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**Research Article**

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# Analysis on the component characteristics and caloric value of medical waste

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**ABSTRACT**

*Medical waste from incineration plant in Chengdu City was separately collected by two-stage sampling and random sampling, and all the samples were divided into seven parts. A more practical measured method developed by energy-saving technology service center of Chengdu City was used to estimate the calorific value, and the classification, components, characteristics and caloric value of medical waste was also discussed. The conclusion that medical waste has higher calorific value and volatile matter and high concentration of water was given. And some suggestions are also given, such as high temperature incineration is the proposed technique to disposal medical waste. It put forward higher requirements for the system's performance of high temperature incinerator in the future research and development according to its characteristics.*

**Key words:** medical waste; characteristics; component; calorific value; incineration; Chengdu City

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## INTRODUCTION

Medical waste (MW) is generated in the medical, prevention, health care and other related activities by the medical and health institutions, which has direct or indirect infectious, toxic and hazardous. Medical waste caused the severe harm to the social, economy and environment, for the irregular management or improper treatment. So it was HW01 of *2008 National Catalogue of Hazardous Wastes*. At present, the annual output of Medical waste was about 650kt, and the output increased by 3% ~ 6% a year[1]. It can bring high safety trouble to human lives and the environment. Though there have been several kinds of medical waste treatment and disposal technologies such as electromagnetic wave, chemical disinfection, sanitary landfill and high temperature incineration currently, they all have their own limits. As it has high degree on waste minimization and resource-regeneration, disposal of medical waste by incineration is greatly beneficial not only to the environment but also to the economy. Nowadays incineration is gradually being used to dispose medical waste in China [2]. However, the combustion of medical waste in the incinerator is unstable due to the complex composition in MW, different proportions of components, calorific value and various characteristics of the waste. Analysis on physical-chemical characteristics and caloric value of medical waste is of greatest importance to regulate and control the incineration system of medical waste.

There has been a considerable amount of researches at home and abroad on characteristics[3-7], component, and calorific value of medical wastes[8,9]. And there have been some researches focused on pyrolysis characteristic of representative medical waste composition[10-13], and proximate analysis and elemental analysis[14-16]. The study on medical waste incineration treatment technology has become a hotspot research in recent years. But up to now, how to regulate and control the influence parameters during incineration process is rarely discussed, and the detection method of calorific value and the conjoint analysis on component and characteristics of medical waste is limited. In this paper, analysis on component and characteristics of medical waste and the detection method of calorific value of medical waste was investigated. First, medical waste samples from incineration plant in Chengdu City was separately collected and divided into seven parts. Then a more practical determining method from

energy-saving technology service center of Chengdu City was used to estimate the calorific value, and the relationship between the components, characteristics and caloric value of medical waste is also discussed. The conclusion that the combustible components have the characteristics of low content of water and ash, high caloric value was given. And some suggestions are also given, such as thermal disposal especially high temperature incineration is the proposed technique to deal with the medical waste.

## EXPERIMENTAL SECTION

### 2.Methods and Materials

### 2.1Sampling method

In this study, combined sampling method with two-stage sampling and random sampling was adopted according to *Technical specifications on sampling and sample preparation from industry solid waste*(HJ/T 20-1998). Because a batch of waste are filled and loaded by many containers successively, such as garbage bags, garbage cans, garbage trucks, and each container is scattered, sampling by stages is necessary[17].First, randomly selected $n_1$ containers from total numbers $N_0$ of the batch of waste, and then collected $n_2$ samples from each container of $n_1$. It was recommended that when $N_0 \leq 6$, $n_1=N_0$; when $N_0 \geq 6$, $n_1$ is calculated by formula: $n_1 \geq 3 \cdot N_0^{1/3}$. In the second stage, the number of samples is $n_2 \geq 3$， that's to say, at least three samples are collected from each container randomly.

The samples in this paper was collected from the incineration plant in Chengdu City. About 1.0 m3 was collected from 20 garbage trucks(the load of each truck is 5 tons), and the reducing of mixed samples was performed by quartering. Then the samples was divided into seven parts, including bamboo ware, fabric, paper, plastics, wastes from animal anatomy, non-combustible material and other wastes. The relative content of each component was measured in table 1 as follows.

**Table 1 the measured results of the content of each component (wet basis)**

| Name of component | Bamboo ware | Fabric | Paper | Plastics | Wastes from animal anatomy | Non-combustible material | Other waste |
|---|---|---|---|---|---|---|---|
| content(%） | 0.40 | 0.96 | 2.84 | 7.60 | 35.88 | 14.60 | 37.72 |

Then, the moisture content of each component was measured in table 2 as follows.

**Table 2 the moisture content of each component**

| Name of component | Bamboo ware | Fabric | Paper | Plastics | Wastes from animal anatomy | Non-combustible material | Other waste |
|---|---|---|---|---|---|---|---|
| content(%） | 53.50 | 60.00 | 60.67 | 36.67 | 58.67 | 15.00 | 33.67 |

As for the moisture content of the whole sample, it was calculated by the following formula:

$$C_w = \sum_{i=1}^{n} C_{i(w)} \times C_{i(wet)} \quad (1)$$

In which, $C_{i(w)}$ is the moisture content of *i* component; $C_{i(wet)}$ is the content of *i* component (wet basis); *n* is the number of compontent. The result of the moisture content of the whole sample was $C_w$=41.24%.

### 2.2Measurement and calculation of calorific value

The component and calorific value of medical waste is foundation data of incineration, which determines the design and operation parameters of incinerator. There are two kinds of measured methods of calorific value currently. The first is to estimate the calorific value of waste by element analysis; the second is to measure calorific value of mixed sample by Bomb Calorimeter. However there are great differences between the measured value by these two methods and the actual value Because of the complex chemical elements of medical waste, the former method is very cumbersome; and the other method is impractical due to no enough samples. In this paper, a more practical measured method developed by energy-saving technical service center of Chengdu City was adopted [18].

The high calorific value of each component in the dry basis was measured by Bomb Calorimeter in table 3 as follows.

**Table 3 the high calorific value of each component in the dry basis**

| Name of component | Bamboo ware | Fabric | Paper | Plastics | Wastes from animal anatomy | Non-combustible material | Other waste |
|---|---|---|---|---|---|---|---|
| calorific value (kJ/kg） | 16251.2 | 15798.7 | 16822.2 | 28806.9 | 10273.4 | 0 | 4586.4 |

Then, the content of each component in the dry basis was measured in table 4 as follows.

**Table 4 the content of each component in the dry basis**

| Name of component | Bamboo ware | Fabric | Paper | Plastics | Wastes from animal anatomy | Non-combustible material | Other waste |
|---|---|---|---|---|---|---|---|
| content(%） | 0.32 | 0.65 | 1.90 | 8.19 | 25.24 | 21.12 | 42.58 |

The high and low calorific value (wet basis) of mixed sample were calculated by the followed formula.

①high calorific value(dry basis) of mixed sample $= \sum_{i=1}^{n}(i_{hcv} \times c)$ (*hcv* is high calorific value, *c* is content of component)=7379(kJ/kg)

②high calorific value (wet basis) of mixed sample=high calorific value(dry basis) of mixed sample×(1－moisture content(%))＝4336(kJ/kg)

③low calorific value (wet basis) of mixed sample≈high calorific value (wet basis) of mixed sample－2440×moisture content(%)≈3329(kJ/kg)

## RESULTS AND DISCUSSION

The method of classifying and collecting of medical waste in the United States was used in this study [19]. Infectious waste and general waste will be placed separately in packages or containers with different color. The classification, component and characteristics of medical waste from incineration plant in Chengdu City were listed in the following table 5.

**Table 5 the classification, component and characteristics of medical waste**

| Classification | Component | Content (%) | Moisture Content (%) | Theoretical high calorific value | Theoretical low calorific value | Actual low calorific value |
|---|---|---|---|---|---|---|
| $A_1$ (Red bags) | Surgical incision | 95 | 80 | 18592-27880 | 1766-8366 | 2789 |
| | Plastics | 2.5 | 0.8 | 32540-46480 | 0-2324 | 418 |
| | Surgical dressing | 2.3 | 19 | 18590-27880 | 0-1394 | 186 |
| | Sterilized cotton | 0.2 | 0.2 | 25560-32530 | 0-65 | 46 |
| $A_2$ (Orange bags) | Infectious mass | 80 | 75 | 20920-37180 | 1673-14874 | 3486 |
| | Plastics | 10 | 0.5 | 32530-46480 | 0-6972 | 976 |
| | Glasses | 2.5 | 0 | 0 | 0 | 0 |
| | Preoperative waste | 7.5 | 25.5 | 18590-20920 | 0-1882 | 1394 |
| $A_{3a}$ (Yellow bags) | Gauze, bandage, paper | 75 | 12 | 18590-27880 | 7809-25099 | 14874 |
| | Plastic injector | 15.3 | 0.5 | 22540-46480 | 3350-6970 | 7553 |
| | Syringe needle | 6 | 0.5 | 139 | 7-11 | 12 |
| | Excreta | 3.5 | 80 | 0-23240 | 0-26 | 69 |
| | Sterilized cotton | 0.2 | 7 | 16268-32540 | 0-65 | 35 |
| $A_{3b}$ (Yellow bags) | Plastics | 55 | 0.2 | 32540-46480 | 16100-27880 | 20916 |
| | Scalpel | 2.5 | 0.3 | 139 | 0-7 | 0 |
| | fibrous material | 7.5 | 1.5 | 18590-27880 | 790-2789 | 1511 |
| | Excreta | 10.8 | 95 | 0-23240 | 0-232 | 69 |
| | Sterilized cotton | 4.2 | 3 | 25560-32540 | 0-65 | 46 |
| | Glasses | 20 | 0 | 0 | 0 | 0 |
| $A_{3c}$ (Yellow bags) | Gauze and bandages | 25 | 10 | 18590-27880 | 651-8366 | 2324 |
| | Plastics and petri dish | 55 | 0.5 | 32540-46480 | 16105-27880 | 20916 |
| | Scalpel and glasses | 10 | 0.5 | 139 | 0-14 | 0 |
| | Excreta | 10 | 89 | 0-23240 | 0-465 | 232 |
| $B_1$ (Blue bags) | Animal anatomy | 94 | 87 | 20920-37180 | 1880-14870 | 3254 |
| | Plastics | 2 | 0.5 | 32536-46480 | 0-46480 | 2324 |
| | Glasses | 1 | 0 | 0 | 0 | 0 |
| | Preoperative waste | 3 | 12.5 | 18592-20916 | 0-1880 | 1394 |

*Note: modified from [19].*

From table 5, in $A_1$(red bags), the component of medical waste are surgical incision, plastics, surgical dressing, sterilized cotton, the low calorific value of the whole bag is 3439 kJ/kg, and the waste from surgical incision accounted for more than 80%.In $A_2$(orange bags), the low calorific value of the whole bag is 5856 kJ/kg, and the infectious waste from surgical incision (3486kJ/kg) accounted for more than 60%. In $A_{3a}$ (yellow bags), the low calorific value of the whole bag is 22543kJ/kg, and the gauze, bandage and paper accounted for more than 66%. In $A_{3b}$ (yellow bags), the low calorific value of the whole bag is 22543kJ/kg, and the plastics accounted for more than 90%. In $A_{3c}$(yellow bags), the low calorific value of the whole bag is 23472kJ/kg, and the plastics and petri dish accounted for more than 85%. In $B_1$ (blue bags), the low calorific value of the whole bag is 6972kJ/kg, and the animal anatomy and plastics accounted for more than 47% and 33%.

It can be concluded that medical waste has higher calorific value and volatile matter, especially in plastic, rubber, fibrous material and the waste from surgical incision, is over 65% of combustible component in medical waste. And the combustible component accounted for more than70% of the whole[20], so it is entirely feasible to disposal medical waste by high temperature incineration or pyrolysis. But medical waste has characteristic of high concentration of water and evident variation of calorific value, auxiliary fuel must be added to guarantee higher furnace temperature in incinerator.

## CONCLUSION

(1)Medical waste has higher calorific value and volatile matter, which can realize the sustained combustion of waste. The combustible component accounted for more than70%, so it is entirely feasible to disposal medical waste by high temperature incineration or pyrolysis.
(2) It is an effective method to estimate the calorific value developed by energy-saving technology service center of Chengdu City. The measured result is closer to the real value and credible, it can provide more accurate and timely information for the design and operation of incineration system of medical waste.
(3)Because of complex component and characteristics and full of more uncertainty, it put forward higher requirements for the system's performance of high temperature incinerator in the actual research and development. Medical waste has characteristic of high concentration of water and evident variation of calorific value, auxiliary fuel must be added to guarantee higher furnace temperature in incinerator.

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