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Possibilities and Challengies to Approach Zero-Disposal of Biodegradable Organic Domestic Solid Waste in Ho Chi Minh City, Vietnam

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Abstract

By summarizing current situation of municipal solid waste management system of HCMC and analyzing results of researches, demonstration studies and projects, the paper focus on evaluating possibilities and challenges of practical applications of solid waste separation at source and getting pure biodegradable organic materials from domestic solid waste for further reuse and recycling. Composting as well as biogas recovery and electricity generation either from anaerobic digestion plant or mono-waste landfill (receiving only separated food waste) seems to be a solution for approaching zero-disposal of biodegradable organic domestic solid waste in HCMC. Possibilities and challenges to reach this target has been discussed in this paper.

Key words: *Municipal solid waste; zero-disposal; solid waste separation at source, biogas, composting, landfilling.*

1. Introduction

The paper focus on the solid waste management system in HCMC and analyses the possibilities and challenges toapproach zero-disposal of organic biodegradable domestic solid waste in Ho Chi Minh City. It is important in its own right as a baseline study about the MSW management developments in a fast-growing South-east Asian City. This analysis is structured according to the integrated solid waste management (ISWM) concept. It is designed as a diagnostic tool for decision-makers to look in a systematic way at their waste problems. The concept is based on the experiences from the Urban Waste Expertise Program (1995 - 2001) carried out by WASTE advisers from the Netherlands (Van de Klundert and Anschuetz 2001). Before proceeding to the ISWM analysis, important information about HCMC is given.

Ho Chi Minh City is a mega city, ranking second for area in Vietnam (2,095 km^2 in comparison with Hanoi – 3,325 km^2), the most populous city in Vietnam (having a population of about 10 million), and ranks the first for socioeconomic development (Nguyen Trung Viet, 2013). Belonging to the Southern key economic zone of Viet Nam and being the driving force in the region, HCMC has a strong potential for economic expansion, commercial services and social and cultural developments. However, HCMC is facing serious urban and environmental management problems, of which MSW management is one of the biggest. Therefore, authorities of HCMC are most interested in and prepared to invest in MSW solutions.

With 2 million of households (villa, town house, and apartment building), 10 thousands of 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 (HCMC DONRE, 2013). 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 (Nguyen Trung Viet, 2012; HCMC DONRE, 2012; Truong et al., 2015), municipal solid waste is of primary concern to environment.

The city has a tropical wet climate with an average humidity of 75%. The year has two seasons: the rainy and the dry season. The rainy season provides most of the annual rain of about 1,800 millimetres on average (about 150 rainy days per year). The average temperature is 28°C. The temperature sometimes reaches 39°C, while the lowest temperature may be below 16°C (Meteorology and Hydrology Station, 2013). In this climate, organic fraction of MSW can easily degrade causing negative effects for the environment due to odour, leachate, spreading of pathogens and related factors. However, this climate is suitable for biological treatment of the organic fraction of MSW.

The environmental law of Viet Nam was set up in 1999 and refined in 2005. Taking this law as point of departure, the Vietnamese government supports the environmental management system with at least 1% of GDP[1]. Similarly, HCMC is putting more and more efforts in environmental protection. One of the impression example is that the expenditure of HCMC on solid waste management, which has increased from 902 billion VND in 2007 to 1,392

[1]In the "Environmental Protection Law" there are several articles on environmental protection. For example, Legislation no. 52/2005/QH11 dated 29/12/2005 stipulates the generalities of solid waste management. Decree no. 80/2006/ND-CP date 9/8/2006 stipulates and gives guidelines to implement some of the articles in the Environmental Protection Law with 25 articles and 2 references. Decree no. 21/2008/ND-CP date 28/2/2008 modifies and adds some articles in Decree no. 80/2006/ND-CP.

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billion VND in 2008 (54% increase in one year)[2](HCMC DONRE, 2009). The environmental management strategy of HCMC (HCMC DONRE, 2002), the national environmental protection strategy (Vietnam MONRE, 2004) and the master plan of the MSW management system of HCMC for the period of 2008 - 2020 (HCMC DONRE, 2006) stipulated that MSW had to be treated with modern technologies by 2010 - 2015. The primary aim is to limit the volume of MSW disposed of at landfills.

Whether it is possible to approach zero disposal of at least organic biodegradable domestic solid waste? What opportunities and what challenges to reach this target are the core discussion drawn in this paper.

2. Current situation of municipal solid waste management in Ho Chi Minh city

MSW is collected separated from other types of waste (construction, sediment, hazardous and industrial, and medical waste). It is collected and transported directly or via transfer stations to sanitary landfills or composting plants. The recyclable waste is separated during the collection activities. This is sold to itinerant buyers and then to recycling companies. The major components of this collection system appear in Fig. 1.

2.1 Waste generation

Households and other waste generators do not have standard containers for MSW storage. Currently waste is stored in plastic bags, tins, bamboo containers, etc. Most households, especially those with confined living areas, use plastic bags to store their commingled waste. Offices, schools, etc. have their own type of containers. Markets store their MSW directly on the floor or in containers. Many restaurants have special storage containers of food waste to be utilized a part as animal feed. No separation of MSW takes place at the source; all sorts of MSW are discharged and stored together. However, most households separate the valuable wastes such as cans, plastic, paper, etc., from their domestic waste and sell this to itinerant buyers. Also many individual waste pickers go around to pick up valuable materials from public waste containers or wastebaskets of the households (during the time the wastebaskets are waiting for collection in front of the houses). This activity causes health problems for the waste pickers and has a negative impact on the urban environment. Therefore, in 2009, district 6 of HCMC carried out the demonstration program "solid waste collection on time" to overcome these problems.

[2]Exchange rate: ~ 18,500 VND/USD in December 2009.

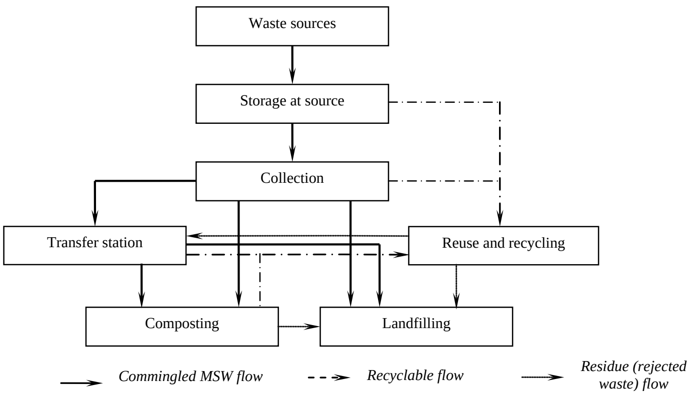

Fig. 1 Municipal solid waste management system in Ho Chi Minh City (Le Thi Kim Oanh, 2012).

The composition of commingled MSW changed since 2002 when the first sanitary landfill, Go Cat, was set up. Since then the construction waste, medical hazardous waste and hazardous industrial waste were collected and treated separately from MSW (HCMC DONRE, 2006). However, the composition of the present commingled MSW is still complex and contains other types of waste, sometimes hazardous, from illegal discharges. Table 1 presents the details of composition of MSW in HCMC.

Table 1 Composition of MSW measured in HCMC

Component	Phuoc Hiep landfill 2007*** (% by wet weight)	Transfer station 2009** (% by wet weight)	PhuocHiep landfill 2014* (% by wet weight)
Organic			
Food wastes	38.10	85.81	61.3-68.9
Paper	1.70	4.18	3.2-4.2
Cardboard		0.66	nd
Plastics and nylon	30.40	5.70	16.1-17.3
Textiles	10.30	0.83	4.1-6.4
Tampon/napkin	nd	nd	3.0-4.1
Rubber	2.40	0.12	0.4-1.6
Leather	0.20	0.07	
Yard wastes	13.30	0.38	
Wood	0.50	0.34	0.5-0.6
Misc. organics	0.60	0.36	0.1-1.4
Inorganic			
Tin cans	nd	0.37	nd
Aluminum	nd	nd	nd
Other metal	1.00	0.02	0.2-0.3
Glass	0.30	0.24	1.4-2.2
Dirt, ash, etc.	1.20	0.99	
Total	**100**	**100**	**100**

Note: nd: no data.
*Sources: * Nguyen Trung Viet et al., (2014), **CENTEMA (2009) and *** DONRE HCMC (2009).*

In summary the critical points related to the waste generation at sources are: high amount of commingled MSW generated, no standard containers for MSW storage, limited place at households for placing containers, high amount of leachate and malodour generation; lack of public awareness, and high amount of recyclable waste sorted at source.

2.2 Waste collection

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MSW is transferred from discharge sources to gathering points using handcarts with a loading volume of 660 litters. From there, a truck transports the waste to transfer stations or directly to landfills or composting plants. Depending on the length and quality of the transport routes, the capacity of the trucks can be selected. MSW from sources along main streets is transported directly by big trucks (7-12 tons/truck) to landfills or composting plants or by small trucks (2 - 4 tons/truck) to transfer stations. The collection equipment is not standardized. This is especially true for handcarts of informal private collectors. The handcart of informal collectors is self-designed and not adapted to the requirements of good hygiene. The volume of this handcart is usually much higher than 660 litters to maximize the amount of carried wastes. Safety facilities such as gloves, hats, and clothes are not strictly required and often not worn. The MSW collection system also collects bulky wastes such as old tables, chairs, beds, etc.

Regarding collection of MSW in HCMC, critical points are: old and damaged narrow transport pathways in the dense areas; non-standardized collection facilities and lack of safety facilities; lack of collection skills and the activity of separating recyclable wastes causes delay in collection time and pollution; lack of monitoring and control; non-integrated management.

2.3 Waste transfer and transportation system

There are three modes of MSW collection and transport (Fig. 2).

Mode 1. MSW is collected and transported to gathering-points with handcarts. Subsequently, the MSW is loaded into small trucks (2 - 4 ton capacity) and moved to the transfer station (standard transfer stations, rendezvous points, transfer points for compressing). From there, big garbage compactor trucks (7- 12 ton capacity) transport the MSW to a sanitary landfills or composting plants.

Mode 2. Handcarts collect and transfer MSW to gathering-points. Subsequently, big garbage compactor trucks (7-12 ton capacity) transport the MSW to a sanitary landfills or composting plants. In mode 2 transfer stations are not used.

Mode 3. MSW is gathered and discharged in street containers with a volume of 240 - 660 litters alongside roads, or the MSW is coming from concentrated sources (supermarkets, commercial centres). The content of the containers is loaded into small trucks and transported to transfer stations or loaded into big garbage compactor trucks and transported directly to a sanitary landfills or composting plants. This mode is particularly used for street-sweeping wastes but also for a considerable quantity of household waste. In mode 3 gathering points are not used.

There are three types of transfer stations in HCMC: (1) open heaps where MSW is discharged on the floor in an open area with or without roof and fence; (2) transfer stations where MSW is stored in a container or on the floor inside; (3) compress transfer stations where MSW is compressed before transport to a landfill or a composting plant. The transport system is complex and inadequate for the following reasons: (1) there are many companies involved in this activity, including CITENCO, 22 public service companies, some cooperatives and some private companies, which are working independently from each other. Therefore, it is difficult to organize and integrate the transport activities and transport routes; (2) inadequate infrastructure, such as narrow and badly paved transport routes, non-standardized collection cars/trucks, lack of gathering-points and transfer stations; (3) a lack of tools, guidelines, regulations to support the transport system; (4) poor management capacity and (5) insufficient funding.

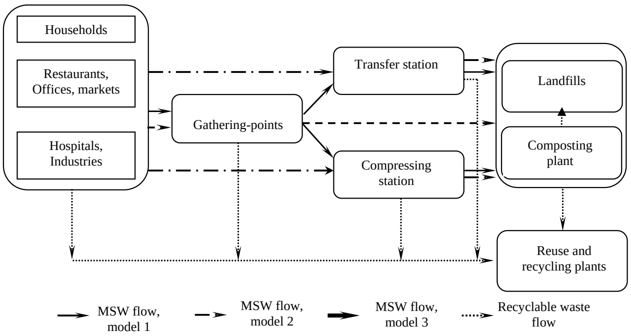

Fig. 2 General diagram of collection and transportation of MSW in Ho Chi Minh City (Le Thi Kim Oanh, 2012).

2.4 Waste reuse and recycling

In a review of MSW treatment practices in HCMC, this section discusses about composting and recycling of valuable materials that are currently applied in HCMC.

Composting

Vietnamese farmers have a long tradition of composting animal manure and agricultural waste at household scale to produce compost for their crops. Large-scale composting of MSW has been developed during the past decades. As early as in 1982, HCMC imported technology from Denmark for the Hoc Mon composting plant. However, the plant was closed soon after start-up as the technology was inadequate for the local MSW. The key problem was the deficient quality of the product, which was due to insufficient separation of unwanted materials from the commingled MSW. Subsequently, Viet Nam imported more installations from Spain (Cau Dien – Ha Noi)[3], New Zealand (Tan Thanh – Ba Ria Vung Tau) and France (Thuy Phuong - Hue and Nam Dinh - Ha Nam). These foreign installations have not been adapted to the typical Vietnamese MSW and had to be closed or operate at low capacity. It has become clear that most foreign technologies must be modified to deal with the Vietnamese MSW. Lately, composting plants with 100% Vietnamese technology were started, such as Thuy Phuong (renewed from old Thuy Phuong plant) and Tan Thanh.

[3] In brackets are the names of cities where the plants are located.

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During the last 10 years, HCMC PC (People Committee of HCMC) has given construction licenses for four composting projects: (1) Vietstar composting plant for 600 ton MSW/day in the first phase, increasing to 1,200 ton MSW/day in the second phase; (2) Earthcare composting plant for 1,500 ton MSW/day; (3) VWS company for 1,000 ton MSW/day and (4) Tam Sinh Nghia composting plant for 1,000 ton MSW/day. Three of these projects are USA based. Only Tam Sinh Nghia is a Vietnamese company. Those composting factories were planned to be operational in 2009 - 2010. If these four composting factories would run at full capacity, not only 100% of the organic MSW in HCMC would be treated to produce compost, but also a part of industrial compostable solid waste, or MSW from the surrounding areas of HCMC, could be treated. However, at the movement April 2015, only the Vietstar project, set up in 2008, has started to run in December 2009 with capacity of 600 ton MSW/day. Tam Sinh Nghia project, set up 2013, has started to run at the end of 2013 with up to now capacity of 100 ton MSW/day. Other two companies are not invested yet. The technology at the Vietstar composting plant is windrow composting. The composted MSW in all Vietnamese plants is commingled waste and therefore the separation process has to take place after transport, which is complex, costly and requires a lot of labour. An abundant component in the waste in Viet Nam is plastics, which needs to be removed before the waste is composted. At Vietstar the plastics are separated, cleaned and processed to raw plastic material, which contribute significantly to the income of the plant.

At the starting phase (2009-2011), Vietstar produces compost as a raw material for others organic fertilizer. Since the beginning of 2012, many MSW composting plants in Viet Nam, for instance the Cau Dien, Nam Dinh and Thuy Phuong plants, produce 2 products (1) raw compost and (2) organic fertilizer based on the quality of their customers. Compost product usually satisfies the Vietnamese standard (10-TCN-526-2002) in terms of heavy metals, organic carbon, and moisture content. However, nitrogen and phosphate concentrations are low and the pH is higher than the required standard. Besides, several aspects, not defined in the standard, point at a less than satisfactory compost quality, such as the presence of injection needles, broken glass, rock, etc.

Recycling

Besides organic waste, which can be recycled to produce compost or biogas, MSW contains other reusable and recyclable materials like plastics, nylon, glass, paper, cardboard, metals and rubber. These are collected at several stages of the collection chain at households, at gathering-points, at transfer stations and during transport and at composting plants.

With its about 10 million inhabitants, 14 industrial zones and about 25,000 small and medium scale enterprises HCMC collects about 1,500 to 1,800 ton recyclable waste per day (HCMC DONRE, 2014). Most of these recyclables are processed by its local reuse and recycling sector. A part of the recyclable waste, like nylon, is exported to China. Depending on the market price, some types of recyclable waste are collected more than others. Additionally, recyclable waste comes from other cities and provinces in the vicinity and is processed in HCMC.

Fig. 3 presents a diagram of waste recycling in HCMC. Recyclable materials (nylon, plastics, wasted papers, glasses, metals) are collected at the sources and sold to the small waste depots. The waste depots further sort the waste prior to reselling it to larger depots or enterprises. Some waste depots with sufficient facilities (space, equipment, labour, etc.) carry out the re-processing step. Most transfer stations function as temporary waste stores and reusable materials are collected there. According to a survey (CENTEMA, 2008 and 2009) on waste composition at the landfills, the percentage of recyclable waste in discharged MSW is still high and the fraction of recyclables in commingled MSW of HCMC has increased in recent years. Thus, it is clear that the efficiency of collecting recyclable wastes could be improved.

Most of the recycling plants in HCMC are small and medium scale. These enterprises have old-fashioned (old and low-tech) often polluting technologies and consume much energy. Moreover, their products are also of low quality. Fortunately, these low quality products still have big markets.

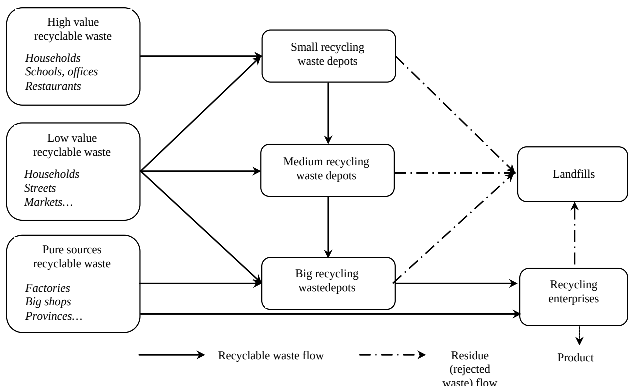

Fig. 3 Diagram of wastes reuse and recycling in Ho Chi Minh City (DONRE, 2006).

The typical issues in the recycling sector in HCMC are: (1) MSW is not separated at source but the recyclable waste is sorted during the collection and at the composting plants; (2) The fraction of recyclable waste is increasing which could lead to higher benefits; (3) The network for recycling activities is large including many stakeholders and not well controlled in terms of environmental protection; (4) Most of recycling plants in HCMC are small and medium scale with old and poor technology; (5) Recycling processes discharge much pollution; and (6) There is a market for recycled products, but the price is low due to low quality.

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2.5 Sanitary landfill

There are presently seven landfills in HCMC: Dong Thanh, Go Cat, Phuoc Hiep 1, Phuoc Hiep 1A, Phuoc Hiep 2, Da Phuoc and Phuoc Hiep 3. Dong Thanh, Go Cat and Phuoc Hiep 1, Phuoc Hiep 1A and Phuoc Hiep 2 were closed in 2002, 2006, 2006, 2007 and 2014, respectively. The landfills of Phuoc Hiep 3 and Da Phuoc are currently in use. All landfills in HCMC are sanitary landfills, except Dong Thanh, which is a controlled dumping site.

In the past at Dong Thanh all types of urban solid wastes including MSW, hospital waste, hazardous waste, industrial waste and construction waste were dumped. Now it is still in use for the disposal of construction waste. As a dumping area, Dong Thanh had no measures against environmental problems except soil covering after each dumping day and applying an enzyme that could abate odour. After closure, Dong Thanh was covered with HDPE (high density polyethylene) and a part of the leachate was being pumped out and treated. In 2002, HCMC started to operate its first sanitary landfill, named Go Cat (DONRE HCMC 2009). A Dutch company has designed, constructed and operated this landfill. The design included dumping cells, a biogas collection system and generators and a leachate treatment system. This landfill is located on soil with geology, suitable for landfill.

Phuoc Hiep 1, 1A, 2 and 3 are located in the same area (Phuoc Hiep – Cu Chi), which is different from Go Cat and Da Phuoc. Local experts designed and constructed Phuoc Hiep 1. Due to lack of experience with construction of landfills on weak soil, many construction and operational problems have occurred, which have caused environmental problems and an increase of the investment and operation costs. Phuoc Hiep 1A is a small sanitary landfill constructed for temporary use during the construction of the Phuoc Hiep 2 landfill. Phuoc Hiep 3 and Da Phuoc are currently in use with a capacity of 3,000 tons/day each. As HCMC lacks of suitable land for landfills, more recently selected sites for landfills and other MSW treatment facilities are located far from the city and situated on geologically weak soil. Phuoc Hiep lies about 48 km and Da Phuoc 24 km from the city center. Therefore, the costs for transport and construction are much higher. According to HCMC DONRE (2006), the construction costs of landfills in geologically weak sites are about twice as high as compared to those in geologically strong areas. The locations of these landfills lead to traffic congestion and pollution along the transport roads as well. The areas for MSW treatment and landfills in HCMC that are still free for future use are located in Phuoc Hiep and Da Phuoc.

Both operational landfills in HCMC are designed as sanitary landfills. However, they face serious environmental problems: inefficient leachate treatment plants cause serious pollution of water reservoirs and groundwater. The latter affects the sources of water supply of HCMC and the areas surrounding the landfills. From 1998 to now, many studies on leachate treatment in Viet Nam have led to improved plant layouts. However, the current leachate treatment plants are not efficient or they are very expensive. Most of them do not reach Vietnamese discharge standards. In addition, the landfills cause air (mainly odours and pathogens) and noise pollution.

3. Possibilities and challenges to approach zero-disposal of biodegradable organic domestic solid waste in HCMC

As mentioned above, biodegradable organic domestic solid waste accounts for about 50% in domestic solid waste. If it is well separated at source, it can be reused as a raw material for further processing instead of sending to landfills as usual. The proposed solution for targeting zero-disposal of biodegradable organic domestic solid waste in HCMC is described in Fig. 4. By applying solid waste separation at sources, it is possible to get pure biodegradable organic materials for further composting or biogas recovering and heat reusing or electric producing. This solution seems not new and is applicable in several countries in the world. However, in HCMC, it is still at the early stage of the whole chain of biodegradable organic solid waste recovery, reuse and recycling. There are still questions on *whether it is possible to following that chain of biodegradable organic solid waste management to achieve zero-disposal of such type of waste? What are difficulties or challenges? Are there other better solutions? And how to put this proposed solution into practice?*

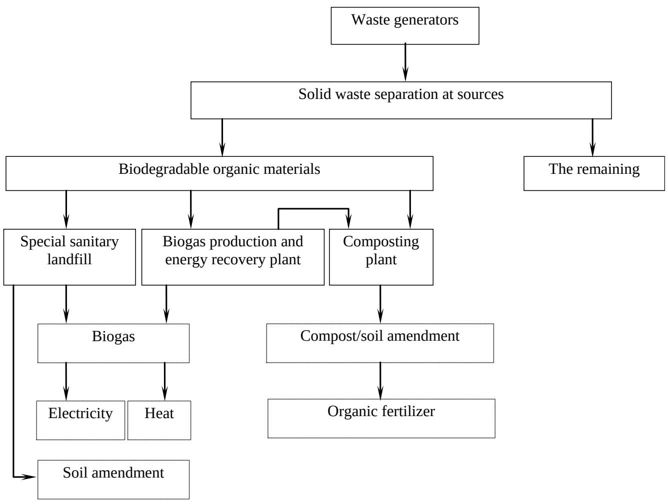

Fig. 4 A proposed solution for reuse and recycling of biodegradable organic domestic solid waste in HCMC.

Several researches, projects have been carried out to evaluate possibilities to put this chain of solid waste management in HCMC into practice.

Possibilities and challenges to recover "pure biomass" from household solid waste

A demonstration study on solid waste separation at source in Ben Nghe Ward, District 1, HCMC with participation of 90 households in two months have shown that (Tran Thi My Dieu et al., 2014) solid waste composition of the push-carts collecting household separated food waste contains

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80.1-90.0% (by wet weight) of food refuse and the remaining is non-food waste components (Table 2).

Table 2 Composition 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***

Source: Tran Thi My Dieu et al., 2014.

Figure 5 shows that the components of separated food refuse include *biodegradable food remnants*, coconut shell, cow bone, and 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 recycling 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%.

The studied result also indicates that waste in a pushing cart collecting *other wastes* 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 (Table 3). Thus, 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 and 0.11-0.20 kg/person/day (typical value), respectively (Table 4).

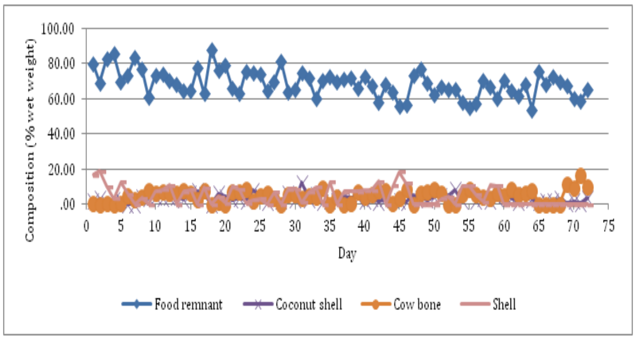

Fig. 5 Components of household separated food refuse (Tran Thi My Dieu et al., 2014).

Table 3 Composition of other waste 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***

Source: Tran Thi My Dieu et al., 2014.

Table 4 Estimating quantity of clean and recyclable material after separating at households

Collected material	Food waste generation rate	Ratio in food waste	Other waste generation rate	Ratio in other waste	Quantity
	(kg/person/ day)	(%)	(kg/person/ day)	(%)	(g/person/ day)
Biomass	0.31 – 0.4	68.8	0.11 – 0.20	30.4	250 – 340
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

Source: Tran Thi My Dieu et al., 2014.

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. Hence, the success of solid waste separation at source program will help in moving a remarkable amount *waste* into *recyclable material*, and influences to 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 of about 2,500 – 3,400 tons food refuse/day.

In 2007, a demonstration program of solid waste separation at the source was carried out at pilot scale in five wards (neighbourhoods) of District 6 of HCMC (HCMC DONRE, 2005f; HCMC DONRE, 2009c). Within this project, the households were given two waste storage containers: one for organic waste (compostable waste) and the other for the rest of the household waste. The results of this program after one and half year were not meeting expectations due to many reasons. These were, among others: (1) the integration among the stakeholders were weak; (2) the public awareness was not sufficient; (3) the lack of regulation/guidelines reduced the efficiency of the activities; (4) the infrastructure for this program was lacking or inadequate, such as a lack of appropriate collection trucks, absence of transfer stations for two different types of MSW, and there was no composting or anaerobic digestion plant to treat the collected organic waste; (5) lack of managerial experience and capacity building; (6) lack of funding. The government became aware that these issues have to be adequately addressed before restarting this program.

So far, demonstration on solid waste separation at source in several districts in HCMC (District 1, 5, 6, 10, Binh Thanh) shows that it seems not difficult to get households participated in the program, but it is still difficult to get "pure" food refuse for composting or biogas production. In the other words, secondary separation at composting or biogas production is still necessary. It seems still need longer time and efforts to really get solid waste separation at source implementation properly.

Possibilities and challenges to produce compost from biodegradable organic domestic solid waste

As mentioned above, besides traditional composting of animal manure and agricultural waste at household scale, large-scale composting of biodegradable organic domestic solid waste has also been developed in HCMC, especially during the last five years. Though the amount of domestic solid waste to be compost is still low, development of Vietstar Composting Plant is a good example for proving possibility to apply this technology in HCMC. In addition, several researches, projects had been carried out to evaluate possibility to apply, to increase capacity and improve quality of compost produced from organic biodegradable domestic solid waste of households, schools, markets, wastewater treatment plants (Nguyen Trung Viet, 2000; Le Thi Kim Oanh et al., 2014; Truong et al., 2015; Nguyen QuocBao and Tran Thi My Dieu, 2015; Vo Tan Phat and Le Thi Kim Oanh, 2015). If based on composition of domestic solid waste of HCMC, it is obviously that composting can be a good choice as it contains high percentage of food refuse (Tran Thi My Dieu et al., 2014), the climate of HCMC is also suitable for biological processes, and a high demand for organic fertilizers/soil conditioners for agricultural and forestry areas.It has been shown that the amount of produced organic fertilizer is small compared to the effective demand and very small compared to the agricultural need (Giac Tam et al. 2006). The grossly insufficient supply of organic carbon causes a strong deterioration of the soils in Viet Nam nowadays.

However, it is also important to know that so far implementation of domestic solid waste composting plants in HCMC is still limited due to high investment and operational costs and low profits, operational problems as a result of high moisture and impurities from the input commingled domestic solid waste and unfamiliarity of farmers with the final compost product. The complicated and lengthy licensing procedure for large-scale plants, lack of details on quality standards for compost and inadequate documentation to certify and assess the quality of compost also harms the attraction of composting plant investment.

Possibilities and challenges to produce biogas and recover energy from organic biodegradable domestic solid waste

The anaerobic digestion technology was applied in Vietnam only for pig manure, not MSW. The investigation on dry anaerobic digestion of MSW conducted in HCMC with a batch system in lab and pilot scale by Kim Oanh et al. (2009) showed that the biogas production reached 59 m^3/ton of an input mixture. Besides, several researches on biogas recovery from organic biodegradable solid waste from markets and food refuse of households using both dry and wet anaerobic digestion carried out by Department of Environmental Technology and Management, Van Lang University for the period of 2013-2015 shows that it is possible to produce about 70-80 m^3 biogas/ton of input material with about 50-60% of methane gas. This amount of biogas generation is not as high as compared to the yields reported in literature. However, it proves that anaerobic digestion is a reasonable technology in HCMC where there is a lack of electricity, especially in the dry season. The advantages of anaerobic digestions could be considered in the following aspects:

- High moisture content of organic biodegradable materials from domestic solid waste;
- It is possible to generate about 80 m^3 biogas/ton of input material and thus about 160 kWh/ton. The digested sludge from anaerobic digestion process can be reused as raw material for composting with production capacity equivalent to 0.25-0.30 ton compost/ton of input material;
- HCMC has experience on electricity production from biogas and connection to the grid via operation of Go Cat landfill. Therefore, the only important step now is to produce sufficient and high quality of biogas. The use of sanitary landfill cells as natural anaerobic digestion by only dumping separated organic biodegradation domestic solid waste may be also simplest solution for biogas recovery and electricity production;
- Regulation of the government support to renewable energy, especially energy generation from biomass;
- Anaerobic digestion requires lower land compared to composting and landfilling technologies;
- Reducing environmental implication compared to composting and landfilling technologies.

However, this technology has not been proved in Vietnam yet. So far, MSW anaerobic digestion facility is not available in HCMC and Vietnam yet and thus experiences on its operation is still lacking. In the other words, technical issues, economic and social benefits as well as challenges in practical application of this technology has not been well defined yet.

4. Conclusions and recommendations

As this paper has shown as well the present system is still plagued by many shortcomings. We would like to start the discussion about these shortcomings from the perspective of the internationally widely adopted principle of the waste hierarchy. This principle prescribes solid waste management activities in an order of decreasing preference as follows: waste prevention (highest preference) > recycling and reuse > composting or/and biogas recovery and electricity production > landfilling (least preferred). This order is based on the sustainability principle of maximum protection and recovery of the resources in waste. For HCMC application, this principle would mean a strong emphasis on activities that avoid the generation of wastes, stimulation of reuse and recycling and on recovery of valuable materials (like energy, compost and others) from collected wastes.

From this perspective first a note should be made about separation of MSW at the source. Waste separation at source could reduce the flow of waste materials going to landfills and deliver recyclable materials in a pure form thus reducing the costs of processing and leading to products of a higher quality.

While the waste hierarchy prescribes a preference for treatment technologies like composting and anaerobic digestion with utilization of biogas, the main technology in HCMC is sanitary landfilling applied to 90% of collected MSW.A relatively small amount of MSW is composted (10% of the waste in 2014). Though sanitary landfilling is a big step forward in comparison to dumping, landfilling will reach its limits, sooner or later, there will be a lack of land, inhabitants will difficultly accept the environmental pollution associated with landfilling and the need to recover materials will grow, which demands other technologies. In the other words, how to put these technologies into practice that suites to HCMC condition is still a question.

Finally, public awareness and human resources related to solid waste management have improved through many activities in capacity building and international cooperation for the last 20 years. If well and timely managed such improvements can be of great value.

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