

Original Research Article

Experimental study on characteristics of municipal solid waste (MSW) in typical cities of Indonesia

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Abstract: A clear understanding of the basic characteristics of municipal solid waste is the basis for the investigation of appropriate disposal technique. Municipal solid waste subdivided into 7 categories were sampled in 7 typical cities of Indonesia in this study. The physical composition, chemical properties of the municipal solid waste, as well as the impact of seasonal and geographical changes on the physical composition have been investigated. The physical and chemical characteristics of municipal solid waste in Indonesia is understood comprehensively and thoroughly.

The average percent content of each Indonesian waste category in sequence is 27.50% food waste, 20.42% mixture waste, 19.41% plastic waste, 14.54% paper waste, 9.25% wood waste, 4.90% textile waste, and 3.98% non-combustible waste. It is found that the seasonal changes have weak impact on the composition of municipal solid waste in Indonesia. The moisture content is all above 30%, and the lower heating value on a wet basis of the overall municipal solid waste reaches 8.6 MJ/Kg, which is well above the World Bank-recommended value (6 MJ/Kg) for utilization in thermochemical conversion processes. The results prove that Indonesian municipal solid waste is potential for converting waste to renewable power or other energy products.

Keywords: Municipal solid waste; Indonesia; physical composition; proximate and ultimate analysis; calorific value analysis

1. Introduction

Indonesian municipal solid waste (MSW) is an untapped renewable energy resource. Total MSW generation of Indonesia is 157000 tons/day in 2012 and increases to 1570002 tons/day during 2017~2018^[1,2]. Now, there are four major ways globally being used to manage MSW: recycling, land filling, composting and

waste to energy (WtE). Because solid waste disposal facilities are seriously lagging behind, land filling is major method disposing MSW in Indonesia.

However, the space occupied for landfill is too large. For example, Supiturang has more than 25 hectares of landfill, of which 75% have been filled with waste^[3]. Moreover, the methane produced by landfilled MSW is

recognized as a long-term source of greenhouse gas emissions and has the risk of explosion. An explosion injuring hundreds of people occurred in the Leuwigajah landfill in Indonesia^[4]. At present, Indonesian government and the waste management industry have recognized chances in converting the energy in MSW to renewable power or other energy products. Indonesia has issued Presidential Regulation (No.35/2018) on the accelerated development of waste-to-energy plants based on environmental friendly technology. According to the statement of Indonesian energy ministry, 12 WtE plants were expected to be completed by 2022, which can convert about 16000 tons of MSW to 234 MW of electricity per day^[5]. The development of WtE projects and technologies are unprecedentedly urgent in Indonesia.

However, knowledge of physical and chemical properties of Indonesian MSW is still lacking. Such kind of knowledge is essential to the design and operation of any type of WtE system, whether combustion or gasification-based. Many researches from developing

and developed nations have illuminated findings of physical and chemical characteristics, including physical components, proximate and elemental analysis and calorific value, via direct measurement. Uyen, *et al*, 2009^[6] and Ashok, *et al*, 2009^[7] made a research for solid waste management in Asian countries which includes Indonesia. Sukarni S, 2016^[4] exploring the potential of MSW as solid fuel for energy generation in the Malang City. But particular and deep going knowledge of MSW's characteristics is still scarce for entire Indonesian.

Herein, the present work aims to make up the lack of data for Indonesian MSW by developing an appropriate method to analysis MSW in terms of calorific value, physical and chemical composition. As part of a comprehensive characterization of the WtE potential of Indonesian waste, the paper emphatically researches the MSW of 7 cities and preliminarily understands the relationship between MSW's space-time distribution, physical and chemical composition and calorific value.

Number	Abbreviations	Explanation
1	MSW	municipal solid waste
2	WtE	waste to energy
3	Non-com	non-combustible
4	wt	weight
5	stdev	standard deviation
6	IQR	inter-quartile range
7	N	sample size
8	C.V	coefficient of variation
9	CI	confidence interval
10	LB	low border
11	UB	up border
12	a.u	arbitrary unit
13	M _w	moisture content on wet basis
14	A _d	ash content on dry basis
15	V _d	volatile content on dry basis
16	F _{c,d}	fixed carbon content on dry basis
17	C _{daf}	carbon content on dry ash free basis
18	H _{daf}	hydrogen content on dry ash free basis
19	N _{daf}	nitrogen content on dry ash free basis
20	S _{daf}	sulfur content on dry ash free basis
21	O _{daf}	oxygen content on dry ash free basis
22	Cl _{daf}	chlorine content on dry ash free basis
23	LHV _w	lower heating value on wet basis
24	HHV _d	higher heating value on dry basis
25	HHV _w	higher heating value on wet basis

Table 1. Explanation of abbreviations

2. Materials and methods

2.1 Selection of sampling cities

Table 2 presents the characteristic of the 7 cities (Figure 1) mentioned in presidential decree. Among them, Djakarta, Bandung, Palembang and Yogyakarta have developed industry; Balinese and Surakarta are well-known tourism cities; ITB and BSD can represent

Indonesian residential areas. The average air temperature of all cities is about 30 °C. Balinese and Palembang are tropical rainy climate, whose precipitation is more than other cities which are tropical monsoon climate^[8]. Each sample site has its own characteristics and can embody the whole condition of Indonesian city. The properties of overall MSW in Indonesia will be clear by analyzing waste of the 7 representative cities.

City	Sampling site	Description
Djakarta	Urban garbage transfer stations	Capital of Indonesia with developed industry
Bandung	Institut Teknologi Bandung (ITB)	Study and living area of college
	Suburban landfill	MSW in Bandung city is landfill here
Surakarta (Solo)	Urban garbage transfer stations	An ancient city in Indonesia, economy is backward and tourism industry is the most significant industry
Tangerang	Bumi Serpong Damai (BSD)	An upscale community developed for the consumption of middle and upper class people
Palembang	Urban garbage transfer stations	The regional business center of South Sumatra, industry is developed
Yogyakarta	Urban garbage transfer stations	Tertiary industry is developed
Balinese (Bail)	Klungkung	World-renowned tourist attraction
	Denpasar	

Table 2. Introduction of sampling cities



Figure 1. Distribution of sampling cities

2.2 Methods of sampling

Because MSW is seriously physically and chemically heterogeneous, it is difficult to collect samples on behalf of the whole city perfectly. One of significant issues in sampling MSW is lacking an Indonesian standard method for sample collection, preparation and analysis, so our work is based on the Chinese standard method "Sampling and analysis methods for domestic waste" (CJ/T 313-2009)^[9] which

stipulates how to collect and analyze MSW. The standard requires sampling in 11 categories, but the waste samples in Indonesia contain less content of lime soil, brick ceramics, metal, glass and other types. Therefore, above-mentioned five categories are classified into non-combustible categories. **Table 3** introduces the standard of classification of MSW. For substances consisting of a variety of materials, if they are easy to split, divided and classified according to **Table 3**. If it is

difficult to disassemble, such as Tetra Pack (made of paper and aluminum plastic), diapers (made of paper and plastic), sanitary napkins (made of paper and plastic), *etc.*, classified according to their main components. Because Indonesia is located in the tropics, a large

number of garden waste is produced and often mixed with MSW, for example, leaves and residual branches. This sampling classifies it as wood waste in this sampling. The sample quartiles is applied to sample MSW from urban MSW transfer stations.

Number	Category	Material details
1	Food waste	Various residues of animal and plant foods (including various fruits)
2	Paper waste	Various discarded paper and paper products
3	Wood waste	Various discarded wood and bamboo products and flowers
4	Plastic waste	Various discarded plastic, rubber and leather products
5	Textile waste	Various discarded cloth (including chemical fiber cloth), cotton and other textiles
6	Mixture waste	Mixtures is made of fragment which is difficult to classified and less than 10 mm Ash, ash, dust, <i>etc.</i>
7	Non-com waste	Various discarded bricks, tiles, porcelain, stones, cement blocks, <i>etc.</i>
		Various discarded glass and glass products
		Various discarded metal and metal products (excluding button batteries)
		Various discarded batteries, paints, pesticides, <i>etc.</i>

Table 3. Seven components of MSW categorized and collected in this study

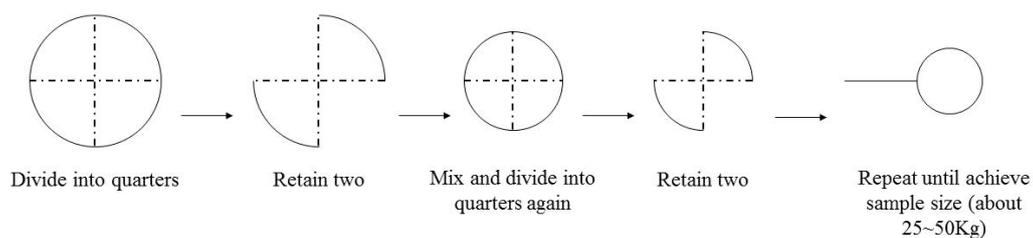


Figure 2. The flow of sample quartiles^[9]

The complexity and diversity of the composition of MSW directly leads to the difficulty of performing a perfect garbage sampling. In general, the uncertainty caused by the sampling process is stronger than the uncertainty in the analysis process^[10]. Therefore, the sampling method and the adequacy of pre-preparation will have a great impact on the final experimental results. According to Pierre's sampling theory^[11], the errors that

need to be paid attention to during the collection and reduction process can be roughly divided into the following six categories:

- 1) Long-range heterogeneity fluctuation error

The error caused by regional differences means that the sampling results at a certain point cannot represent the results of the entire region. There are significant differences in the composition of MSW generated by

different cities in Indonesia due to distinctions in natural environment, climate characteristics, urban planning, economic development, and food and energy structure. In order to obtain the characteristics of MSW in Indonesia, seven typical Indonesian cities were selected for this sampling. Each city's samples were mixture consisting of samples collected from multiple sampling points, which minimized the impact of regional changes on the results.

2) Periodic heterogeneity fluctuation error

Seasonal changes and the occurrence of special events can affect the results of solid waste sampling. Indonesia has two seasons, rain and drought. Because of constraints of time and funds, only two cities, BSD and Bandung, are sampled in the rainy and drought seasons. For other cities, Jakarta and Surakarta are sampled during the rainy season, Palembang, Yogyakarta and Bali in the dry season. Tropical weather of Indonesia is changeable, it is difficult to guarantee the same weather during a few days before sampling. Therefore during the days when we did the samplings, the weather were quite similar.

3) Fundamental error

Different MSW components will mutually pollute, for example, the liquid in the food waste may penetrate into the paper waste or textile waste. Moreover, the waste needs to be screened in the sorting process, which causes some organic small particles are mixed with dust and classified as non-combustible waste. In order to solve the problem of mutual pollution of MSW, garbage transfer stations are selected as sampling points, where the MSW was not compressed the mutual pollution is not serious for MSW is not compressed at.

4) Grouping and re-aggregation error

The fragments obtained by breaking MSW have different sizes, densities and compositions, which makes

the sample used to analyze different from the actual one. In order to reduce this error, the samples of each sampling point in this sampling are mixed by multiple sub-samples, and each sub-sample will be broken as much as possible before being shrunk.

5) Increment extraction error

Some samples may be lost during the sampling process. For example, during the sampling and shrinking process, a small amount of samples attached to the ground and tools cannot be collected. This requires that the samplers use appropriate tools to collect the remaining samples carefully.

6) Preparation error

The sample may be contaminated during the preparation process and the particles are likely to adhere to the tool or be blown away by the wind. If the sample is left for too long, chemical reactions and physical reactions such as changes in moisture content will occur. Therefore, the sorting and drying of the samples should be carried out on the same day.

3. Physical composition

3.1 General characteristics of Indonesian MSW

Physical composition of MSW of Indonesia typical cities is presented in Table 4. The average percent of each waste category in sequence is 27.50% food waste, 20.42% mixture waste, 19.41% plastic waste, 14.54% paper waste, 9.25% wood waste, 4.90% textile waste, and 3.98% non-combustible waste. Firstly, the content of food waste is the most and exceeds others obviously. The second is mixture waste, which indicates that there are a lot of fine wastes in Indonesian MSW. Secondly, because the percent content of non-combustible waste is only 3.98%, about 96% of Indonesian MSW is organic combustible substance that contributes to WtE.

City	Physical composition (wt%)						
	Organic						Inorganic
	Food	Paper	Wood	Plastic	Textile	Mixture	Non-com
Djakarta-1 ^a	36.95	23.22	1.41	24.21	1.32	8.21	4.68
BSD-1 ^a	43.12	16.67	3.97	20.37	2.12	8.47	5.29
BSD-2 ^b	36.38	18.09	3.70	18.79	2.09	17.91	3.03
Solo-1 ^a	10.84	1.42	23.34	41.49	16.67	1.98	4.27
ITB-1 ^a	51.79	14.38	3.48	11.82	1.83	12.77	3.92
ITB-2 ^b	38.11	13.34	4.34	12.88	14.64	12.59	4.10
Landfill-1 ^a	15.15	17.09	5.06	20.77	12.41	26.09	3.45
Yogyakarta-2 ^b	7.28	18.60	7.66	15.26	0.89	39.54	10.77
Palembang-2 ^b	25.99	18.70	1.03	23.96	0.18	28.53	1.60
Bali_Den-2 ^b	15.60	9.85	22.73	17.38	1.66	31.10	1.68
Bali_Klu-2 ^b	21.34	8.61	25.00	6.60	0.07	37.38	0.99
Mean	27.50	14.54	9.25	19.41	4.90	20.42	3.98
Max	51.79	23.22	25.00	41.49	16.67	39.54	10.77
Min	7.28	1.42	1.03	6.60	0.07	1.98	0.99
Median	25.99	16.67	4.34	18.79	1.83	17.91	3.92
Variance	213.55	36.35	89.35	82.01	39.99	162.33	6.95
Stdev	14.61	6.03	9.45	9.06	6.32	12.74	2.64
Range	44.51	21.80	23.97	34.89	16.60	37.56	9.78
IQR	22.96	8.75	19.25	11.08	11.52	22.63	3.00
N	11.00	11.00	11.00	11.00	11.00	11.00	11.00
C.V(%)	53.13	41.46	102.23	46.65	129.08	62.40	66.24
90%CI							
LB	19.52	11.25		14.46		13.45	
UB	35.49	17.84		24.36		27.38	

Table 4. Physical composition of MSW in typical cities in Indonesia. ^{a, b}: 1 and 2 represents the rainy and dry season sampling, respectively, and the vacancy of CI indicates that the data of the group does not constitute a normal distribution.

Both Indonesia and China are typical Asian developing countries. WtE is the major way to dispose Chinese MSW now. Until 2016, 299 WtE plants had been established, 94% of MSW managed harmlessly^[12], which is a clear international precedent. So it is significant to compare characteristics between MSWs of two countries in order to develop technology fitting Indonesia by referring to China.

Table 5 shows that the amount of food waste of Indonesia is significantly lower than the food waste of

China, which is because China and Indonesia have different dietary habits. On the contrary, wood and mixture garbage is significantly more than Chinese. The former is mainly due to the development of Indonesian planting industry. The output of tropical fruits is one of the national economic pillars which results in the mixture of MSW and a lot of garden waste such as branches and leaves. The latter shows that compared to China, Indonesian MSW contains a large amount of fine waste less than 10mm in diameter.

City	Physical composition (wt%)						
	Organic						Inorganic
	Food	Paper	Wood	Plastic	Textile	Mixture	Non-com
Beijing-summer ^[13]	64.58	14.31	0.28	12.44	2.06	3.62	4.39
Beijing-winter ^[13]	48.42	13.36	0.90	7.56	3.95	4.18	8.32
Hangzhou ^[14]	56.00	11.00	1.00	19.00	3.00	8.00	5.00
Guangzhou ^[15]	37.76	8.10	2.26	25.55	20.44	3.34	2.55

Table 5. MSW physical composition of typical cities in China

3.2 Space-time distribution of MSW in Indonesia

The difference from season and location has a serious effect on the physical composition of MSW. The design of furnace is based on properties of feedstock which physical composition has significant influence on. So understanding space-time distribution of MSW in Indonesia is essential.

Table 6 shows the physical components of MSW in different seasons at BSD, ITB and Beijing. It can be seen

that seasonal changes have a significant impact on the composition of MSW^[16]. Firstly, the proportion of food waste in the rainy season in Indonesia exceeds that in the dry season, while in Beijing it is higher in summer than in winter, which indicates that with the dietary structure of residents changing for the seasonal variation, the foods that are prevalent in the dry season in Indonesia produce less waste. Secondly, the dry season sampling time of ITB is at the end of the dry season in Bandung, perhaps the significant increase of textile content is caused by the renewal of students' clothing.

City	Physical composition (wt%)						
	Organic						Inorganic
	Food	Paper	Wood	Plastic	Textile	Mixture	Non-com
BSD-1^a	43.12	16.67	3.97	20.37	2.12	8.47	5.29
BSD-2^b	36.38	18.09	3.70	18.79	2.09	17.91	3.03
Stdev	4.77	1.00	0.19	1.12	0.02	6.68	1.60
mean	39.75	17.38	3.84	19.58	2.11	13.19	4.16
C.V	11.99	5.78	4.98	5.71	1.01	50.61	38.41
ITB-1^a	51.79	14.38	3.48	11.82	1.83	12.77	3.92
ITB-2^b	38.11	13.34	4.34	12.88	14.64	12.59	4.10
Stdev	9.67	0.74	0.61	0.75	9.06	0.13	0.13
mean	44.95	13.86	3.91	12.35	8.24	12.68	4.01
C.V	21.52	5.31	15.55	6.07	109.99	1.00	3.17
Beijing-summer[13]	64.58	14.31	0.28	12.44	2.06	3.62	4.39
Beijing-winter[13]	48.42	13.36	0.90	7.56	3.95	4.18	8.32
mean	56.50	13.84	0.59	10.00	3.01	3.90	6.36
Stdev	11.43	0.45	0.44	3.45	1.34	0.40	2.78
C.V	20.22	3.26	74.31	34.51	44.47	10.15	43.73

Table 6. Seasonal effect on the physical composition of MSW. ^{a, b}: 1 and 2 represent the rainy and dry season sampling, respectively.

Coefficient of variation (C.V) is generally used to compare variable degree of two or more data, reflecting the degree of dispersion of different samples. Because the average value of each component is different, the

standard deviation cannot reflect the degree of dispersion between each other, so the coefficient of variation is chosen as a comparative factor to measure the significance of each component's space-time

change^[17]. The calculation formula of C.V is as follows:

$$C.V = \frac{stdev}{mean} \times 100\% \quad (1)$$

By comparing the variation of the composition of the three sites with the seasonal variation, it can be found that C.V of the two sampling cities of Indonesia is lower than that of Beijing. This is due to Indonesian tropical weather that leads to annual high air temperature, the major difference between the rainy season and the dry season is the discrepancy of precipitation. Compared with the city in the temperate zone, the distribution of physical components of Indonesian MSW does not fluctuate greatly due to seasonal changes.

The spatial location changes lead to the changes of many factors, such as cultural customs, economic level, industrial structure, which have an important effect on physical composition of MSW^[18]. Firstly, residential areas are both BSD and ITB whose the percent content of food waste obviously exceeds that of other sites, the percent content of wood waste and mixture waste lower than the average. Moreover, BSD plastic waste is higher than that of ITB for BSD is a high-end commercial living area where plastics are used more than students' living area. Landfill as the final treatment site for Bandung waste can represent the whole city. It can be found that

the structure of ITB's MSW is significantly different from the entire Bandung. Secondly, tourism industry is the mainstay of the economy in Bail and Solo. Their food waste and paper waste content is significantly lower than the average, while wood waste is the opposite. The composition of MSW at Solo is also obviously different from other regions because industrial and commercial level and economy of Solo is far from the other cities. The level of city modernization has a significant impact on the physical composition of MSW^[1].

Table 7 verifies whether the data of each garbage component constitutes a normal distribution^[19-21]. The food waste, paper waste, plastic waste and mixture waste satisfy the normal distribution conditions. The 90% confidence intervals of the content are 19.52%-35.49%, 11.25%-17.84%, 14.46%-24.36%, 13.45%-27.38%, respectively. **Figure 3** is a box plot of the distribution of MSW in Indonesia^[22]. It can be found that the distribution of wood waste, textile waste and non-combustible waste who do not conform to the normal distribution condition is more concentrated than the others. Most of the data is between 0% and 10%, which illustrates the effect of time and space on them is relatively weak.

Normality Test			
Sample	Shapiro-Wilk(a.u)		
	Statistics	N	Significance
Food	0.945	11	0.582
Paper	0.931	11	0.425
Wood	0.739	11	0.001
Plastic	0.899	11	0.178
Textile	0.709	11	0.001
Mixture	0.939	11	0.504
Non-com	0.831	11	0.024

Table 7. Normal distribution test of MSW components of Indonesia. Test standard: When significance >0.05, the sample can be approximated as a normal distribution.

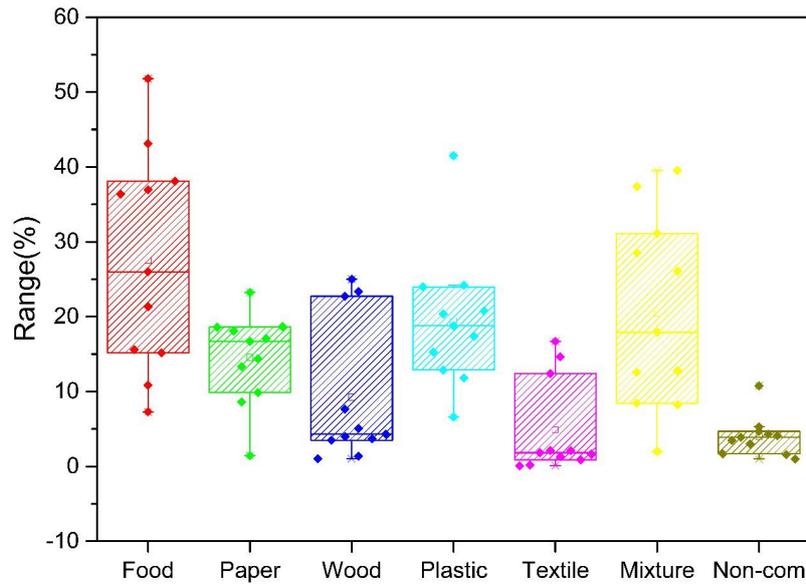


Figure 3. Box chart of Indonesian MSW components

4. Chemical composition

4.1 Proximate analysis

The MSW sample is burned at 800 °C-850 °C, the residue after cooling is ash, the reduced weight flammable, including volatiles and fixed carbon. Table 8 shows that the moisture content of each component of Indonesian waste is above 30%. The maximum of moisture content is food waste, about 70%. Mixture waste contains the most ash, followed by food waste, and the ash of other types are between 5% and 11%, textile

waste is the least; Volatiles can be used to estimate the content of organics in MSW samples^[25] the highest volatile content is plastic waste, nearly 90%, so it contains the most organic matter, while organic matter content of mixture waste is the lowest. The average value of volatiles in Indonesian MSW reaches nearly 70%, which indicates that MSW contains relatively more organics. Compared with Shenzhen and Taiwan, Indonesia has a high content of water due to the rainy weather, then the difference between ash and flammable fraction is not obvious^[23,24].

Category	Proximate analysis (wt%)				Ultimate analysis (wt%)						Calorific value (KJ/Kg)	
	M _w	A _d	V _d	Fc _d	C _{daf}	H _{daf}	N _{daf}	S _{daf}	O _{daf}	Cl _{daf}	LHV _w	HHV _d
Food	69.93	16.56	67.32	16.12	50.76	5.80	2.06	0.32	41.06	0.33	2693.21	16020.68
Papar	45.33	10.13	78.26	11.62	48.56	5.81	0.58	0.41	42.24	0.40	7654.68	17232.18
Wood	35.77	9.62	72.67	17.70	50.84	5.08	1.59	0.26	39.00	0.21	8382.84	17344.00
Plastic	32.95	7.56	89.65	2.79	77.38	10.98	0.48	0.57	10.60	0.82	24257.54	34545.40
Textile	32.17	5.08	84.85	10.07	57.51	4.46	0.48	0.41	36.57	0.31	11917.37	19544.00
Mixture	50.74	27.18	60.39	12.43	51.27	5.75	1.95	0.44	40.58	0.46	5486.23	14018.55
Average	48.49	20.61	68.93	10.46	58.91	7.12	1.14	0.42	32.41	0.50	8609.79	19892.08
Shenzhen ^[23]	48.17	27.06	72.93		49.31	6.35	0.45	0.31	33.33	0.43	6462.00	
Taiwan ^[24]	39.69	18.76	81.23		54.05	6.96	2.74	0.76	34.91	0.59	8643.78	17254.08

Table 8. Data of MSW proximate analysis, ultimate analysis and calorific values in Indonesia and other cities

4.2 Ultimate analysis

The element composition of MSW is an important

analytical indicator for measuring the quality of waste. Essentially, the chemical nature of MSW is

determined by the chemical composition of each type of waste and its own properties. The content of carbon and hydrogen can reflect the oxidability of the sample itself^[26]. The overall carbon and hydrogen content of Indonesian MSW is higher than that of Shenzhen and Taiwan, which indicates that Indonesian MSW has fine potential for WtE relatively. Nitrogen of MSW mainly concentrated in organic waste, such as food waste and wood waste. Compared with Shenzhen, the higher nitrogen content of Indonesian MSW may cause more NOx during waste incineration. Except for the low oxygen content of plastics, the oxygen content of other categories is about 40%. The content of sulfur and chlorine in all waste types is very small.

4.3 Calorific value analysis

HHV_d of samples is directly measured by oxygen bomb calorimeter, HHV_w and LHV_d being deduced by following functions:

$$HHV_w = HHV_d \times \frac{100 - M_w}{100} \quad (2)$$

$$LHV_w = HHV_w - 24.4 \times \left[M_w + 9H_d \times \frac{100 - M_w}{100} \right] \quad (3)$$

Dimitrios, *et al*, 2012^[27] shows that moisture content has a significant impact on calorific value, as is the case with Indonesian MSW whose average calorific value of dry basis is about twice than wet basis. Among all kinds, plastic waste has the highest calorific value, food waste the lowest. The LHV_w of Indonesian MSW reached 8.6 MJ/Kg. According to the World Bank report, when the waste heat value exceeds 6 MJ/Kg, it can be treated as heat treatment^[28]. Compared with typical MSW in other countries, such as 4.8 MJ/Kg (India^[29]), 8.9~9.0 MJ/Kg (Japan^[30]), 8.16~11.92 MJ/Kg (Korea^[31]), 9.22 MJ/Kg(UK^[32]), 5.34 MJ/ Kg (China^[16]), Indonesian waste heat value is generally at a high level and suitable for converting own energy to renewable power and energy commodities.

5. Discussion and conclusion

According to the sampling and analysis of MSW in seven typical cities of Indonesia, the MSW's characteristics of physical and chemical composition are the ingredients below:

1) The average percent content of each Indonesian waste category in sequence is 27.50% food waste,

20.42% mixture waste, 19.41% plastic waste, 14.54% paper waste, 9.25% wood waste, 4.90% textile waste, and 3.98% non-combustible waste. It is found that the seasonal changes have weak impact on the composition of MSW in Indonesia. On the contrary, the composition of waste in difficult city varies greatly. Moreover, the changes of wood waste, textile waste and non-combustible waste with seasons and locations are small, the food waste, paper waste, plastic waste and mixture waste meeting the normal distribution conditions. The 90% confidence intervals are 19.52~35.49, 11.25~17.84, 14.46~24.36, 13.45~27.38, respectively.

2) Indonesian MSW has high moisture content, volatile matter content, as well as carbon and hydrogen content, contains more organic matter. Moisture content is a major factor impacting calorific value. The LHV_w of the entire MSW sample was found to 8.6 MJ/Kg, which is not only relatively high compared with average calorific value, but also above the World Bank-recommended calorific value minimum for WtE applications. In conclusion, MSW of Indonesia is suitable for WtE, whether combustion or gasification-based.

Acknowledgements

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