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Effective incineration technology with a new-type rotary waste incinerator

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Abstract: The technology of steady combustion in a new type of rotary incinerator is firstly discussed. The formation and control of HCl, NOx and SO_2 during the incineration of sampled municipal organic solid waste are studied with the incinerator. Results showed that the new model of rotary incinerator can effectively control and reduce the pollutant formations by post combustion.

Keywords: rotary incinerator; municipal organic solid waste; HCl, NOx, SO_2 control

Introduction

Increasing amount of wastes produced by either inhabitants or industrial companies require to use efficient ways for the disposal. The recent focus on incineration has been on environmental impact in addition to performance. In particular, the limitations, as well as the advantages, of incineration are increasingly recognized. Incineration is not a waste disposal method but rather a waste processing technology. Municipal solid waste incinerators (MSWI) and hospital medical waste incinerators (HMWI) can be operated as components of integrated waste management systems. They offer a reduction in both the mass, about 70%, and the volume, about 90%, of the waste subjected to final disposal, as well as the possibility of energy recovery.

In China, the discharge amount of municipal solid wastes now is about 1.4×10^6 t/a and the growth rate is 8%—10%. The traditional means of disposal of municipal solid wastes has been either open dumping or landfill. At present, it is important for us to develop waste combustion study and new technology according to the situation of China. Because wastes collected in China are different from most developed countries and mainly in mixed way, the characteristics such as its composition, moisture content, calorific value and so on are different too. Suitable technologies and equipment are the most important prerequisite to the development of combustion now in China. Therefore, simply adoption of foreign waste combustion technology or coal burning technology will not avoid difficulties in realization of effective combustion and controlling pollutant problems.

1 Experimental conditions

1.1 New type rotary waste incinerator and characteristics

Based on the relative combust technics developed internationally and domestically and with Chinese economic level considered, the experiments were designed and carried out in a central water-cooling rotary incinerator, which is shown in Fig.1. The incinerator can be divided into four special zones: A is the zone of warming-up and drying. The main heat source is by the radiation and convection from the fume coming from the combustion of fixed carbon; B is the zone of pyrolysis or volatile evolving. The main heat source comes from the combustion of fixed carbon, too; C is the zone of the complete combustion of fixed carbon; D is the zone of the combustion of the volatile from the pyrolysis process of waste in the first chamber.

This system with two combustion chambers which are connected with a changed section column integrates drying-pyrolysising-catalyzing as a whole and sorts the air supply. Solid wastes are put into the incinerator through the feeding port. Primary air is blown in from the bottom of the first chamber in three sections. In the bottom of each section there is an air distributing plate, which can make the input air uniform. There is a slag exit under the air distributing plate. Secondary air is blown in from the end of the flue and perpendicularly mixed with the fume from the first chamber. Then the mixed gases enter the second chamber and completely combust. There is center pivot with helix fins in the first chamber. The central pivot is hollow so that water can be fed into it to regulate the combustion temperature. The helix fins on the pivot which can drive the waste forward in the first chamber and are propitious to the heat and mass transfer. It assemblies enhancing drying, energy utilization, efficient pyrosis, clean combustion.

The monitoring system is composed of temperature measuring system, air supply and measuring system and flue gas analysis system. Five K-type thermocouples are used to measure the temperature: three points

Foundation item: The Natural Science Foundation of Guangdong Province, China. * Corresponding author in the first chamber, one in the flue and another in the second chamber. A powerful fan supplies the air. Rotor flow meters are used to measure airflows of different sections. A gas sampling system is applied to sample the flue gas at the exit of each chamber.

Variation of several operating conditions was employed to study the rotary incinerator technics during the experiment and the acid gases were detected too. The formation necessary to the improvement of the incinerator was thus collected and used for the fume control with addition of Ca-base compounds, the acid gases from rotary incinerator was effectively controlled.

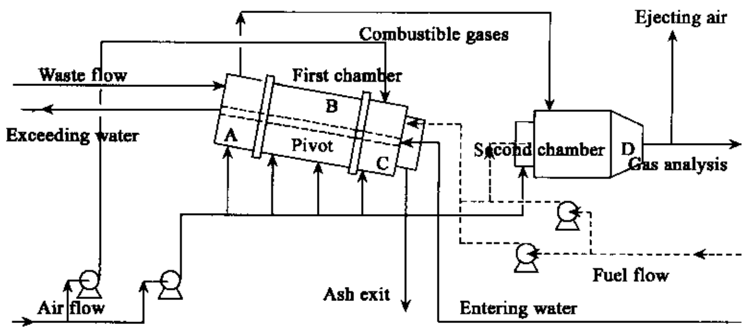

Fig. 1 Flow chart of the new model rotary incinerator

1.2 Sample of municipal waste and analysis

Composition of municipal waste (MW) is influenced by energy structure of a city, the level of economic development and seasons. Based on the statistics data from 2000 of Guangzhou Environmental Sanitation, Table 1 and Table 2 present the analysis results of MW.

Table 1 Component of model municipal organic solid waste

Components	Animal	Vegetable	Paper	Cloth	Plastic	Total
Weight, %	1.84	71.90	4.49	4.25	17.53	100.01

Table 2 Proximate analysis and ultimate analysis of MOSW(w%)

Water	Volatile	Carbon	Ash	Nitrogen	Sulfur
52.23	31.62	12.46	3.69	0.59	0.12

2 New type rotary waste incinerator technology

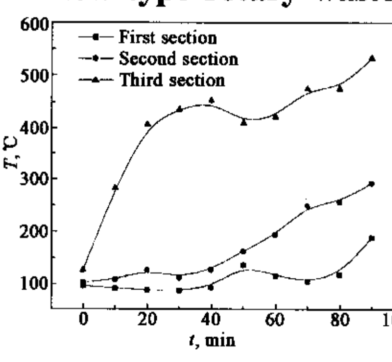

Fig. 2 Change of temperature during start-up

In order to investigate the combust state of each zone in the incinerator, the experiments were carried out with variation of several operating conditions. Keeping waste feed and air supply constant, the temperature in each section was monitored regularly. The change of the temperature as shown in Fig.2, and it shows that the temperature gradually increased with combusting process, and the temperature in drying segment was the lowest, 100—150℃, gasifying segment was 150℃—300℃, and the third segment 400—550℃. After the fed wastes were lighten, pushed into the third segment by the central pivot, the temperature rose up rapidly. After the temperature in the 3rd segment reached 400℃, it became rather stable and might mean that there was a balance between the heat carried away by the fume, absorbed by the newly ingoing wastes and the heat released from the combustion. The wastes were composed of complicated mixtures, so some components could combust at lower temperature, and caused the temperature raise up rapidly. The temperature could be controlled by cooling water which was fed into the pivot with center hollow during tests. The changes of air supply influence on combustion stability were discovered. Table 3 shows that the changes of air feed strongly influenced the combustion state. The 1st sect was warm-up and desiccation. In order to keep a certain temperature, it was not suitable to provide with too much air. The quantity of 2nd sect air was a little higher than 1st sect. It was for the vaporization and pyrolysis of the wastes. The 3rd sect air was for the combustion of coke. The quantity of oxygen was slightly excess in the 1st chamber. The slag of 1st phase was a little black and slightly caked. The slag of 2nd sect was hoar in the surface, but pliable and gradually blackens inward. The slag of 3rd phase was white and frailty.

Table 3 The influence of air flow on combustion temperature

Air, m^3/h				Temperature, ℃				
1st sect	2nd sect	3rd sect	2nd chamber	1st sect	2nd sect	3rd sect	Flue	2nd chamber
2.8	6.2	8.6	15	87	108	493	521	456
1	5.5	9.5	15	110	230	430	495	415
1.4	1.6	6	10	85	165	428	623	929
1	2.4	6	10	85	210	519	691	697
1	3.2	5	10	90	108	641	819	855
1.4	2	8	10	127	208	331	740	834
1	3	8	10	83	220	591	875	1020

In a word, the airflow can not be too small, otherwise wastes are incompletely incinerated, for emitting too little heat to realize the second combustion. But if the airflow is too much, because the combustible matter concentration will be relatively low in the first chamber, so that the secondary combustion can not be realized and consume a great deal of heat. After the whole experimental course is carefully examined the following optimizing conditions are obtained: first stage air ratio: 0.4—0.6, feed rate: 13—13.5 kg/h, rotation speed of fulcra: 3.5—5 r/min.

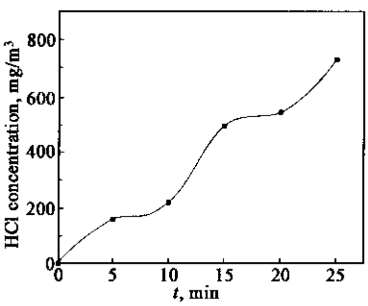

Fig. 3 Correlation of HCl concentration and time

3 Acidic gas formation and control

3.1 Formation and control of HCl

3.1.1 HCl emission in the rotary incinerator

HCl emission during the combustion is shown in Fig. 3. The concentration of HCl increased with temperature, and the highest concentration reached about 700 mg/m^3. The analysis results showed that HCl released utterly in the first chamber. The experiments have proved when incinerator was kept at the temperature expected, incinerating technology has not great effect on the formation of HCl.

3.1.2 PVC contributing to the formation of HCl

The HCl mainly comes from chlorine-contained plastic and paper in combusting process. In order to study PVC contributing rate to the formation of HCl in the rotary incinerator, two groups of experiments, with and without PVC addition, were carried out, the PVC was added to the sampled municipal organic solid waste in proportion. The ultimate analysis of PVC and the related experimental results are listed in Table 4 and Table 5.

Table 4 Ultimate analysis of PVC (w%)

Item	Carbon	Hydrogen	Sulfur	Nitrogen	Chlorine
PVC	40.3	5.82	1.25	0.07	52.36

Table 5 The influence of PVC on HCl formation

Item	Without PVC added	With PVC added	Contributing rate, %
HCl concentration, mg/m^3	186.66	515.78	63.8

Note: Experiment proved that about 60%—65% HCl came from PVC

3.1.3 Controlling the HCl formation in the rotary incineration

Two Ca-base compounds were investigated how to influence HCl formation in the rotary incinerator. The experiment result is shown in Fig.4. The concentrations were reduced with the increase of the molar ration, Ca:X (X = Cl + S). Because the central pivot with helix fins could turn over and mix the waste, the heat and mass transfer among phases were enhanced, and the dechlorination may be realized at further low temperature (about 550℃). However, the combustion process which was controlled by the mass transfer and reaction dynamics was very complicated. The HCl removal ratio by the calcium compound was only 30%—50% and unsteady sometimes.

3.2 NOx formation and control

3.2.1 The influence of temperature and excess air ratio

Temperature and excess air ratio influenced on the NOx formation had been investigated in a fixed bed incinerator(Liang, 1999; 2000a). The result showed that the concentration of NOx increased with the increase of temperature, and reached the maximum value at about 700 mg/m^3. After that, the concentration decreased. NOx concentration increased with the increase of excess air ratio α at the beginning of the incineration, but then remained stable when α came to a certain value. Under high temperature, the influence of excess air ratio on NOx formation was not as sharp as that at low temperature.

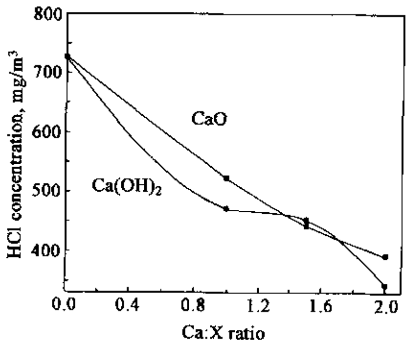

Fig. 4 Influence of Ca-base additive on the formation of HCl

3.2.2 NOx formation in the rotary incinerator

NOx formation with time begun to count after the wastes were heated up 20 minutes(Fig.5). NOx concentrations increased with the increase of incineration time, but the concentrations decreased as stable combustion was reached. The reason is as follows: at the beginning, the volatile and deoxidizing mass concentrations were rather low and difficult in bringing secondary combustion, so the NOx contents were gradually accumulated. Then, the combustible gases brought the secondary combustion with the combustion developed, some matters such as hydrocarbon and CO deoxidized NOx, resulting in the NOx concentrations reduction.

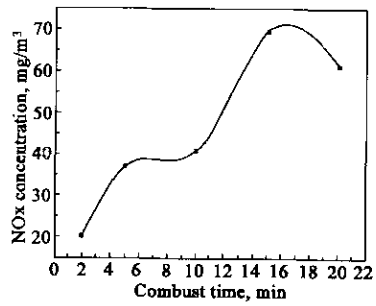

Fig. 5 NOx formation with incineration time

Fig. 5 also shows that NOx formation quantity in the rotary incinerator was much less than the NOx concentration which was 130 mg/m^3 (Liang, 2000b) of the fixed bed incinerator, secondary combustion technology greatly decreased NOx formation. The NOx concentrations were determined by the balance between the oxidization of fuel N and the deoxidized NOx. In the first chamber, part volatile CN, HCN and NH_3 etc. which were formatted in the B zone were oxidized to NOx. But in C, D zones, the coke, CO, NH_3 deoxidized the NOx at the reductive atmosphere. So the quantity of the NOx deoxidized by substances including coke, CO, NH_3 and so on in the first chamber excesses the quantity from fuel N converting to NOx formation in the second chamber, the NOx total formation decreased.

3.2.3 Influence of Ca-base compounds on the formation of nitrogen

Fig. 6 and Fig. 7 show how the additives influence NOx and NH_3 concentration. The NOx and NH_3 concentration increased with addition of CaO, the NH_3 formation quantity rapidly increased with the Ca-base additives addition. The reason was that Ca-base compounds which acted as catalyst enhancing the reaction rate from amine and nitrogen to NH_3, ammonia was further oxidized to NO in the first combustion chamber. Then, CaO also acted as catalyst for NOx reducing reaction, making CO which was generated in the first combustion chamber reduced NO, promoting to denitrification. The experimental results showed that CaO promoted NH_3 releasing rate was higher than NOx reducing rate, separately 25.41% and 4.30%, so the NOx formation concentrations increased. Lu *et al*. (Lu, 2000) indicated that CaO cooperating with CO could improve NO conversion rate. Some other researchers(Francesco, 2001) believed Ca-base compounds could reduce SO_2 concentration, but SO_2 might promote CO emission, and favored NOx decomposition.

3.3 SO_2 formation and control

3.3.1 SO_2 formation in the rotary incinerator

When organic wastes were steadily combusted in the rotary incinerator, the SO_2 emission concentrations were near the same of the fixed bed incinerator(Li, 2000).

3.3.2 Influence of Ca-base additives on the emission of SO_2 in rotary incinerator

Ca-base additives such as CaO, $Ca(OH)_2$, $CaCO_3$ usually are used to get rid of acidic gases in incinerator. Influence of Ca-base additives on the emission of SO_2 was studied. The results given in Fig.8 show that under lower temperature(about 450—550℃), not only did Ca-base additives desulfurize in the rotary incinerator but also the effectiveness was better than in the fixed bed incinerator(Li, 2000). The reasons were that central pivot with helix fins could mix the wastes, strip $CaSO_4$ ashes in the Ca-base surface, accelerate the mass transfer between additives and wastes. Fig.8 also shows that desulfurization rate appeared an increasing trend with the additive percentage went up, but there was a peak in curvilinear back, maybe due to the inhomogenous mixting between additive and wastes.

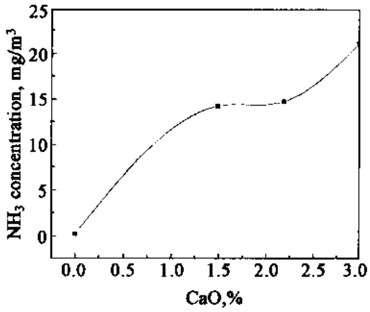

Fig. 6 Influence of Ca-base additives on the formation of NH_3

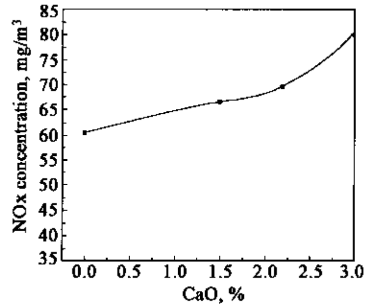

Fig. 7 Influence of Ca-base additive on the formation of NOx

4 Conclusions

The air supply is distributed according to each section in the new type rotary incinerator, the change of input air plays a key role to steady combustion.

The new type rotary incinerator may greatly reduce the NOx emission by adopting the secondary combust technology.

Adding calcium additives can desulfurize at lower temperatures in the rotary incinerator. As Ca:(Cl + S) is 2, the desulfurizating ratio is over 30%.

HCl originates organic chlorine during solid waste incineration, PVC contribution rate to HCl formation is similar with fluidized bed incineration, about 60%—65% comes from PVC, and increases with the combustion temperatures increase.

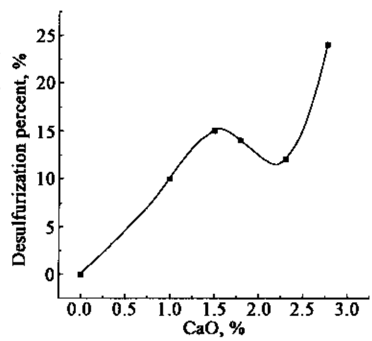

Fig. 8 Influence of Ca-base additives on the formation of SO_2

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