste accounted for the largest part in the total general waste, followed by paper, plastic, grass and wood.

Household with business: The waste compositions in various business categories of households with business sector were considered by 4 types of business: manufacturing industries, sale/repair of automobiles, wholesale/retail, and other services; the physical composition varied greatly among four types as presented in Table 4.

Table 5 Correlation analysis of waste generation (kg/day) and relevant factors (\star)

Cate	egory	Sub-category	General	Recyclable	Food residues	Garden	Total
		(1) School/class/office					
	sity	Number of Students/pupils	0.738***	0.655**		0.689***	0.746***
	ers/ers	Number of Class	0.754***	0.612**		0.567**	0.746***
	Jniv n se	Number of Classrooms	0.706***	0.619**		0.739***	0.758***
	Schools/ University/ Education service	(2) Canteen (food stall)					
ste	ool	Number of Students/pupils	0.603**	0.652**	-		-
×a.	Sch	Number of Class	0.699**	0.742***	-		-
ਫ਼	3 1	Number of Classrooms	0.517*	0.669**	-		=
tion	are	Number of beds	0.988***	-	-	-	0.969***
Institutional waste	lthc	Number of staff	0.986***	-	-	-	0.964***
Ins	Healthcare	Number of patients	0.983***	-	-	-	0.957***
		Number of rooms	0.441**	-		-	-
	SS	Number of staff	0.526***	-		0.496**	0.420**
	Offices	Land area (m ²)	0.395*	-		0.647***	0.487**
	Õ	Floor area (m ²)	0.744***	-		0.977***	0.798***
		Garden area (m ²)	0.863***	-		0.955***	0.786**
		Number of workers	0.907***	0.752***	0.913***	0.485**	0.916***
		Floor area (m ²)	0.441*	0.622**	0.585**	0.264	0.522*
	Hotel	Number of rooms	0.803***	0.670***	0.855***	0.418**	0.834***
	Нс	Number of beds	0.911***	0.678***	0.931***	0.441**	0.923***
ste		Number of guest	0.673***	0.384***	0.693***	0.328***	0.713***
×a		Net-sales	0.772***	0.536***	0.682***	-	0.775***
ia	Ħ	Number of total staff	0.645***	0.283**	0.479***	-	0.668***
Commercial waste	Restau -rant	Number of tables	0.817***	0.222*	0.266*	0.318**	0.612***
ш	R -r	Number of chairs	0.816***	0.242*	0.293**	0.299**	0.651***
<u>ō</u>	Marke	et and supermarket	NA	NA	NA	NA	NA
	h ss	(1) Business facilities					· · · · · · · · · · · · · · · · · · ·
	wit	Number of staff	0.386***	-	-	-	0.375***
	HH with business	(2) Household					
	F d	Household size	0.308***	-		0.173*	0.204*

 $^{^{(\}star)}$ Correlation analysis using Pearson correlation (2-tailed) * p < 0.05 ** p < 0.01 *** p < 0.001 NA: Not available

Relevant factors influencing waste generation

The authors analyzed the correlations between the generation rates and the relevant factors such as business scale indicators, household size, and net-sales. The analyses were implemented by 4 waste types and total: general waste, recyclable waste, food residues, garden waste, and total waste. The results of correlation analyses were presented in Table 5. The positive significant correlations were found in many subcategories of the commercial and institutional sectors to relevant factors. Among 5 segments of waste type, the authors found numerous significant correlations in the waste generation rate for general waste and total waste, followed by recyclable waste, garden waste, and food residues.

CONCLUSION AND RECOMMENDATION

The major focus of this study was to estimate the generation and characteristic of waste generated from the commercial and institutional sectors. The waste generation rate (kg/unit/day) was discussed by business category, business scale indicators. The physical compositions were also analyzed and estimated. The interrelationships among the waste generation, the business category and business scale were analyzed.

This is the first step for developing predictive models. Further studies are necessary in consideration of a deep and wide analysis of relevant factors and levels. Through these studies, it would be possible to develop predictive models on commercial and institutional waste generation, and they will support the waste authorities for prediction, planning, and integrated solid waste management.

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