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Determination of the Municipal Solid Waste Characteristics of Hanoi City, Vietnam

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Abstract: The objective of this study was to evaluate the composition and characteristics of the municipal solid waste (MSW) of Hanoi city in order to obtain information for further treatment and management. Solid waste sampling and laboratory analysis were carried out according to the American Society of Testing and Materials (ASTM) standards to determine the waste compositions and proximate analysis (moisture content, volatile matter, ash content and fixed carbon). Heating values were estimated from empirical models. The study showed that the main compositions of the generated waste were 48.8% organics (food and yard wastes), 13.6% plastics, 8% paper, 1.2% metals, 2.1% glass, 8.0% textiles, rubber, leather, 2% wood and 15.8% other wastes. The average moisture content and volatile mater content of the waste were 52.2% and 30% correspondingly. The higher heating value were from 5.1 to 11 MJ/kg and the lower heating value ranged between 1.2 to 4 MJ/kg. Due to high shares of the organics and moisture content combining with the low volatile content and heating value, the energy recovery from incineration of this MSW could not so effectively. The appropriate treating methods were composting and anaerobic for energy recovery.

Key words: Hanoi, municipal waste component, proximate analysis, heating value, ASTM.

1. Introduction

Management of solid waste, including the municipal solid waste (MSW), is a major challenge in urban regions of most part of the world. Due to the lack of effective management programs, regulations, and policies, the waste is causing severe health hazard including communicable diseases, bad odors, nuisance and environmental impacts, such as, contamination of water, soil and air. Most Southeast Asian cities are lacking efficient MSW management programs (Verma, 2016).

Hanoi city is the capital of Viet Nam, consisting 12 urban districts, 1 district-leveled town and 17 rural districts. The city is a center of culture, economy and education. It is the country's second largest city by population. In 2015, the population of Hanoi was 7.56 million, comprising 8 percent of the country (Viet Nam GSO, 2017). Due to the rapid urbanization, economic growth and migration of people from other parts of the country, the population of Hanoi city is growing significantly. The population increased by twofold in the period of 1995 to 2015 with the yearly growing rate of 1.7%, equivalent to 200.000 people per year (Viet Nam GSO, 2017). It is estimated that by 2050, the Hanoi's population would be double to about 14 million. With such population growth, the capital is under great pressure in all areas, especially in the MSW.

MSW generation and separation in Hanoi

The Hanoi People's Committee must face the challenge of managing more than 6,400 tons of the MSW per day which accounts for 62.6% of total amount of solid waste (MONRE, 2016). According to the Viet Nam's Environmental Protection Law 2015, waste generators are responsible for sorting waste at source in order to facilitate its re-use, recycling, energy recovery and disposal. In fact, in Vietnam only industrial and medical wastes are required to be separated at source and treated separately. For other types of waste, there is no mandatory regulation on sorting at source.

The separation of domestic waste at source is not implemented widely, nor in Hanoi, nor throughout the country. It was only implemented in some pilot projects financed by international sponsors such as the project “3R-HN”, the project “Improvement of capacity in solid waste management in Gia Lam district” (Marie and Cong, 2015).

Waste collection and transport

The MSW is collected every day and transported to temporary local gathering points. Afterwards, it is loaded into garbage trucks and then moved to disposal sites. By the end of 2014, the collection rate in urban areas was nearly 98% (approximately 100% for four historical urban districts). The entire amount collected is transferred to the Nam Son Waste Treatment Complex. For suburban and rural area, the average collection rate was reported to be approximately 89% but only 82% of the volume collected was taken to the municipal disposal centers or treatment sites at district level. The rest was dumped in uncontrolled landfills (DONRE, 2015).

Currently, the Nam Son Waste Treatment Complex, the biggest waste treatment site in Hanoi, receives daily 3,800-4,200 tons, making up to 59- 65% of the total amount of waste generated in Hanoi. Garbage trucks have to travel approximately 50km to transport waste directly from inner districts to the Nam Son Treatment Complex. This operation increases the transportation expense and presents potential risk of polluting the environment during transfer.

Solid waste disposal

By the end of 2014, 91% of amount of the MSW in Hanoi were collected and processed in municipal waste disposal centers and waste treatment sites of districts (DONRE, 2015).

Landfill: For the moment, landfilling is the predominant treatment because of its low cost. Over 90% of quantity domestic waste in Hanoi was treated by land filling, mainly in 8 municipal waste disposal centers and waste treatment sites at district level.

Incineration: In Hanoi, there are three incinerators with a treatment capacity of less than 1,000 tons/day. They are all operated by private companies. These incinerators, with mostly Chinese technologies, were manufactured in Vietnam or China with some technical improvement to adapt to Vietnamese waste specificities (composition, moisture, specific heat capacity). The recovery of heat from the combustion process has also gradually been researched or planed in some plants for electrical generation or reusing for drying waste before incineration, but for the moment no result has been certified (Marie and Cong, 2015).

Composting: There are two compost/organic humus production plants in Hanoi. Cau Dien composting plant was designed with a processing capacity of 50,000 tons/year but currently treats less than 13,000 tons/year due to the lack of financial support from the city. In 2015, the waste disposal site in Kieu Ky received daily approximately 50-60 tons of domestic waste from Gia Lam District with a treatment rate in organic humus of approximately 35% in volume. Because of the lack of investment, this system now produces only organic humus and not real compost.

Recycling: Recycling activities from recyclable materials in waste is carried out mainly in some craft villages inside or outside Hanoi. These activities are still spontaneous and use old recycling technologies, causing air, soil and water resource pollution in the region. The pollution situation in some craft villages is now a challenge for the Hanoi government due to the lack of close supervision and examination by local authorities,

This study aimed to identify the municipal solid waste characteristics at the Nam Son Waste Treatment Complex, the biggest waste treatment site in Hanoi in order to propose appropriate methods of treatment. In order to achieve this, the study applied the ASTM standards to determine the waste composition and proximate analysis. Heating values of the MSW was estimated from empirical models.

2. Materials and methods

2.1. Sampling and sorting events

Sampling was carried out at the Nam Son Waste Treatment Complex according to the Standard Test Method for Determination of the Composition of Unprocessed MSW (ASTM D 5231-92) (2003). This test method applies to determination of the mean composition of MSW based on the collection and manual sorting of a number of samples of waste over a selected time period covering a minimum of one week. In this study, the samples of waste were selected and tested in one week (7 days) in August, December in 2016, March and June 2017. The sample was sorted manually into 9 waste categories as the showings in table 1.

Table 1: Descriptions of waste component categories

Category	Description
Paper	Office paper, computer paper, magazines, glossy paper, waxed paper, newsprint and corrugated
Plastic	All plastics
Food waste	All food waste except bones
Yard waste	Branches, twigs, leaves, grass, and other plant material
Wood	Lumber, wood products, pallets, and furniture
Textiles, rubber, leather	Textiles, rubber, leather, and other primarily burnable materials not included in the above component categories
Metals	Iron, steel, tin cans, and bi-metal cans; Aluminum, aluminum cans, and aluminum foil
Glass	All glass
Other wastes	Rock, sand, dirt, ceramics, plaster, non-ferrous nonaluminum metals (copper, brass, etc.), and bones

Based on the ASTM D5231-92 standard, the number of sorting samples (that is, vehicle loads) (n) required to achieve a desired level of measurement precision is a function of the component (s) under consideration and the confidence level. The governing equation for n is as follows:

$$n = (t^{*} s / e\bar{x})^{2} \qquad (1)$$

where t* is the student t statistic corresponding to the desired level of confidence, s is the estimated standard deviation, e is the desired level of precision, and $\bar{x}$ is the estimated mean. The number of samples was calculated according to the ASTM D5231-92 standard, taking into consideration a 90% confidence level and a 10% of precision (e). Therefore, the number of samples for each component were calculated and shown in table 2. The vehicles for sampling were selected randomly during each day of the one-week sampling period (7 days), as to be representative of the waste stream.

Table 2: Number of samples

Component	Standard deviation* (s)	Mean* ($\bar{x}$)	Samples/ week	Samples/ day
Paper (newsprint, corrugated)	0.07	0.24	25	4
Plastic	0.03	0.09	32	5
Food waste	0.03	0.1	26	4
Yard waste	0.14	0.04	331	47
Wood	0.06	0.06	271	39
Textiles, rubber, leather	0.06	0.05	390	56
Metals	0.03	0.06	69	10
Glass	0.05	0.08	108	15
Other wastes	0.03	0.06	69	10

* Data referred from the ASTM D5231-92 standard.

Each sorting sample weighed 91–136 kg and was prepared properly (mixed, coned and quartered) for the sampling. After the sampling, hand sorting applied for the classification of MSW into nine categories. Each material category is then weighed and registered in the data sheets. The weight fraction of each component in the sorting sample was calculated by the weights of the components. The mean waste composition was calculated by using the results of the composition of each of the sorting samples. Individual waste components and composite samples were transported to the laboratory for proximate analysis.

2.2 Proximate analysis

2.2.1 Moisture content

The percent moisture (M) of the MSW samples was determined by weighing 1 kg of the samples into a pre weighed dish and drying the samples in an oven at 105°C to a constant weight (ASTM D3173 standard). The percent moisture content was calculated as a percentage loss in weight before and after drying.

$$\% \text{ M} = [(\text{Wet Weight - Dry Weight})/\text{Wet weight}] \times 100\% \qquad (2)$$

2.2.2 Volatile matter content

The volatile matter content (VM) was determined by the method of the ASTM D3175 standard. The triplicate samples of MSW material used in the moisture content determination were weighed and placed in a muffle furnace for 7 minutes at 950°C. After the combustion, the samples were weighed to determine the ash dry weight, with volatile solids being the difference between the dried solids and the ash.

$$\% \text{ VM} = [(\text{Dry sample weight - Ash weight})/\text{Dry sample weight}] \text{ x } 100\% \qquad (3)$$

2.2.3 Ash and fixed carbon contents

Ash content of waste is the non-combustible residue left after waste burning, which is represents the natural substances after carbon, oxygen, sulfur and water (Amin, 2012). Analysis includes of dried the samples at 750°C for 1 hour (ASTM D3174 standard). Fixed carbon defined by carbon found in the material which was left after volatile test. The fixed carbon (FC) was determined by removing the mass of volatile from the original mass of the sample.

FC (Wt% wet basis) =100-(Wt% moisture content+ Wt% Ash +Wt% volatile matter) (4)

2.3. Estimation of heating value

The most common methods currently being practiced to evaluate the heating value of the MSW are by using the estimated equations or experimentally by using the bomb calorimeter. There are numerous mathematical equations, which were created based on data from the physical composition, proximate or elemental analysis of the MSW. Kathiravale et al. (2003) did a research to establish a mathematical model that could calculate the higher heating value (HHV) of Malaysian MSW. The study showed that the correlation from the physical composition gave the best result when compared to the other correlation created based on the proximate or elemental analysis results. Therefore, three models predicting the HHV of the MSW based on physical composition were selected for this study. They are as the followings:

- The model estimation of the energy content of the MSW generated by Abu-Qudais and Abu-Qdais (2000):

$$HHV = 0.004[267.0(Pl/Pa) + 2285.7] \quad (5)$$

- The model estimation of the energy content of the MSW generated by Kathiravale et al. (2003):

$$HHV = 0.001\,[112.157\,Fo + 183.386\,Pa + 288.737\,Pl + 5064.701] \quad (6)$$

- The model estimation of the energy content of the MSW by Usón et al. (2012):

$$HHV = 0.001[112.815\,Or + 184.366\,Pa + 298.343\,Pl - 1.920\,W + 5130.380] \quad (7)$$

Where HHV is the higher heating value, wet mass content (MJ/kg), *Pl* is the percentage of plastic (%), *Pa* is the percentage of paper/cardboard (%), *Or* is the percentage of organic material (food, wood and grass) (%), *Fo* is the percentage of food waste (%), *W* is the moisture content (%).

Estimation of the lower heating value (LHV) was based on the following equation (Oak Ridge National Laboratory, 2012):

$$LHV = HHV\,(1 - M) – 2.443\,M \quad (8)$$

Where LHV is the lower heating value, M is the moisture content, mass fraction decimal.

3. Results and discussions

3.1. MSW composition

Recently, the amount of domestic waste generated in Hanoi was reported as being approximately 6,400 tons/day, of which 4,528 tons/day came from urban areas (12 urban districts and Son Tay town). Urban areas represented only 12.6% of total area of Hanoi but accounted for 46.6% of the population and generate 70.8% of the total volume of domestic waste. All this MSW were transported to the Nam Son Waste Treatment Complex.

The waste composition for the waste stream entering the Nam Son Waste Treatment Complex is shown in Figure 1. The percentage composition of waste included 48.8% organics (food and yard wastes), 13.6% plastic, 8% paper, 1.2% metals, 2.1% glass, 8.0% textiles, rubber, leather, 2% wood and 15.8% other wastes (most of them are coal slag, soil, sand). Indeed, organics were the largest composition. This was a precious source for composing or anaerobic digestion to get energy. Metal was the smallest composition for all samples. Combustible materials (food and yard wastes, wood, textiles, rubber, leather, paper, plastic) accounted for 80.9% of the total weight.

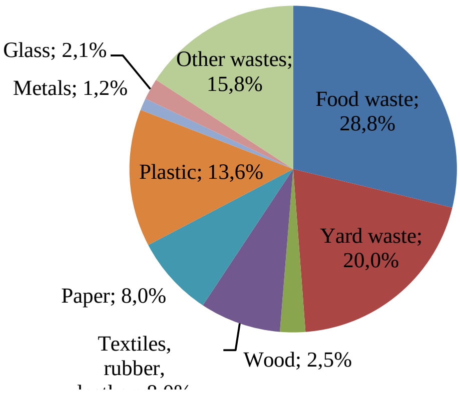

Figure 1: Composition of the MSW in Hanoi, Vietnam

3.2. Proximate analysis

In this study, the proximate analysis involves in determination of the moisture content, volatile matter, ash content, fixed carbon of individual components and composite samples. Overall proximate analysis of the waste samples is presented in Figure 2.

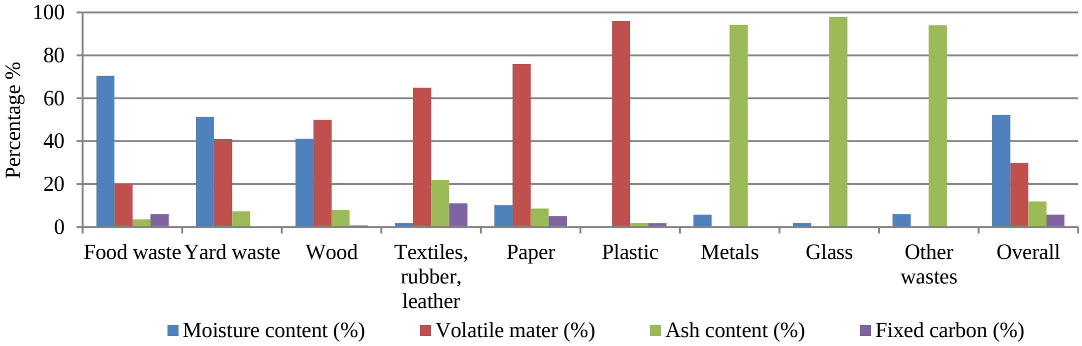

Figure 2: Proximate analysis results of each waste category of Hanoi city

As can be seen on the Figure 2, the average of moisture content analysis based on the random truck sampling is 52.2 %. The highest percentage of the moisture content (70.4%) is on food waste whereas plastic is the lowest (0.2%). Results from the moisture content analysis are directly affected by the quantity of wet basis materials such as food waste in the waste stream. As showed in the Figure 1 and 2, the higher percentages of food waste amount (28.8%) and moisture (70.4%) are the reasons of increasing the percentage of moisture content.

Volatile matter is the portion of the wastes which is converted into the gas phases during the heating process (950°C). As shown in the Figure 2, the percentage of volatile content is relatively high in plastic (96%), paper (76%) and textiles, rubber, leather (65%). Food waste has the lowest volatile content which is 20%. It should be noted that the plastic and paper have high volatile contents which result to high energy content, those components account for low shares in total waste amount (13.6% and 8% respectively). Consequently, energy recovery from the incineration of this MSW of Hanoi city could not so effectively. The average volatile mater content is 30%.

The Figure 2 also shows that the high percentages of ash content are in metals, glass and other waste coal (slag, soil, sand) due to they are non - combustible. The high percentage of the fixed carbon in waste materials such as textiles, rubber, leather (11%) shows that this element requires a longer detention time on the surface of the furnace.

3.3 Heating value

Table 2 presents the results of energy content predicted from the selected models developed on physical composition analysis. As can be seen on the table, the results are different between the models. The heating value estimated by the equation 5 is two times higher than those from the equations 6 and 7. The estimated HHV of the MSW of Hanoi city ranges from 5.1 to 11 MJ/kg, while the LHV is from 1.2 to 4 MJ/kg.

Table 2: Estimation of the energy contents of the MSW in Hanoi city by the selected models

Model	Estimated HHV (MJ/kg)	Estimated LHV (MJ/kg)
Abu-Qudais and Abu-Qdais (2000) (Equation 5)	11.0	4.0
Kathiravale *et al.* (2003) (Equation 6)	5.2	1.2
Usón *et al.* (2012) (Equation 7)	5.1	1.2

The successful outcome of a waste incineration project depends on fairly accurate data on the future waste quantities and characteristics that form the basis for the design of the incineration plant (Marina et al., 2012). Therefore, waste for incineration must meet certain basic requirements. In particular, the energy content of the waste must be above a minimum level. The average annual lower calorific value must be at least 7 MJ/kg, and must never fall below 6 MJ/kg in any season (Rand et al., 1999). The estimates of the energy content of the MSW in this study suggested that the LHV was quite low and the energy recovery from incineration of that waste was not effective.

4. Conclusion

The MSW of Hanoi city contained 48.8% organics (food and yard wastes), 13.6% plastic waste, 8% paper 1.2% metals, 2.1% glass, 8.0% textiles, rubber, leather, 2% wood and 15.8% other wastes. The average moisture content and the volatile mater content of the waste were 52.2% and 30% correspondingly. The higher heating value were from 5.1 to 11 MJ/kg and the lower heating value ranged between 1.2 to 4 MJ/kg. With all above characteristics of the MSW, the suitable treating methods are composting or anaerobic for energy recovery.

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