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HCl and PCDD/Fs Emission Characteristics from Incineration of Source-Classified Combustible Solid Waste in Fluidized Bed

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Abstract: A fluidized bed incineration experiment was performed by means of refuse-derived fuel (RDF) from source-classified garbage to study the emission characteristics of the hydrogen chloride (HCl) pollutants and polychlorinated dibenzo-p-dioxins and dibenzofurans (PCCD/Fs). This study analyzed the influence of material ratio, incineration temperature, and the additive volume of calcium oxide (CaO) on the emission characteristics of HCl and dioxins. Results show that plastics in garbage are direct factors in the emission of HCl and PCCD/Fs. The HCl yield significantly increases when plastic component ratio increases from 35% to 45%. The RDF containing 45% plastics releases the highest toxicity concentration of total dioxins, whereas the RDF of 35% plastics releases the lowest dioxins toxicity concentration. The optimal incineration temperature is 850 °C, the emission concentrations of HCl and PCCD/Fs significantly reduce at 850°C. Adding CaO in combustible solid waste can effectively reduce the emission concentration of HCl and PCDD/Fs in flue gas.

Keywords: Source-classified garbage; Combustible solid waste; Fluidized bed incineration; HCl; PCCD/Fs

1. Introduction

At present, the increasing of municipal solid waste(MSW) has become a serious challenge for environmental management and pollution control every year. In China, the annual output of municipal solid waste outnumber 260 million ton and it still increases with the rate of 8% to 10% annually. The accumulated stock of municipal solid waste is about 7 billion in China and more than two thirds of cities are surrounded by garbage in the nationwide[1,2]. Therefore, it is necessary to explore a lower pollution and higher energy recovery treatment for MSW. The methods of waste treatment include landfilling, high temperature composting and incineration power currently[3-5]. The incineration has been developing rapidly because of the significant effect of volume reduction, resource utilization and less environmental pollution. At present, the incinerator mainly includes the grate furnace incinerator, fluidized bed incinerator and rotary kiln incinerator[6-8]. Compared with other incineration methods, the technology of fluidized bed incineration can avoid rapid cooling and thermal shock phenomenon for steady continuous burning as a result of its advantage of large heat storage capacity. We also can take comprehensive measures to decrease secondary pollution and to dispose harmful substances generated in fluidized bed incineration. In consequence, the technology of fluidized bed incineration has been widely used because of the characteristics of high combustion efficiency, wide fuel adaptability, wide range of load regulation and low pollutant emission[9,10]. Waste incineration will cause secondary air pollution. Especially, the combustible component containing chlorine (such as PVC) and chloride in waste will produce the dangerous pollutants of HCl, polychlorinateddibenzo-p-dioxins and polychlorinated dibenzofuran which are enormously harmful to the environment and human body in incineration. Therefore, it is very necessary to research the emission characteristics of HCl and dioxins in MSW incineration for the oligosaprobic and resource utilization of MSW.

Numerous scholars have confirmed that incinerating refuse-derived fuel (RDF) manufactured by municipal solid waste can reduce the emissions of dioxins and other pollutants[11,12]. Incinerating source-classified combustible solid waste with low moisture content and high calorific value is the most effective means of waste reduction in fluidized bed, and also is an excellent method of converting combustible solid waste into efficient energy. Hydrogen chloride (HCl) is generated during incineration. This process corrodes flue gas treatment facilities directly and promotes the generation of toxic dioxin substances because of the huge amounts of chlorine (Cl) and inorganic salts in municipal household garbage[13,14]. Dioxins are considered to be the most hypertoxic organic pollutant among all pollutants generated by waste incineration. Therefore, the optimal incineration operating modes and conditions is one of the decisive factors for low pollutant emission in flue gas.

Xie et al.[15] deemed that the adding of calcium oxide (CaO) decreases the emissions of sulfur dioxide (SO_2) and HCl. Partanen et al.[16] studied the influence of fluidized bed temperature on CaO dechlorination, and the absorption characteristics of CaO to HCl in flue gas. The aforementioned research found that the absorption of CaO to HCl is in connection with the humidity of flue gas when incineration temperature is 850 °C. A stable and sufficient combustion condition also can decrease dioxins yield. The United States Environmental Protection Agency proposed that efficient combustion is one of the most effective measures to control the emission of polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs)[17]. In addition to the above mentioned factors, there are also many other factors to influence the dioxins yield. For example, incineration temperature can influence the generation of PCDD/Fs significantly, however there is no obvious effect on homolog distribution according to the current study[18]. A key method to control the emission of dioxins is to maintain incineration temperature above 800 °C because dioxins can be decomposed above this temperature. Therefore, the incineration temperature of fluidized bed is an important factor in dioxins generation[19,20]. The dioxins yield also can reduce when some additives is added into MSW sometimes. Ruokojarvi et al.[21,22] found that injecting chemical inhibitors such as dimethylamine and ammonia into a combustor at 670 °C can effectively decrease dioxins concentration in flue gas. M.Y. Wey et al.[23] studied the effect of adding CaO on formation of pollutants (HCl, chlorophenols (CPs) /chlorobenzenes (CBs), PAHs, benzene, toluene, ethylbenzene and xylene (BTEX)) by organic chloride in waste incineration using fluidized beds thoroughly and comprehensively. The above-mentioned research found that adding CaO inhibited the production of HCl, CBs and CPs, but did not seriously affect PAHs and BTEX. Yan et al.[24] conducted assessment research on the emission characteristics of dioxins generated in fluidized bed mixed incineration of coal and urban solid refuse.

Currently, the most researches are mainly aimed at the emission characteristics of HCl, dioxins and other pollutants when source-classified combustible solid wastes are incinerated in conventional fixed bed reactor. While in this research, combustible solid waste were incinerated in pilot-scale fluidized bed reactor and the influences of source-classified material composition, additives, and incineration temperature on HCl and dioxins emissions were also considered. The research results can not only provide fundamental research for the resource utilization of the municipal solid waste, also provide better guidance for optimizing the furnace, achieving zero emission and using energy efficiently.

2. Experiments

2.1. Experimental materials

Combustible solid wastes with high-calorific values were sorted by source-classified technology as experimental materials. The solid wastes were collected from the domestic garbage of Luzhi Town in Jiangsu Province. The typical components of combustible solid waste include waste plastics, waste fabrics, waste paper and wood chips. All the typical components are dried in drying oven at 100℃ for two hour in order to eliminate the influence of moisture on experimental study. Then the materials were crushed into 8 mm molding particles using a crushing appliance easily. Finally, the experimental samples particles were made into RDF by the modeling machine according to the typical component proportion which is studied in this experiment. The ultimate and proximate analyses of the RDF are shown in Table 1.

2.2. Experimental apparatus

The experiment was performed using a small pilot-scale fluidized bed, the structure of fluidized bed incinerator is shown in Fig. 1. The experimental table includes a fluidized bed body, a feeding system, an ignition system, an air supply system, a temperature and pressure control system, and a flue gas analyzer. The height and diameter of the fluidized bed combustor are 1500 mm and 60 mm, respectively.

2.3. Experimental Process

In this research, the quartz sands are put into reactor as bed materials for the small pilot fluidized bed incinerator and the height of bed materials is about 100mm in stable operation state. The ventilation quantity of entrance is about $4.8m^3/h$ and the incinerator temperature vary from 700℃-900℃ during runtime. When the fluctuation of bed temperature is tiny, the reactive materials are put into incinerator with the continuous feeding. The feeding speed is about 500g/h. The detailed operating steps are as below:

1) Open the pilot circulating fluidized bed boiler. When the fluidized bed temperature reaches the reaction temperature, then switch on spiral feeder power and transport reaction materials from the feed inlet;
2) Fine-tune the quantity of primary air and observe the differential pressure gauge. Then connect the absorption equipment of dioxins;
3) The Gasmet gas analyzer is blown out with high purity nitrogen before each experiment test;
4) Open Gasmet gas analyzer sample device valve to measure the instantaneous release concentration of HCl;
5) The PCDD/Fs are analyzed and measured according to the United States EPA1613 method. The 17 poisonous 2,3,7,8-PCDD/Fs are tested using the method of HRGC/HRMS (high resolution chromatography and high resolution mass spectrometry). The test of dioxins includes the pretreatment and analysis progress. Preprocessing steps are Soxhlet extraction, purification and concentration, and then analyze the concentrates utilizing the analytical equipment. Finally, the dioxins content are tested by the JMS-800D HRGC analyzer and HRMS analyzer manufactured by Japan Electron Optics Laboratory Co., Ltd.

3. Results and discussion

3.1. The emission characteristics of HCl

3.1.1. Influence of material ratio on the emission characteristics of HCl

The Fig.2 shows the average emission concentration of HCl when the RDF containing 45%, 35%, 25%, 15%, and 10% plastic respectively was incinerated at 850℃,the oxygen content of furnace exit at 9%. As shown in the Fig.2, HCl concentration increases with increasing plastic content. The HCl concentration in exhaust gas is the lowest (2.60 mg/m^3) when the plastic content accounts for 10%. The HCl concentration is 10.21 mg/m^3 when the plastic content accounts for 45%. The emission load of HCl significantly increases from 6.58 mg/m^3 to 10.21 mg/m^3 when the plastic content increases from 35% to 45%. Compared with the other components of RDF, the chlorine content of plastics in RDF is the highest. The chlorinity of RDF increases with the augment of plastic content and then the HCl emission increases. In incineration process, the organic chlorides of household refuse, such as polyvinyl chloride (PVC), also can produce HCl. The substituent of chloride could be removed. The reaction equation as shown below:

$$RDF+O_2 \rightarrow CO_2+H_2O+HCl+ \text{ incomplete comburent.} \quad R_1$$

3.1.2. Influence of bed temperature on the emission characteristics of HCl

Fig.3 indicates the variation trend of HCl emission concentrations when the RDF is incinerated at 750 °C, 800 °C, 850 °C, and 900 °C respectively and the oxygen content of furnace exit at 9%. The RDF is composed of 45% plastics, 15% paper, 20% wood, 15% fiber, and 5% CaO. The generation and inhibition reaction pathways are as follows:

$$RCl + O_2 \rightarrow CO_2 + H_2O + HCl, \quad R_2$$

$$HCl + CaO \rightarrow CaCl_2 + H_2O, \quad R_3$$

$$CaCl_2 + SO_2 + H_2O \rightarrow CaSO_4 + 2HCl, \quad R_4$$

$$2HCl + 1/2O_2 \Leftrightarrow Cl_2 + H_2O. \quad R_5$$

As shown in Fig.3, HCl concentration increases with increasing the bed temperature. However, the influence of bed temperature on HCl yield is getting less stark with the increase of bed temperature. The cause for these results is that HCl is mainly produced at low-temperature areas. The higher the fluidized bed temperature is, the higher the partial pressure of RCl vapor becomes. Thus, the reaction R_2 is more violent toward the right, the more HCl is generated. The removal of calcium compound to chlorine is the best in 600°C to 700°C. While when the bed temperature exceeds 650°C, the removal efficiency of CaO to chlorine decreases with the increase of bed temperature. Thus the influence of bed temperature on HCl yield in exhaust gas is noteworthy in ours laboratory study.

In combustible solid waste incineration process, the most chlorine-bearing compound can be decomposed at the low temperature section from 200°C-350°C to achieve side group elimination reaction, which produces HCl and conjugate and double-bond polyene hydrocarbons. With increasing temperature, the polyene hydrocarbons degrade randomly into generate tar and micromolecule gaseous hydrocarbons in aerobic conditions, which diffusive combust with the surrounding O_2. Therefore, the most HCl are released during devolatilization when temperature ranges from 200°C to 350°C. When the temperature ranges from 750°C to 900°C, the conversion rate curve of HCl is gentle.

3.1.3. Influence of CaO quantity on the emission characteristics of HCl

CaO was used to remove the HCl of exhaust gas in this experiment. The RDF containing 3%, 5% and 7% CaO were incinerated respectively when bed temperature is 850°C and oxygen content of furnace exit is 9% in fluidized bed. Figs.4-5 show the HCl emission experimental results of two groups of RDF (Table 2) with different CaO quantities respectively. As shown in Figs.4-5, we can find that the HCl removal efficiency increases while HCl concentration decreases with increasing CaO. From the Figs.4-5, the HCl yield of the first group RDF is higher than the second group RDF added into biomass. After adding biomass, the ratio of plastic containing the most chlorine reduces. The K and Na existing in biomass also can react with HCl. In summary, the HCl concentration of RDF containing biomass is significantly lower than that of the RDF without biomass.

The CaO added in RDF can react with chlorine-bearing compound in the incineration process and then inhibits the release of HCl. When the amount of CaO is too little, the limited quantity of CaO reacts completely, thus the HCl concentration in Fig.2 would increase suddenly.

In actual engineering, the molar ratio of Ca/Cl is an important data for dechlorination. Thus it is very important to confirm the range of Ca/Cl molar ratio reasonably. Fig.6 shows the HCl average emission concentration under different Ca/Cl mole ratios. We can conclude that the increase of Ca/Cl can reduce the HCl yield from Fig.6. However, the the HCl removal efficiency becomes weaker and weaker with increasing CaO. Related data reveal that there is not obvious dechlorination when Ca/Cl ratio is greater than 6. With increasing Ca/Cl molar ratio, the remaining particles of CaO become unevenly distributed. The adsorption between the CaO particles and gas phase HCl or chlorine is reduced, and then decreases the effective utilization of reaction. In addition, HCl concentration becomes extremely low when Ca/Cl reaches a certain value. In summary, there is not very obvious dechlorination even if the CaO continues to increase.

3.2. The emission characteristics of dioxins

3.2.1. Influence of material ratio on the emission characteristics of dioxins

Figs.7 (a,b,c) show the changing trend of dioxins concentration when RDF containing 25%, 35%, and 45% plastics was incinerated respectively in fluidized bed, the bed temperature is 850°C and the oxygen content of furnace exit is 9%. There are different distributions of dioxins and homolog productions when the three RDFs with different plastic contents are incinerated respectively. In PCDDs, the toxic concentrations of 2,3,7,8-TCDD and 1,2,3,7,8-PeCDD are higher, whereas the yield of 2,3,7,8-TCDF, 1,2,3,7,8-PeCDF, and 2,3,4,7,8-PeCDF is more in PCDFs homologous substantia. Based on the overall yield of dioxins homolog, the main dioxins contributors are 2, 3, 7, 8-TCD and 2, 3, 4, 7, 8-PeCDF. Meanwhile, based on the toxic concentration distribution of PCDDs homolog generated by RDF with different plastic content in incineration, the toxicity of each product shows a decreasing trend with increasing the degree of chlorination. The toxicity concentrations of OCDD and OCDF generated by the RDF containing 35% and 25% plastics respectively are not detectable.

The toxic concentration of 2,3,7,8-TCDD in PCDDs and 2,3,7,8-TCDF, 1,2,3,7,8-PeCDF, and 2,3,4,7,8-PeCDF in PCDFs produced by RDF with 45% plastics always are the highest, while the toxic concentration above-mentioned dioxins generated by RDF with 35% plastics is the lowest. The other dioxins homolog toxic concentration increases as the plastic content of RDF increases. Since the toxicity of different dioxins is disparate, the total toxic concentration of dioxins produced by the RDF with 45% plastics is the highest, which is 0.18 ng I-TEQ/Nm^3; that of the RDF with 25% plastics is second-largest, which is 0.1425ng I-TEQ/Nm^3; the total toxic concentration of the RDF with 35% plastics is the lowest, which is only 0.135ng. In summary, the yield of dioxins have correlativity with chlorine content, the production of dioxins can be reduced by means of controlling the plastic content of RDF.

3.2.2. Influence of bed temperature on the emission characteristics of dioxins

Figs.8 (a,b,c) reveal that the distributions of PCDDs and PCDFs homologs, as well as the change of total toxicity concentration in flue gas when the RDF containing 45%plastic content is incinerated at 750°C and 850°C respectively and the oxygen content of furnace exit in 9%. Previous research has shown that[18] combustion temperature exerts a significant influence on PCDD/Fs generation, however the influence of temperature on homolog distribution is not obvious. As shown in Figs.8 (a,b,c), dioxins and its homolog distribution and total toxicity concentration are different when the incineration temperature of the fluidized bed changes. At 750°C, the toxicity concentration of seven PCDDs homologs accounts for 60% of the total 17 dioxins homologs gross, which is 1.408ng I-TEQ/Nm^{-3}. In PCDDs congener, the toxic concentration of 1, 2, 3, 7, 8-PeCDD is the highest, which reaches 0.3909ng I-TEQ/Nm^{-3}. The second is 2, 3, 7, 8-TCDD, which has a toxic concentration of 0.1866ng I-TEQ/Nm^3. With increasing the number of chlorine atoms replaced, the quantity of OCDD is 0.0023ng I-TEQ/Nm^3. In PCDFs homolog, the toxic concentration of 2,3,4,7,8-PeCDF is the highest, which reaches 0.2255ng I-TEQ/Nm^3. With increasing the number of chlorine atoms replaced, the toxic concentration of PCDFs homolog reduces gradually after increases firstly. In summary, when the bed temperature is 750 °C, the total toxic concentration of dioxins in flue gas exceeds 1ng I-TEQ/Nm^3, which is the emission standard in China. When the bed temperature is 850°C, the distribution of dioxins homolog is changed. In PCDDs homolog, the toxic concentration content of 2, 3, 7, 8-TCDD with the highest toxicity is the highest, which reaches 0.0300ng I-TEQ/Nm^3. This is because that the lower-chlorinated dioxins congeners increase and then the amount of total dioxins yield is less. In summary, the higher temperature is beneficial to the decomposition of higher-chlorinated dioxins. With increasing the number of chlorine atoms replaced, the toxic concentration of the PCDDs homolog decreases. The lowest is that of OCDD with 0.0002ng I-TEQ/Nm^3. Compared with the 750°C, the changed trend of PCDFs homolog distribution is tiny at 850°C. The major dioxins contributor remains 2, 3, 4, 7, 8-PeCDF, which reaches 0.034ng I-TEQ/Nm^3 and which also is the main toxic dioxin in household refuse. The generation of lower-chlorinated PCDFs is inhibited at 850°C. According to the dioxins homolog distribution and its total toxicity concentration at different temperatures, the increase of incineration temperature can decrease dioxins generation obviously. When the incineration temperature is 750°C, the total dioxin generated by RDF incineration is 1.408ng I-TEQ Nm^{-3}. However, when the incineration temperature is 850°C, the total dioxins are lower, which is 0.1469ng I-TEQ/Nm^3 and approximated to the international emission standard of 0.1ng I-TEQ/Nm^3. At 750°C, The emission of dioxins is significantly higher than the international standard of 0.1ng I-TEQ/Nm^3 and close to the emission standard of China. In consequence, dioxins generation are closely related to the fluidized bed incineration temperature, the increase of fluidized bed temperature can effectively decrease total dioxins emission.

3.2.3. Influence of adding CaO on the emission characteristics of dioxins

The dioxins homolog distribution and its total toxicity concentration in flue gas are shown in Figs.9 (a,b,c) when the RDF containing 3% and 7% CaO respectively is incinerated at 850°C and the oxygen content of furnace exit in 9%. The RDF composition ratio of plastics/wood/paper is 1:1:1.

Figs.9 (a,b,c) show that there is a very weak influence of adding different amounts of CaO on the distribution of PCDDs and PCDFs homologs. In situation of adding 3% CaO, the distribution diagram of PCDDs shows that the toxicity concentration distribution of homologs decrease with the increase chlorinated PCDDs. The toxic concentration of low-chlorinated 2,3,7,8-TCDD is the highest, which is 0.0567ng I-TEQ Nm^{-3}, but the higher-chlorinated OCDD is not detectable. For the distribution of PCDFs homolog, the toxicity concentration of 2,3,4,7,8-PeCDF is the highest, which reaches 0.0657 ng I-TEQ Nm^{-3}. The toxicity concentration of the higher-chlorinated PCDFs homolog becomes smaller and smaller until OCDF isn't detected with increasing the number of chlorine atoms replaced. Compared with the addition of 3% CaO, the toxic concentration of PCDDs homologs and PCDFs homologs dioxins generated by the RDF are significantly decreased for adding 7% CaO. The CaO added in RDF removes some chlorine, as a result, HCl generated by incineration decreases in flue gas and then reduces the emission of dioxins. In summary, the adding of alkali compound CaO can effectively decrease dioxins generation in the incineration.

4. Conclusions

1) The emission of HCl is closely related to the influence factor of normal pollutant. For the RDF with different plastic content, the yield of HCl increases with the increase of its plastic content. When plastic content ratio increases from 35% to 45%, the increases of HCl emission load is faster which increases from 6.58mg/m^3 to 10.21mg/m^3. The yield of HCl also increases with the increase of chlorine content. When the chlorine content of RDF is higher than 1.5%, the increase of HCl yield slows down. The influence of the chlorine source on dioxins is studied by means of adjusting the chlorine-containing plastic proportion in the RDF. When the plastic content is different in the RDF, the yield of dioxins and the distributions of dioxins homolog also are different in incineration. For the quantity of every dioxins homolog, the major production of dioxins are 2,3,7,8–TCDD and 2,3,4,7,8–PeCD. The toxic concentration of PCDDs homolog produced by the RDF with different plastic contents shows a decreasing trend with the increase of the degree of chlorination. For the total concentration of dioxins, the dioxins produced by the RDF with 45% plastics are highest while the dioxins produced by the RDF with 35% plastics are the lowest. In summary, the reasonable plastics content are beneficial to inhibit the emissions of dioxins.
2) When the fluidized bed temperature varies from 750 °C to 850 °C, most HCl are produced in the low-temperature area of fluidized bed and then the increase of HCl concentration is also not obvious. When the incineration temperature is 750 °C, the total yield of dioxins reaches 1.408ng I-TEQ Nm^{-3}, which approaches the emission standard of China. However, when the incineration temperature is 850 °C, the total yield of dioxins reaches 0.1469ng I-TEQ Nm^{-3}, which approaches the international emission standard. Therefore, the increase of incineration temperature can decrease dramatically the toxic concentration of the dioxins in the fluidized bed incinerator.
3) When antichlor CaO is added in the RDF, with the increase of CaO additive amount, the

HCl yield gradually decreases while the trend of decrease is more and more slowly. In other words, the influence of CaO on dechlorination is restricted when the content of CaO reaches a certain value. Adding alkali compound CaO can decrease the toxic concentration of dioxins. The toxic concentrations of PCDDs and PCDFs homologs and the dioxins produced by the RDF with 7% CaO decrease sharply compared with the addition of 3% CaO.

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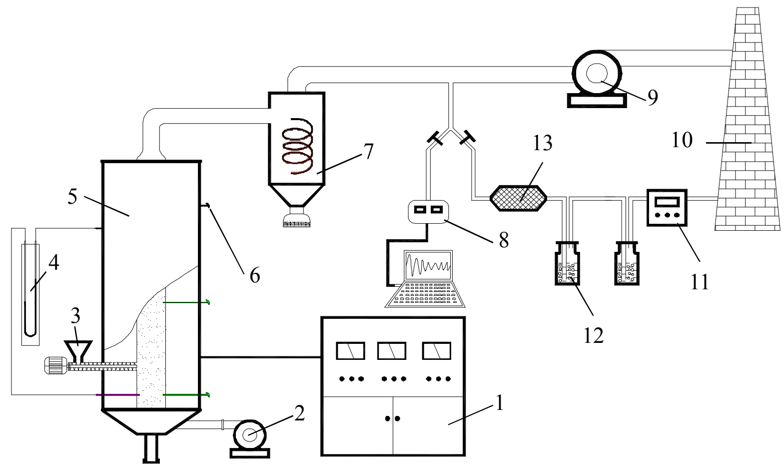
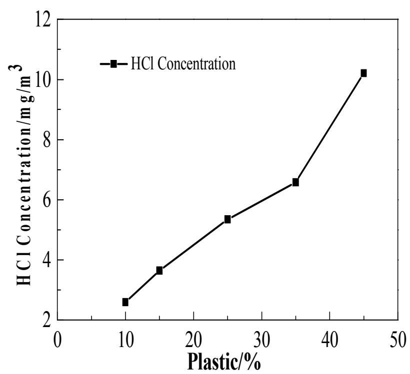


Fig. 1. Schematic diagram of the fluidized bed test bench:

(1) Intelligent control cabinet, (2) Root blower, (3) Screw feeder, (4) Pressure measuring device, (5) Fluidized bed, (6) Temperature measuring device, (7) Cyclone separator, (8) Gasmet gas analyzer, (9) Induced draft fan, (10) Chimney, (11) Pump, (12) Toluene absorbing liquid, and (13) XAD-2 resin.



(2)

Fig. 2. HCl average emission concentration under different material ratios.

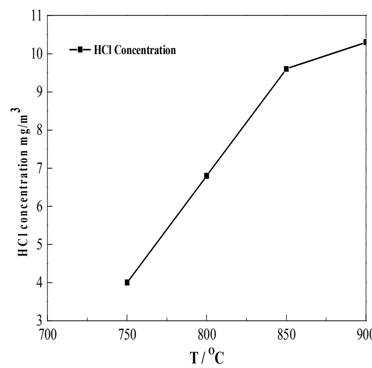


Fig. 3. HCl average emission concentration under different bed temperatures.

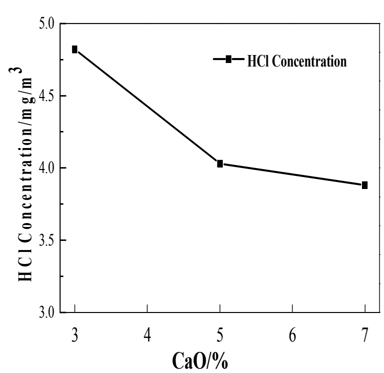


Fig. 4. HCl average emission concentration under different CaO quantities of two components.

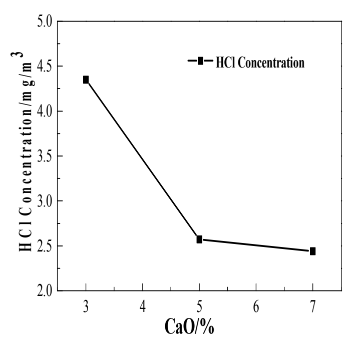


Fig. 5. HCl average emission concentration under different CaO quantities of three components.

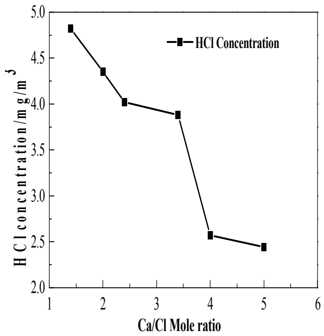
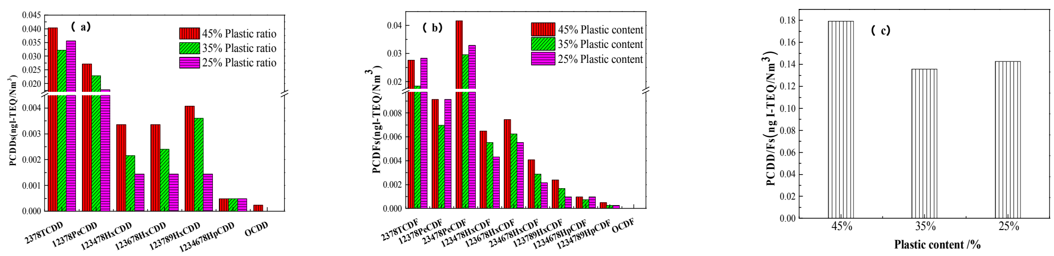
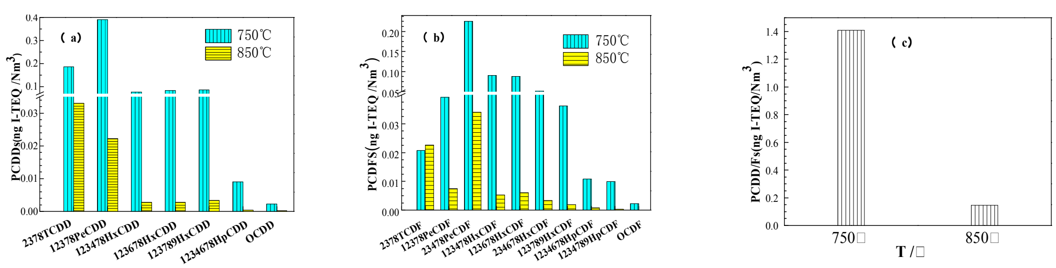


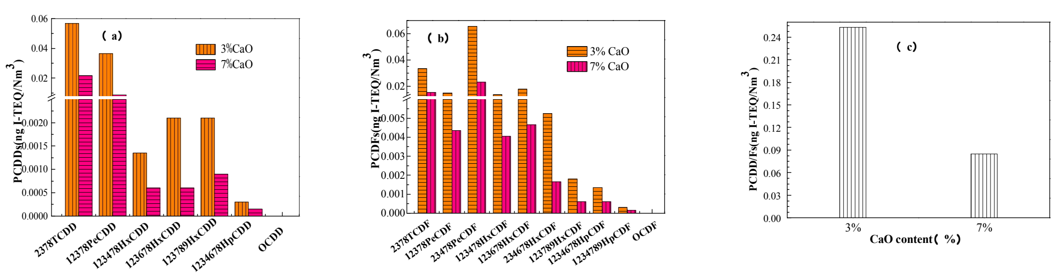
Fig. 6. HCl average emission concentration under different Ca/Cl mole ratios.



Figs. 7 (a,b,c). PCDD/Fs distribution under different plastic proportions.



Figs. 8 (a,b,c). PCDD/Fs distribution under different incineration temperatures.



Figs. 9 (a,b,c). PCDD/Fs distribution under different CaO quantities.

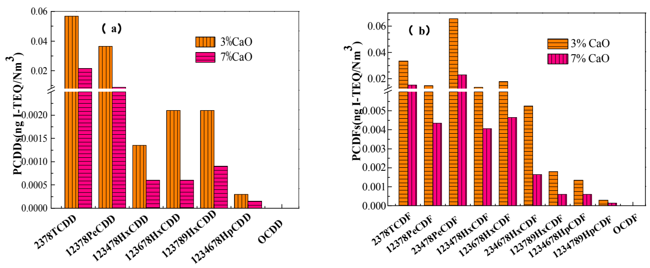
Table 1. Ultimate and proximate analyses of the RDF.

Sample	Moisture /%	Volatile /%	Fixed carbon /%	Ash content /%	C/%	H/%	O/%	N/%	S/%	Cl/%	Lower calorific value ($kJ\cdot kg^{-1}$)
45% plastic	1.59	83.05	6.91	3.46	60.88	8.96	18.68	0.941	0.105	1.443	27465
35% plastic	1.66	81.43	8.48	3.41	58.07	7.99	21.21	1.43	0.108	1.367	24660
25% plastic	1.74	79.80	10.05	3.40	55.53	7.02	23.73	1.91	0.132	1.111	21855
15% plastic	1.81	78.18	11.62	3.39	52.98	6.05	26.26	2.40	0.114	0.945	19050
10% plastic	2.16	76.64	12.31	3.66	50.22	5.62	29.39	2.14	0.10	0.758	17818

Notes: The ratios for plastic, paper, wood, fabrics, and CaO in the RDF are 45%, 15%, 20%, 15%, and 5%, respectively, for 45% plastic; 35%, 15%, 20%, 25%, and 5%, respectively, for 35% plastic; 25%, 15%, 20%, 35%, and 5%, respectively, for 25% plastic; 15%, 15%, 20%, 45%, and 5%, respectively, for 15% plastic; and 10%, 15%, 30%, 40%, and 5%, respectively, for 10% plastic.

Table 2. The experimental results of different CaO quantities.

Fuel	Paper1 Plastic1	Paper1 Plastic1	Paper1 Plastic1	Paper1 Plastic1 Biomass1	Paper1 Plastic1 Biomass1	Paper1 Plastic1 Biomass1
CaO	3%	5%	7%	3%	5%	7%
Ca/Cl	1.4	2.4	3.4	2	4	5
HCl concentration (mg/m^3)	4.82	4.02	3.88	4.35	2.57	2.44



Adding different CaO quantity in the combustible solid waste can inhibit the production on PCDD/Fs in incineration.