Composition and Generation Rate of Household Solid Waste: Reuse and Recycling Ability

A case study in District 1st, Ho Chi Minh City, Vietnam

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***Abstract*-Research result shows that in Ho Chi Minh City, household waste generation rate is in the range of 0.53 – 0.63 kg/capita/day (2.1 – 2.5 kg/household/day). After separated into two components, food waste (FW) and remaining wastes, each component becomes *"cleaner"*. Food waste consists of 80.1 – 90.0% of food refuse, whereas in the composition of remaining wastes, recyclable materials consist of 12.2 – 18.0%, combustible waste for heat recovery accounts for 40.1 – 50.0%. At present, household solid waste is holding about 50% of total municipal solid waste in the city. Therefore, the success in solid waste separation at sources will assist in shifting a remarkable amount of *"waste"* into *"recyclable materials"*, and significantly affects the efficiency of other processes of municipal solid waste management system in Ho Chi Minh City.**

Keywords- Household Solid Waste; Waste Separation at Source; Reuse and Recycling

I. INTRODUCTION

Ho Chi Minh City is a mega city, ranking second for area in Vietnam (2,095 km^2 in comparison with Ha Noi – 3,325 km^2), the most populous city in Vietnam (having a population of about 10 million), and ranks the first for socioeconomic development [1]. With 2 million households (villa, town house and apartment building), 10 thousands restaurants, hotels – guesthouses, enterprises, and thousands of training organizations (senior high/high school, junior college, university, institute, and research center,…), hundreds of medical centers, more than 10 thousand clinics, and about 12 thousand industrial enterprises (belonging and not belonging to industrial clusters/zones or export processing zones), etc, the total daily waste generation (not including wasted sludge) in Ho Chi Minh is 10,000 – 11,000 tons [2]. Among which, the number of municipal/household solid waste generated from residential areas, commercial areas, organizations, schools, offices, industrial enterprises (cafeteria and office), non-infected medical centers (cafeteria, office and sickroom) is about 9,000 tons/day. With the rate of increase in quantity of about 6 – 8% per year [3, 4], municipal solid waste is of primary concern to environment.

Municipal solid waste (MSW) management systems are becoming more complex in many countries, with movement from landfill-based systems to resource-recovery-based solutions [5]. In addition, the waste sector is a significant contributor to GHGs emissions and is accountable for approximately 5% of the global greenhouse budget [6]. The majority of these emissions are a result of landfills, which remains the primary waste disposal strategy globally [7]. It is indispensable for characterization of municipal solid waste due to the need to estimate material recovery potential, to identify sources of component generation, to facilitate design of processing equipment and to estimate physical, chemical, and thermal properties of waste [8, 9]. Many literature reviews have been carried out to isolate waste composition, physical and chemical characteristics, and its potential for recycling [9, 10]; to identify correlations between household solid waste quantities and characteristics and relevant socioeconomic factors [11-15], and the results showed that household solid waste and its composition were varied among countries. In addition, mathematical models have been proposed and applied to simulation of municipal solid waste management system, analyzing the recovery of recyclable components and solid waste generation. In Vietnam, data on waste flows and city and national level was insufficiently, and statistic information on waste grown in cities of Vietnam for basic researches, planning, and management is a requirement [16]. Besides, there are few researches performed to study the solid waste composition in Vietnam, such as a study to assess the possibility of composting organic solid waste in Da Nang city performed by Byer [17]; a study on household solid waste composition and its characteristic in a Mekong Delta city, Vietnam by Nguyen Phuc Thanh in 2010 [16]. However, the details about municipal solid waste in Ho Chi Minh City are still limited. In the City, practical performance of municipal solid waste treatment/recycling facilities (sanitary landfill, composting, recycling from different portion of waste) shows inefficiency and faces problems since solid waste has not been well separated at sources, and it is still mixed with other hazardous components generated during daily activities [18]. In order to enhance efficiency of waste recycling activities, waste separation at source emerges as an approach for dealing with the mentioned issues.

To evaluate the ability to recover and reuse solid waste generated from households in residential area when deploying waste separation at source programe, a pilot study is conducted in Ben Nghe ward, district 1, Ho Chi Minh City. The studied area is selected based on the following criteria: firstly, waste collection is conducted by the Public Service Company, because it is easier to contact and train waste collectors to collect separated wastes from households in this area than other areas where

waste is collected by both public and private sectors. Secondly, the demonstration program in this area is supported by local authority. Lastly, higher cultural standards of people living in the studied area make the training for solid waste separation at household become feasible. Lastly, there is difference in economic conditions among residential quarters in Ho Chi Minh. The study aimes to determine composition of separated solid waste and its generation rate from households which is a basic for selecting suitable technologies to recycle household solid waste and determining priority in action plan of solid waste management of the City. Moreover, the research results also help in assessing the involvement of waste generators (households, restaurants…) in waste separation program. In order to obtain such core objective, the following research activities are carried out: (1) surveying and determining composition and household waste generation rate and (2) evaluating the potential for recovering and recycling household solid waste after separated at sources and possibilites to gain other benefits with respected to economic, social, and environment.

II. METHODOLOGY

90 households located in Ben Nghe Ward, District 1, Ho Chi Minh City are selected to conduct the survey. Before launching the program, all participants are trained to differentiate between *food waste* and *other waste*, to understand why do they have to separate waste and store them into different bags, and give the right solid waste bags to the right waste collectors. Generally, there are 3 types of waste generated at houses, organic, recyclable, and remaining waste. However, before being collected, recyclable materials are usually sold to junk buyers by household. As a result, the waste generated at household is only organic waste and remaining waste. Hence, each selected household is provided with 2 sample bags/day, green bag for food waste and red bag for other wastes. Samples were collected from house to house daily (Fig. 1).

Fig. 1 Collecting and characterizing the composition and quantity of separated waste components from households

Research team derived waste from these pushing carts to identify composition and generation rate since August 15th, 2013 to December 5th, 2013. Sorted-at-house waste sample from each household is analyzed manually. Each component is sorted and weighted separately by 100 kg-scale with the precise of ± 100 – 300 g. The ratio of each component to total collected waste measured daily determines the composition of waste.

III. RESULT OF WASTE SEPARATION AT SOURCES ACTIVITY

A. Components of Separated Household Waste and Recycling Potential

The total amount of daily collected waste ranged from 100 to 250 kg. Analyzed results of solid waste composition from the pushing cart collecting house separated food waste indicates that the separated food waste component is still blended with impurities (non-food waste components) which are: (1) plastic bags (1 bag contains household waste and other bags contains other wastes dischagred together with food waste bags); (2) milk containers; (3) other plastics (unsued baskets, vessels, etc.); (4) ash, ceramic, and (5) other wastes, combustible nonrecyclable waste includingdisposable diaper, sanitary napkin, clothes, rags, instant dishes, yogurt container,… (Table 1).

TABLE 1COMPOSITION OF FOOD WASTE COMPONENT

Composition	Percentage (% wet weight)		
	Range	Typical value (highest frequency)	Mean value
Food refuse	64.3-98.3	80.1-90.0	81.6
Biodegradable food remnant	53.7-88.2	60.1-70.0	68.8
Coconut shell	0.0-12.4	3.1-4.0	3.3
Cow bone	0.0-16.7	0.0-1.0	4.6
Shell/bivalve	0.0-18.9	0.0-5.0	4.9
Plastic bags	0.0-7.4	4.1-6.0	4.9
Clear bags	0.0-3.4	1.1-2.0	1.9
Color bags	0.0-4.9	2.1-3.0	2.9
Plastic	0.0-6.6	< 1	1.3
Milk container	0.0-1.0	0.0-0.1	0.1
Ash, ceramic	0.0-18.1	0.0-1.0	0.7
Incinerable waste for heat recovery	0.0-25.2	10.1-15.0	11.0

Among which, biodegradable food remnant and other hardly degradable food waste (accounted for 80.1 – 90.0%), which are called as food refuse, are the largest portion of waste stream, followed by combustible nonrecyclable waste (accounts for 10.1 – 15.0%). Depending on the willing of participated households to classify waste at source, compositions of separated food waste varies day by day the survey period (Fig. 2).

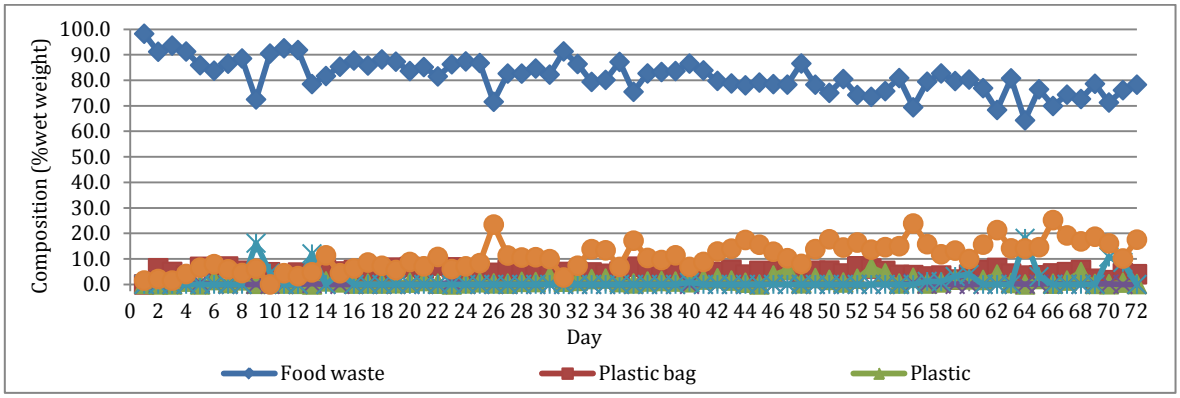

Fig. 2 Waste composition of pushing cart collecting food waste which was separated from 90 households at Ben Nghe Ward, District 1, HCMC

Analyzed results of compositions from the pushing cart collecting food waste in 72 days provides that food refuse consisted of up to 64 – 98% and the rest is the impurities as mentioned. During the survey's period, the composition of food refuse accounts for 80.1 – 90.0% (the highest frequency during 72 daysof the survey) (Fig. 3).

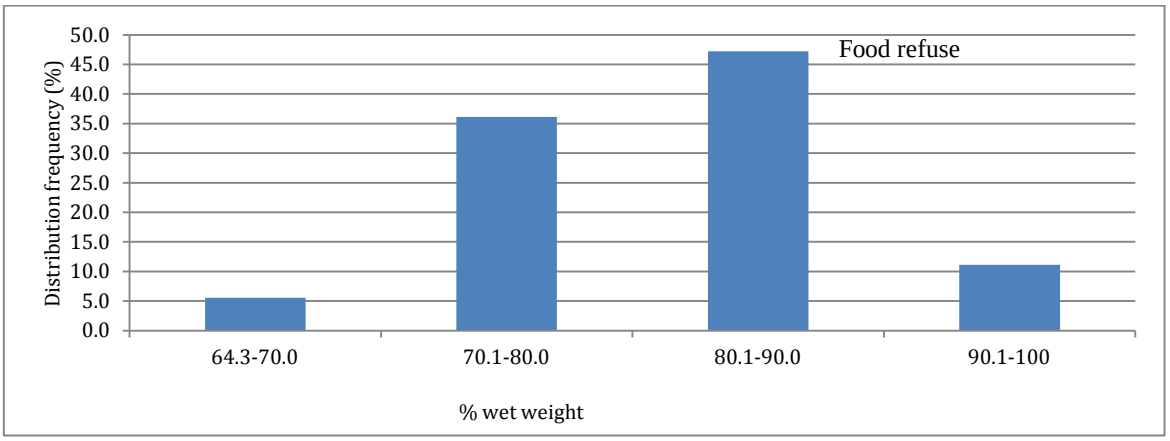

Fig. 3 Distribution frequency of ratio of food refuse in pushing cart collecting household food waste

Fig. 4 gives information about the components of food refuse which are biodegradable food remnants, coconut shell, cow bone, shell/bivalve. Hence, if food waste is reused as a biomass source for composting or biogas recovery and electric generation, the elimination of cow bone, shell/bivalve, etc is important. The fraction which can be reused as material for recyclying by biological methods is mainly biodegradable food remnant which consists up to 53.7 – 88.2% (wet weight). During 72-day survey, this value normally holds 60.1 –70.0% (Fig. 5).

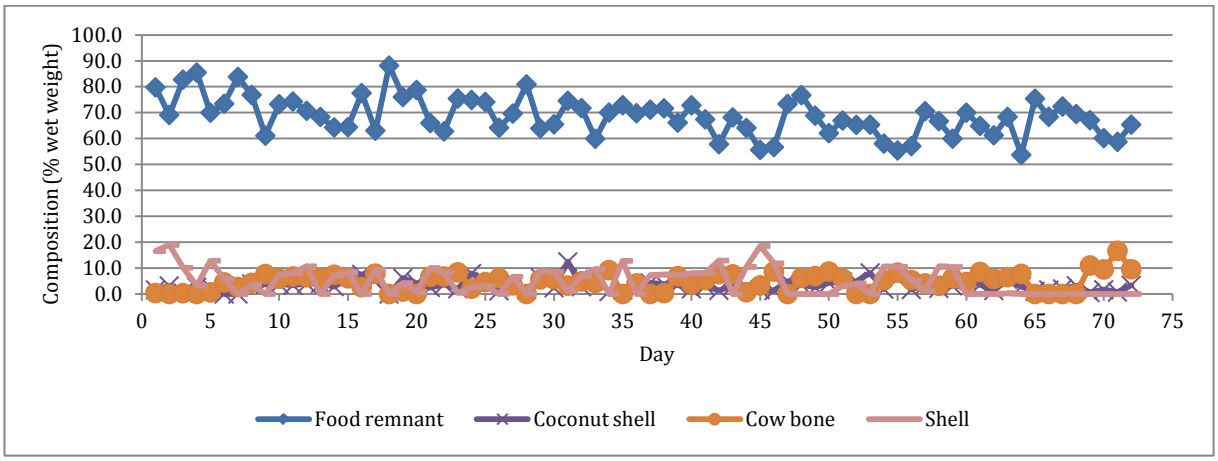

Fig. 4 Components of household separated food refuse

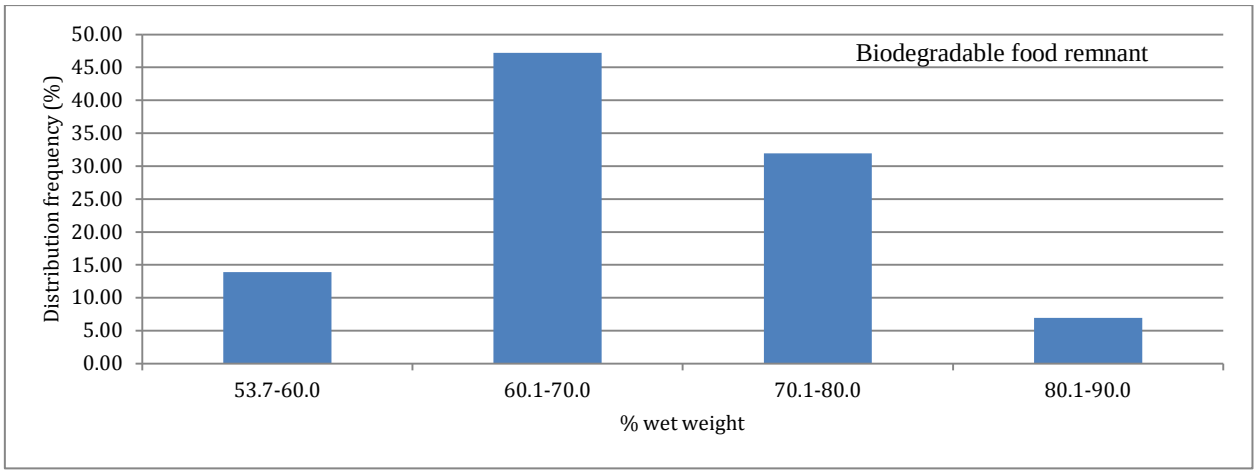

Fig. 5 Distribution frequency of ratio of biodegradable food remnant in pushing cart collecting household food waste

Together with food refuse, waste gathered by the food waste pushing cart still lefts some valuable materials as plastic bags, plastic, and combustible waste, among which, plastic bags (clear and color bags) [Fig. 6] and plastic accounts for the highest percentage in the waste component. Normally, color plastic bags consist of 2.1 – 3.0% and clearplastic bags are only about half of that value (1.1 – 2.0%) (Figs. 7 and 8), while buying price of color bags at junk stores is only 1/5 that of washed clearplastic bags (1,000 VND/kg of color bag and 5,000 VND/kg of color bag).

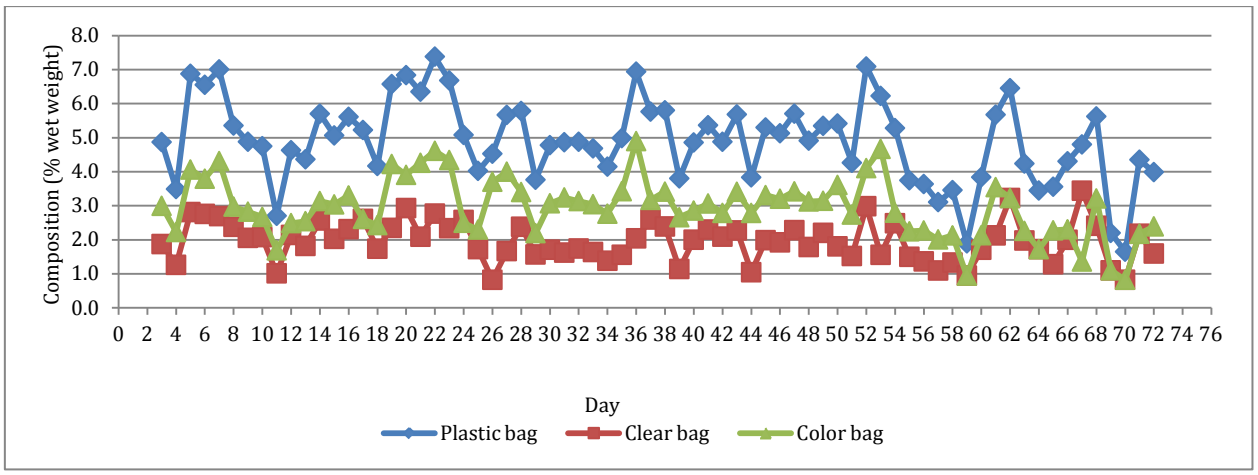

Fig. 6 Percentage of plastic bags in the household separated food waste

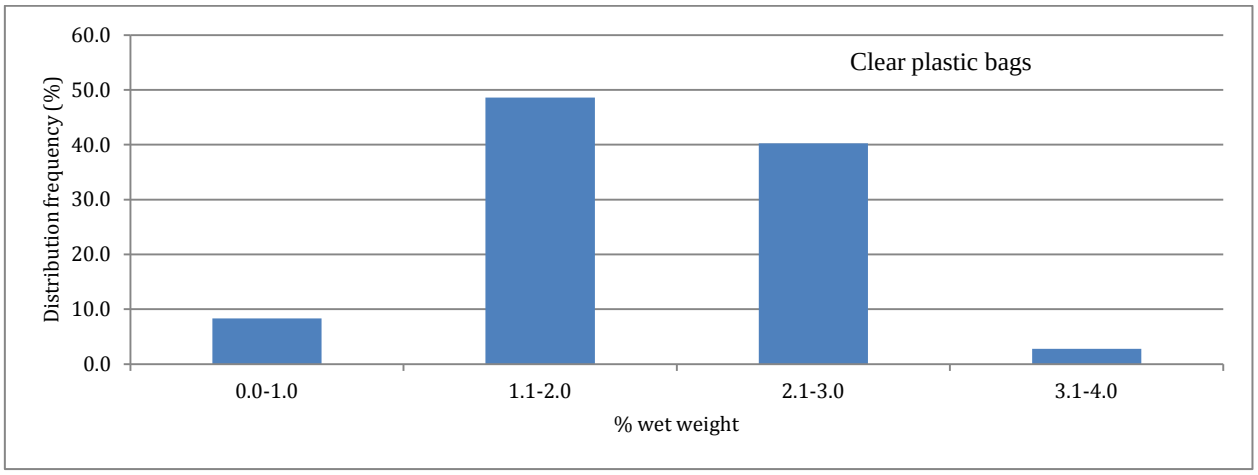

Fig. 7 Distribution frequency of ratio of clear plastic bag fraction in pushing cart collecting food waste

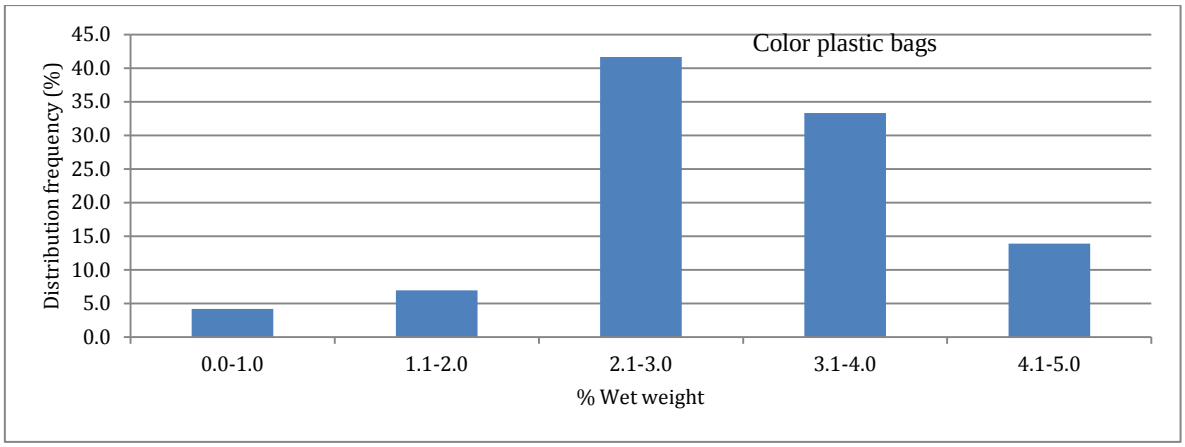

Fig. 8 Distribution frequency of ratio of color plastic bag fraction in pushing cart collecting food waste

Plastic (including PET bottles, baskets, plastic vessel,…) in the separated household food waste consists of less than 1% to 6.6%, in which, the typical value is less than 1% (Fig. 9). Milk containers, ash, and ceramic emerge unsually in food waste bags. The rest accounting for the remarkable component is combustible nonrecyclable waste (such as instant dishes, yogurt containers, disposable diaper, sanitary napkin, clothes, rags, etc). Its ratio ranges from 0.0 – 25.0% (wet weight) with the typical value of 10.1 – 15.0% (Fig. 10).

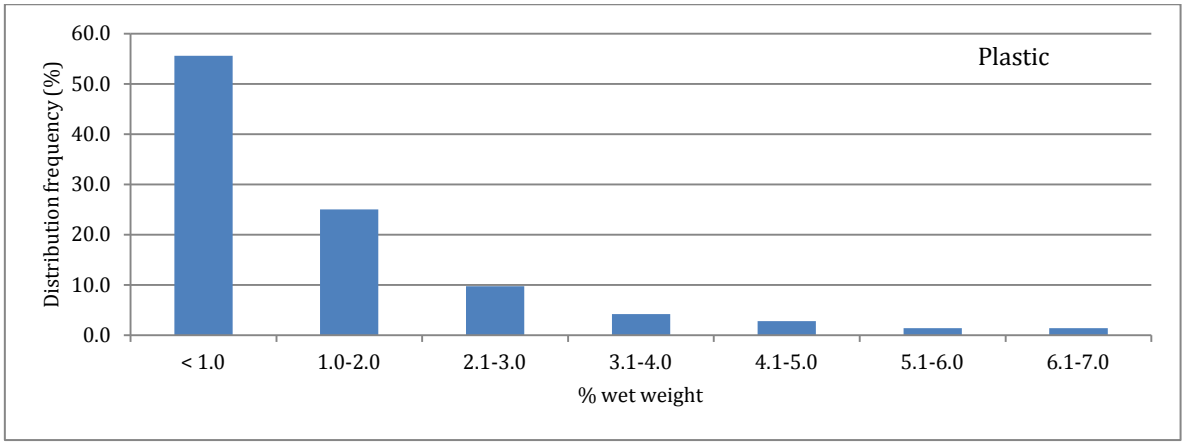

Fig. 9 Distribution frequency of ratio of plastic fraction in the pushing cart collecting household food waste

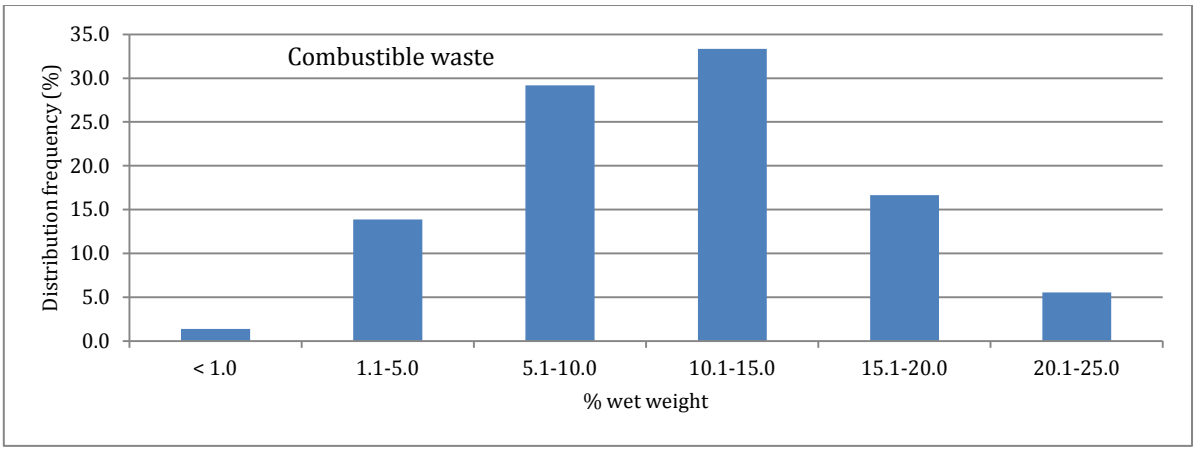

Fig. 10 Distribution frequency of ratio of combustible waste in the pushing cart collecting household food waste

Hence, if household waste separation program is launched, portion of waste picked from pushing cart collecting food waste will comprise a large amount of food refuse (80.1 – 90.0%, average 81.65%), in which, biodegradable food remnant holds 60.1 – 70.0% (average value of 68.8%). Plastic bags and plastic can be accumulated for recyclying. The combustible nonrecyclable waste can be incinerated and recovered heat. Composting or biogas recovery from biodegradable food remnant are feasible option.

B. Waste Composition of Pushingcart Collecting Other Wastes and Its Recyclable Potential

The result indicates that waste in a pushing cart collecting other wastes (Fig. 11) which is separated from households has a composition similar to that of the food waste mentioned above. However, the ratio of these fractions has different correlation compared to that of the food waste. The combustible nonrecyclable waste obtains the highest ratio (average value of 44.4%, and typical value of 40.1 – 50.0%), followed by food waste (average value of 34.7%, typical value of 30.1 – 40.0%). Recyclable materials are mostly plastic bottles (average of 9.2%, typical value of 6.1 – 9.0%), plastic bags (average value of both color and clearplastic bags is 8.55%, typical value of 6.1 – 9.0%). Milk containers, ash, ceramic account for 0.2% (Table 2). Valuable materials such asaluminum cans, metal, steel, and copper were sorted and sold for scavengers or salvaged by scavengers.

Fig. 11Waste materials in pushing cart collecting other wastes separated by households

TABLE 2 COMPOSITION OF OTHER WASTES AFTER SEPARATED AT SOURCES

Composition	Ratio (% wet weight)		
	Range	Typical value	Mean value
Food refuse	10.7-54.2	30.1-40.0	34.7
Biodegradable food remnant	9.5-51.3	20.1-40.0	30.4
Coconut shell	0.0-8.3	0.0-1.0	1.4
Cow bone	0.0-27.1	0.0-1.0	1.9
Shell/bivalve	0.0-8.4	0.0-1.0	0.9
Plastic bag	2.6-14.7	6.1-9.0	8.5
Clear bag	1.2-8.5	3.1-5.0	4.3
Color bag	0.8-8.0	3.1-5.0	4.3
Plastic	1.1-24.7	6.1-9.0	9.2
Milk container	0.0-2.5	0.0-1.0	0.2
Ash, ceramic	0.0-2.8	0.0-1.0	0.2
Combustible waste for heat recovery	0.0-64.1	40.1-50.0	44.4

C. Household Waste Generation Rate and Possibility to Recover and Recyclying Waste

By combining solid waste collected daily in the food waste pushing cart with the other waste pushing cart, it is found from 1-month survey result that household waste generation rate (in term of kg/household/day) at the study area ranges from 1.7 – 3.0 kg/house/day, with the mean value of 2.4 kg/house/day (Fig. 12), among which, the value occupies the highest frequency ranges from 2.1 – 2.5 kg/house/day (Fig. 13). Hence, in average, for a household of 4 members, the household waste generation rate is about 0.43 – 0.75 kg/person/day, average of 0.6 kg/person/day, and typical value of 0.53 – 0.63 kg/person/day.

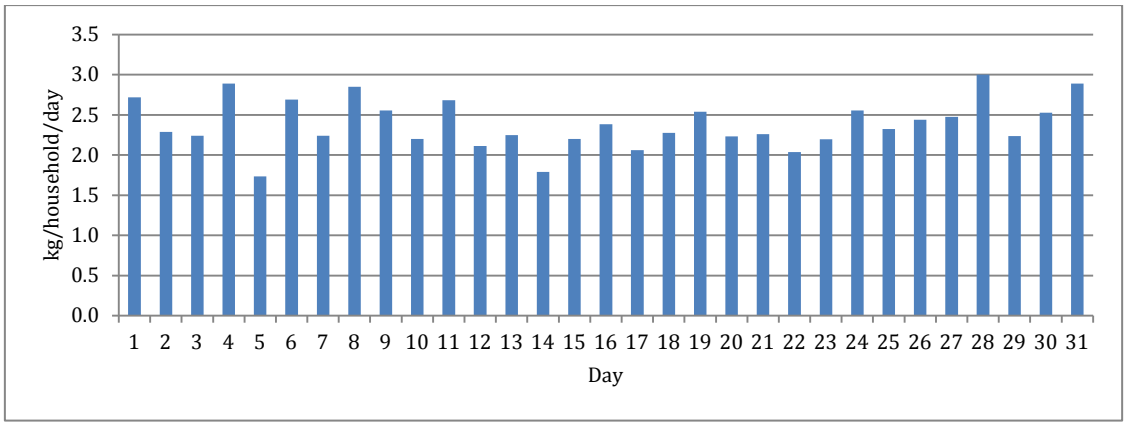

Fig. 12 Household generation waste rate (in term of kg/household/day)

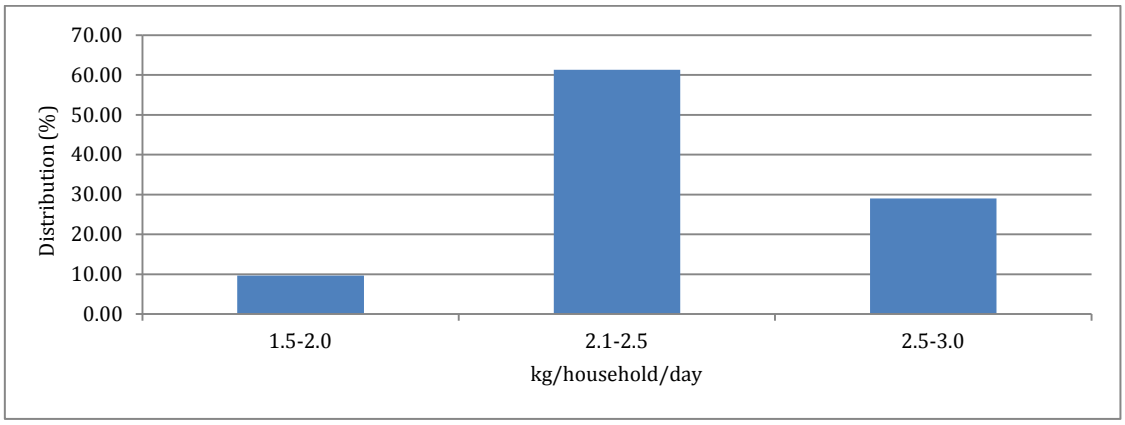

Fig. 13 Distribution frequency of household solid waste generation rate (kg/household/day) – the case of Ben Nghe ward, District 1, HCMC

If calculated for the wastes separated at source, household waste generation rate of the food waste and other wastes ranges from 0.31-0.40 kg/person/day và 0.11-0.20 kg/person/day (typical value) (Fig. 14).

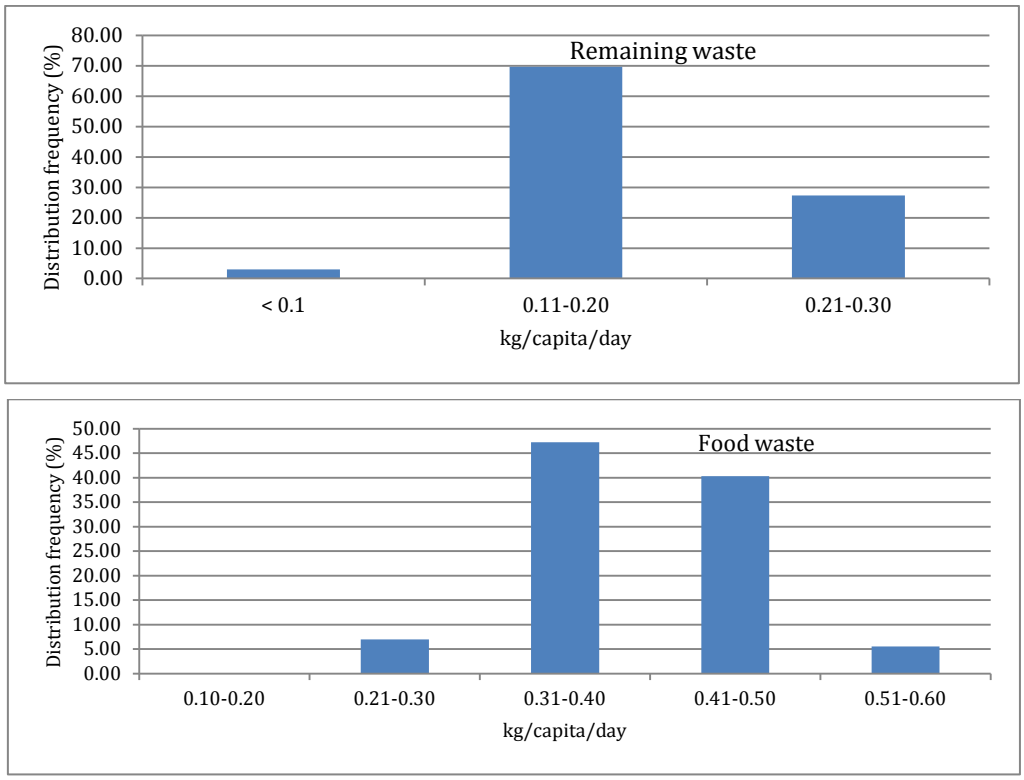

Fig. 14 Distribution frequency of solid waste generation rate of food waste and other wastes (in term of kg/capita/day)

With the compositions of separated solid waste from households as presented above, if solid waste separation at source activity is done properly, the amount of "clean" and recyclable materials (not including portions of waste separated and sold by household or salvaged buy scavenger) can be estimated as indicated in Table 3.

TABLE 3 ESTIMATING QUANTITY OF CLEAN AND RECYCLABLE MATERIAL

Collected material	Waste generation rate	Ratio in waste	Other waste generation waste	Ratio in other waste generation waste	Quantity
	(kg/person/day)	(%)	(kg/person/day)	(%)	(kg/person/day)
Biomass	0.31 – 0.4	68.8	0.11 – 0.20	30.4	0.25 – 0.34
Clean plastic bags		1.9		4.3	10.6 – 16.2
Color plastic bags		2.9		4.3	13.7 – 20.2
Plastic		1.3		9.2	14.2 – 23.6
Milk container		0.1		0.2	0.53 – 0.80
Combustible waste		11.0		44.4	82.9 – 132.8

Thus, with the current population of 10,000,000 in Ho Chi Minh, if solid waste separation at source is peformed perfectly, estimation based only on solid waste generated from households provides that the City can daily recovery about 2.09 – 3.38 billionsVND from collected plastic bags, plastic, and milk containers (Table 4).

TABLE 4 ESTIMATING QUANTITY AND ECONOMIC VALUE RECOVERING FROM SEPARATED WASTE IF SOLID WASTE SEPARATION AT SOURCE IS SUCCESSFULLY APPLYING IN HO CHI MINH CITY

Collected material	Quantity		Unit (VND/kg)	Price (million VND/day)
	kg/person/day	ton/day		
Biomass	0.25-0.34	2,500-3,400	-	
Clean bag	(10.6-16.2) x 10^{-3}	106-162	5,000	530-810
Color plastic bag	(13.7-20.2) x 10^{-3}	137-202	1,000	137-202
Plastic	(14.2-23.6) x 10^{-3}	142-236	10,000	1,420-2,360
Milk container	(0.53-0.8) x 10^{-3}	5-8	1,000	5.3-8.0
Combustible waste for heat recovery	0.083-0.133	829-1,328	-	
Total		3,719-5,336		2,092-3,380

In addition, the City can also gain benefit from "pure" waste streams via composting or biogas recovery and electric generation. The other wastes can be incinerated for heat recovery. If all waste generation sources in Ho Chi Minh City (schools, offices, restaurants, hotels, commercial areas, markets, supermarkets, clinics, enterprises, public areas) conduct solid waste separateion at source properly, these above values would be increase significantly, as a result of waste to landfill will be reduced significantly.

IV. CONCLUSIONS AND RECOMMENDATIONS

The demonstration study indicates that household solid waste generation rate in Ho Chi Minh City is in the range of 2.1 – 2.5 kg/household/day or 0.53 – 0.63 kg/person/day accounted for 50% of total waste generated in whole City, and higher than that in Can Tho City, 0.283 kg/person/day [16]. A comparison among Ho Chi Minh City and other cities shows that daily per capita household waste generation is similar to Abuja, Nigeria (0.634 kg/person/day) and Chihuahua City, Mexico (0.676 kg/person/day). Hence, the success of solid waste separation at source program will help in moving a remarkable amount waste into recyclable material, and influence the success of the program launched for separating waste of other sources. The measuring result provides that after separated into two components, the potential for recovering *"pure"* biomass material from household solid waste for composting or biogas recovery and electric generation is considerable. This also helps in reducing the demand for landfilling (about 2,500 – 3,400 tons food refuse/day). Recyclable materials contribute to economic value (only from selling wasted materials) of about 2,092 – 3,380 million VND/day which does not include recyclable materials sold by households and heat energy recovered from incinerating high calorific value wastes. The study result is one of the evidences of the need for launching solid waste separation at source program to solve existing environmental problems caused by waste and more important to convert "waste" into "valuable materials".

The study is carried out within two months in a small residential area of 90 households so it does not cover all factors that may affect changes of solid waste composition and generation rate from households. Therefore, it is recommended to repeat the survey and conduct the research in larger residential area.

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