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Analysis of ingredient and heating value of municipal solid waste

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Abstract : Great differences between municipal solid wastes (MSW) produced at different places and different times in terms of such parameters as physical ingredient and heating value lead to difficulty in effective handling of MSW. In this paper , ingredient , heating value and their temporal varying trends of typical MSW in Beijing were continuously measured and analyzed. With consideration of the process in pyrolysis and incineration , correlation between physical ingredients and heating values was induced , favorable for evaluation of heating value needed in handling of MSW from simple analysis of physical ingredients of it.

Key words : MSW; incineration ; pyrolysis ; ingredient ; heating value

Introduction

MSW includes various wastes generated from people 's daily life and industrial process. With the improvement of people 's life , the increasing amount of MSW is becoming a problem baffling every government (Sino-UN , 1999). Without effective handling , MSW may seriously threaten people 's health , improvement of environment and man 's sustainable development. With ceratin value as a resource , incineration for energy recovery (Sheng , 1994) and low-temperature pyrolysis (Zhang , 1995) are considered effective measures preventing pollution. Incineration for energy recovery has been widely adopted in advanced countries (Zhang , 1997) and investigated with great effort in domestic scientific institutes (Jiang , 1998 ; Sheng , 1997 ; Yang , 1998 ; Nie , 1999). Low-temperature pyrolysis concentrates on research on pyrolysis characteristics of each ingredient , pyrolysis dynamics and development of small-scale pyrolysis systems (Deng ,1995 ; Coats , 1964 ; Patrick , 1996). Aiming at energy recovery ,collection and analysis of MSW are prerequisites for design of incineration and pyrolysis system.

Analysis of MSW concentrates on its producing area , producing rate , ingredients and characteristics (Zhang , 1997) and so on. With different producing area , MSW has different types including domestic waste , commercial waste , road sweeping waste , hospital waste , construction waste , slurry from waste water handling industry , industrial waste and so on. The last three items have special handling means. Changes of MSW in terms of physical ingredient and heating value in Beijing in recent years were analyzed in this paper. Correlation between heating value and ingredients was reduced from measured data.

1 Measurement of physical ingredients and heating value of MSW

Fig. 1 presents the procedure of sampling and analysis of MSW. According to statistical sampling theory , single random sample , storied random sample , systematic random sample and authoritative sample were specifically adopted in terms of the diversity of waste and necessary accuracy of the result (Zhang , 1997).

Because of the lack of available knowledge of the sample diversity , storied random sample was adopted . A heap of waste was divided into several layers that were later divided into several randomly selected groups as samples. Each sample was classified into 8 types as metal , glass , plastic , paper , cloth , botany , ash and culinary waste. Raw weight of each ingredient was measured to figure out wet-based content of each ingredient in MSW. Classified samples were dried with a temporal period of 24h and an environmental temperature between 105 - 110 ℃. Then the

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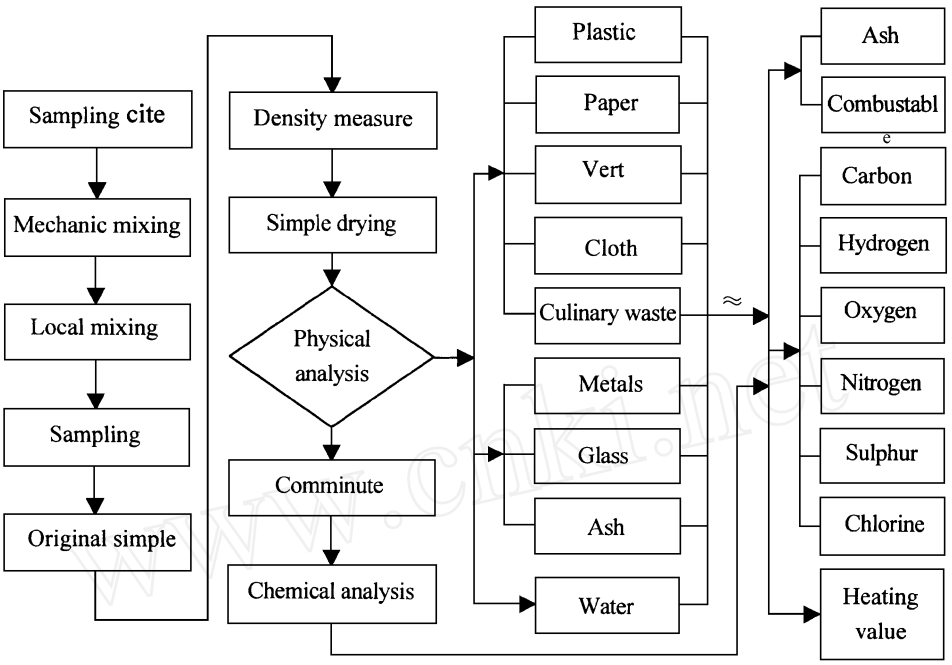

Fig. 1 Course of the sampling and analysis of the MSW

weight of each dried ingredient was measured to get the moisture. From integration of the results, total moisture of MSW as well as percentile content of each ingredient as receive could be calculated. Dry sample of MSW was assembled from several ingredients at certain ratio. Heating value of the sample was obtained with oxygen bomb calorimeter. Then high heating value and low heating value of the sample of MSW could be figured out with Formula (1) and Formula (2), respectively.

$$Q_h^y = Q_h^q \times (100 - W^y) / 100, \quad (1)$$

$$Q_l^y = Q_h^y - 25(W^y + 9H^y). \quad (2)$$

(The nomenclature is listed in the end of this paper)

High content of organic ingredient in MSW leads to high hydrogen content, about 2 % - 5 %, which could be obtained through chemical ingredient analysis or roughly evaluated from physical constitute (Zhang, 1997).

2 Physical ingredient analysis of MSW

Great bias lies between MSW from different districts even in the same capital, in terms of physical ingredient, heating value and moisture that effectively affect incineration and pyrolysis. Nine typical sampling sites were adopted converting domestic area, commercial area, footpath, hospital and facilities etc. Fig. 2 present yearly average percentages of each ingredient as receive in commercial area, dormitory with gas and central heating supplies and bungalow, respectively. Fig. 3 shows the yearly fluctuation of MSW in terms of high heating value, low heating value and moisture, respectively. Fig. 4 give varying trends of heating value and combustible including plastic, paper, cloth, botany and culinary waste in recent years.

Domestic waste, primary from dormitory with gas and central heating supplies, covers a large portion in the whole MSW. Fig. 2 demonstrate that the waste from dormitory is made up primarily of food which covers more than 40 % on dry base, certain portion of paper and plastics covering within 5 % - 10 % and generally on ash. Waste from bungalow demonstrates the highest ash content among various types of wastes, covering more than 60 %, and lower contents of plastics

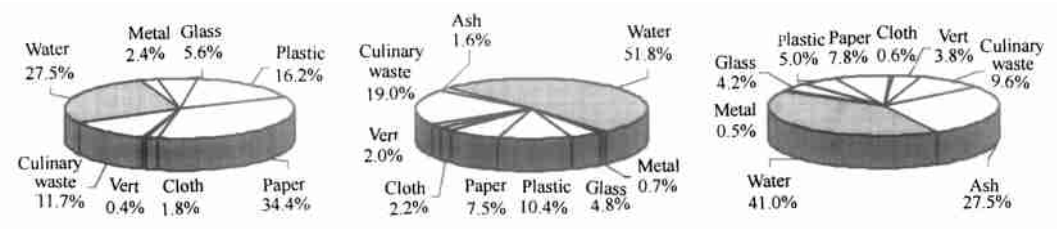

Fig. 2 Ingredient analysis of MSW

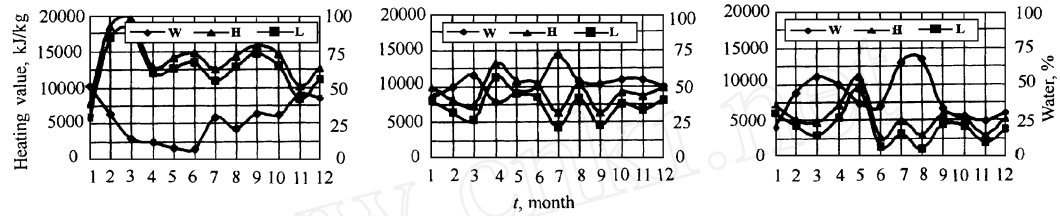

Fig. 3 Heating value and moisture of MSW

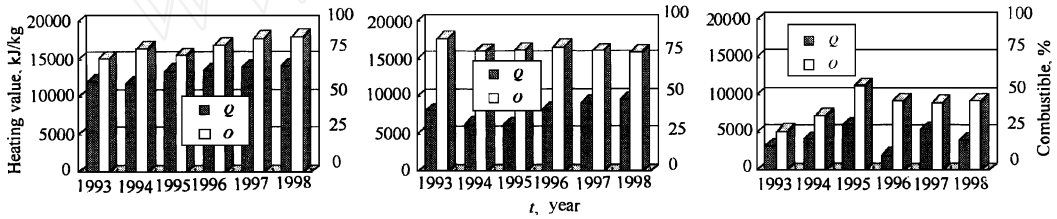

Fig. 4 Heating value and combustion contents of MSW

and paper than those from dormitory , about 55 %. Commercial waste shows the highest contents of plastics and paper , about 30 % - 50 % and very low ash content , about 0 %.

Moisture in MSW directly influences the processes of incineration and pyrolysis as well as the utilization of their products. Existence of moisture decreases the low heating value of MSW and increases the difficulty of waste handling. With high specific heat , large quantity of moisture not only decreases the gas temperature but also changes the characteristics of heat transfer between gas and boiler , and thus decreases the operational efficiency of boilers. As a result , it is necessitated to carry out moisture analysis of MSW. It is shown from Fig. 3 that the moisture in the waste from dormitory is relatively high , about 50 % , but with small yearly fluctuation , except some sharp increase in summer due to the concentrated rainfall. Vigorous fluctuation of moisture happens in the waste from bungalow , even other season more than rainy season. Ingredients of commercial waste , with combustible mainly as plastics and paper , show little variation and low value of about 25 %.

Results of continuous inspect of MSW in the past several years show no apparent temporal variation in terms of main physical ingredients and their contents.

3 Heating value analysis of MSW

As a mixture of various kinds of waste , MSW has very complex ingredients. Heating value of MSW , as an indicator of combustible contents in MSW , plays a key role in determining the measure of MSW handling. If MSW can be handled with incineration and pyrolysis , heating value serves as an important parameter in systematic design in terms of facilities and operation.

Fig. 3 and Fig. 4 show that waste from dormitory has high moisture , but due to high combustible contents , it demonstrates large high heating value , generally higher than 5000 kJ / kg with a yearly average value of 7500 kJ / kg. Waste from bungalow has high ash content and low

combustible contents, and thus has low high heating value, within 1000 kJ/kg - 6000 kJ/kg. Commercial waste presents the highest high heating value among all tested wastes, with an average of 10000 kJ/kg and the highest of 18000 kJ/kg. With continuous improvement of people's living conditions, the heating value of the waste from dormitory demonstrates yearly increasing trends.

Heating value can be obtained with oxygen bomb calorimeter or through chemical ingredient analysis with Dulong Formula, Steuer Formula and Scheure-Kestner Formular (Zhang, 1997) which have nearly the same structure and constants as Mendelyeev Experimental Formula. But due to the complexity of MSW ingredients, large bias exists in the measurement of the chemical content measurement. Heating value can also be obtained through analysis of physical ingredients of MSW with bi-ingredient formula, tri-ingredient formula and multi-ingredient formula (Zhang, 1997; Wang, 1993).

$$Q_l^y = 188\,O^g \times (100 - W^y)/100 - 25(W^y + 9H^y), \quad (3)$$

$$Q_l^y = [335\,R^g + 180(O^g - R^g)] \times (100 - W^y)/100 - 25(W^y + 9H^y), \quad (4)$$

$$Q_l^y = [369\,R^g + 170(F^g + P^g)] \times (100 - W^y)/100 - 25(W^y + 9H^y), \quad (5)$$

$$Q_l^y = [42\,M^g - 5\,G^g + 481\,R^g + 147(C^g + F^g + P^g + V^g)] \times (100 - W^y)/100 - 25(W^y + 9H^y). \quad (6)$$

During the transition from bio-ingredient formula to multi-ingredient formula, contribution of each ingredient in MSW to heating value is considered in more detail. During classifying of samples and measurement of heating value, it is discovered that ash is not absolutely incombustible. There are small combustible particles in ash especially in that from footpath. During the measurement of heating value, some metal may liberate a great quantity of heat through vigorous oxidizing reaction, but during incineration and pyrolysis, no oxidizing reaction occurs and glass does not melt and thus does not absorb heat. As a result, no attribution of metal and glass is considered in formulas calculating heating value.

Physical ingredients and heating value can be induced to the correlation as follows:

$$Q_l^y = [\alpha R^g + \beta(C^g + F^g + P^g + V^g) + \gamma A^g] \times (100 - W^y)/100 - 25(W^y + 9H^y). \quad (7)$$

Due to large heating value, plastics and rubbers are considered specifically in combustible. Papers cloth, botany and culinary waste are primary made up of figures and have similar heating value, so can be considered as one type of combustible material. We obtain: $\alpha = 458.0$, $\beta = 141.1$, γ is given in Table 1 which different value according to its producing area.

Table 1 Value of γ

Mixed waste	8.2
Facility waste	0.0
Commercial waste	5.2
Waste from bungalow	7.2
Waste from dormitory	0.0
Waste from footpath	13.8

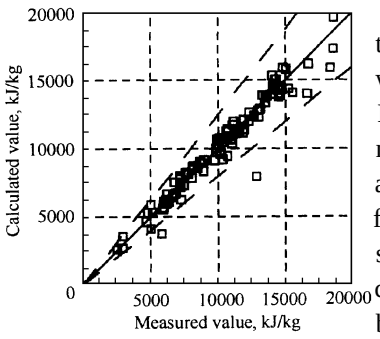

Fig. 5 Comparison between measured and calculated data

As shown in Table 1, the ash from footpath has the highest heating value in this kind of waste due to its content of combustible particles and defoliation. Even the ash from mixed waste also contains some combustible materials. Fig. 5 shows that the results from calculation are in fine agreement with the measured values. Comparison between the formerly discussed five formulas for prediction of heating value are shown in Fig. 6. The results demonstrated that the calculation consequences from Formula (5) and Formular (6) have relative bias of about 5 % from measured values. Multi-ingredient formula has greater versatility than either bi-ingredient formular or tri-ingredient formula.

4 Conclusions

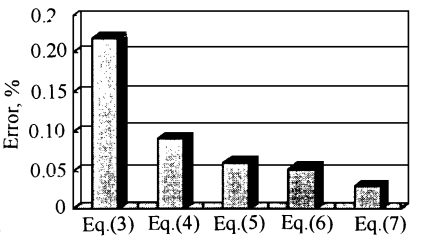

Fig. 6 Erros of Eqs. (3) - (7)

Continuous inspection of typical MSW from several districts in Beijing in terms of ingredients, heating value and their varying trends was carried out. On the basis of the results, main characteristics of MSW were obtained as: (1) MSW in Beijing show high temporal and special fluctuation in terms of heating value and physical ingredients; (2) MSW indicate very high moisture, some of which reaches 80 %, disadvantageous for incineration; (3) with the improvement of people's living condition, the heating value of MSW increase and the ash content decrease; (4) MSW in Beijing show enough high heating value, generally able to be handled by incineration.

Relationship between physical ingredients and heating values was induced. With consideration of contribution of ash to heating value instead of that of metal and glass, the predicted heating value shows fine agreement with measured one. The accuracy is higher than those predicted by bi-ingredient, tri-ingredient and multi-ingredient formula.

Nomenclature:

Variables:

A content of ash, %	*C* content of cloth, %	*F* content of culinary waste, %
G content of glass, %	*H* content of hydrogen, %	*M* content of metals, %
O content of combustible materials, %	*P* content of paper, %	*Q* heating value, kJ/kg
R content of plastic, %	*V* content of vert, %	*W* content of water, %

Labels: *g* dry base *h* high heating value *l* low heating value *y* base as receive

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