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Research on municipal solid waste composting with coal ash①

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Abstract: Considering the fact that there is much coal ash in the municipal solid waste (MSW) in some cities of China, the feasibility of composting in this situation was studied and the effect of content of the coal ash on the composting process and some basic relative technological parameters were investigated. The values of the moisture, the total organic matter, the content of coal ash, the C/N ratio and the ventilation were suggested to be 50%－60%, 40%－60%, 40%－60%, (25:1)－(35:1) and 0.05－0.20 $m^3/(min\cdot m^3)$, respectively.

Key words: coal ash; municipal solid waste; composting; technological parameters
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1 INTRODUCTION

Composting is a simple and effective method for the municipal solid waste (MSW) treatment by decomposing organic matter, producing a stabilized residue and disinfecting pathogens [1, 2], which has been gradually received and applied by people.

In many previous researches on the composting, coal ash was used as a kind of additive[3-5]. For example, the addition of coal ash during sewage sludge composting has been demonstrated to be a promising way to reduce metal pollution [3, 4]. Coal ash can be used for replacement of lime in the raw compost materials to prevent a quick drop in pH during composting [5].

In fact, the content of coal ash in the MSW is relatively high in many middle or small cities in China, for instance, the content of coal ash in some districts of Shandong Province reaches up to 40% or much higher.

Because screening the coal ash from the MSW is very difficult and not economical, and in some cases the addition of coal ash can improve the soil and increase the trace element needed by the plants [6-8], the research on the MSW composting with coal ash appears to be practical. The objectives of this research mainly focus on investigating the feasibility of the composting with MSW and some basic relative technological parameters.

2 EXPERIMENTAL

2.1 Experimental materials

The MSW used for the experiments was mixed artificially according to the statistical data for the actual contents of MSW in Jining City of Shandong Province, which is one of the typical middle or small cities in North China. The easily rotted organic matters were gathered from the residues from the dining room, while the inorganic matters (coal ash) were collected from the stove of this dining room. The contents of nitrogen, phosphor and kalium in the coal ash were 0.02%－0.04% N, 0.1%－0.8% P_2O_5, 2.5%－3.4% K_2O, respectively. Some waste papers were added into the materials as the degradable organic wastes needing the relatively long time. In order to adjust the moisture and C/N, some sludge was adopted, whose particle size was between 20 mm and 60 mm.

2.2 Experimental equipment

Fig. 1 shows the flow diagram for the MSW composting at laboratory. The body of the reactor was made of stainless steel. The raw composting mixture (the MSW used for the experiment) was put into the compost chamber. The air was pumped into the chamber by air compressor. The chamber can be wheeled in the support to stir the mixture. Measuring the temperature of compost and sampling the compost can be done through the sampling port. The air exhausted from the chamber was passed through the flow meter, the air filter and then into the carbon dioxide sensor.

2.3 Experimental methods

After 10－12 h spontaneously fermentation from

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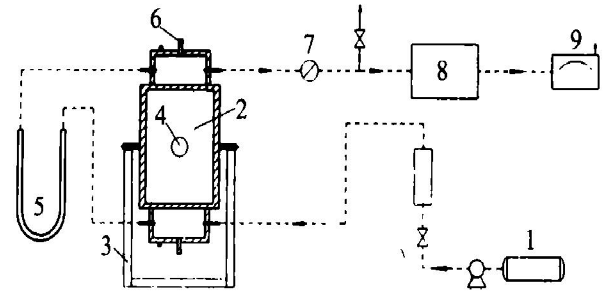

Fig. 1 Flow diagram for MSW composting
1 —Air compressor; 2 —Compost chamber; 3 —Support; 4 —Sampling port; 5 —Barometer; 6 —Leachate trap; 7 —Flow meter; 8 —Air filter; 9 —Carbon dioxide sensor

beginning, the forced ventilation will start to supply oxygen. The temperature of mixture usually can reach up to 60 ℃ only if there were enough organic matters in the mixture and the moisture and the ventilation were on the proper levels. After keeping about 60 ℃ for 3 − 5 d, the temperature in the mixture will begin to drop and then maintain at 35 − 40 ℃, which indicates that the first composting is over and the mixture can be taken out for the next process.

As the temperature is the key factor influencing the composting process [9−11], the effects of the moisture, the total organic matters, the coal ash and the C/N on the temperature were researched by a series of experiments in order to reveal the relationship between the factors and the composting process, which will help us to find the optimum technological parameters for the MSW composting.

2.4 Analytical methods

The temperature was measured every 6 h from the beginning. The air exhausted from the chamber was measured by the flow meter, then the majority of the air was discharged directly and the other part was passed into the CO_2 sensor to determine the concentration of CO_2 after being dewatered and filtered.

The energy emitted from decomposing the organic matter can be divided into two parts. One keeps the microbial activity and the other heats the mixture. 2 872.2 kJ energy is emitted after 1 mol glucose is decomposed completely, among which 40.5% will be saved as ATP, and the rest will be emitted as heat. If the organic matters in the mixture are all glucose, we can find out that giving off 1 mol CO_2 must be followed by producing 283.6 kJ heat. Therefore, the total heat emitted can be estimated.

The moisture content (105 ℃ for 5 h), the total C (loss on ignition), the total N [12] and the total organic matter in the compost sample were analyzed by the methods listed in Refs. [12, 13].

3 RESULTS AND DISCUSSION

3.1 Effect of moisture content on temperature

Water is absolutely necessary for decomposing of the organic matters and growing of the microbe during composting [14]. Fig. 2 shows the effect of moisture of MSW on the composting temperature. The organic matter, the C/N, the ventilation rate and the coal ash content were adjusted to 40% − 50%, (25:1) − (30:1), 0.15 − 0.2 $m^3/(min \cdot m^3)$ and 40% − 45%, respectively.

From Fig. 2, it is easy to find that improper moisture content (≤20% or ≥70%) restrains the composting. The microbes only utilize the nutriment dissolved into the water. When the moisture content is very low (≤20%), the organic matter in the liquid phase is so lack that the microbes can not get enough nutriment from the mixture. So the temperature rising to the thermophilic phase needs 10 d from the beginning. When the moisture content is very high (≥70%), the composting is also restrained. The excessive water fills most of the small interspaces in the mixture and creates low oxygen tensions[15], so the microbes can not grow well because they can not get enough oxygen and maybe give off the odor in the anaerobic condition. In Fig. 2 the moisture content of 50% − 60% is the ideal content, with which the temperature rises to the thermophilic phase within 2 d due to a period of intense microbial heat generation at the expense of the organic waster, and the peak temperature reaches up to 70 ℃ which is helpful to disinfect the pathogens.

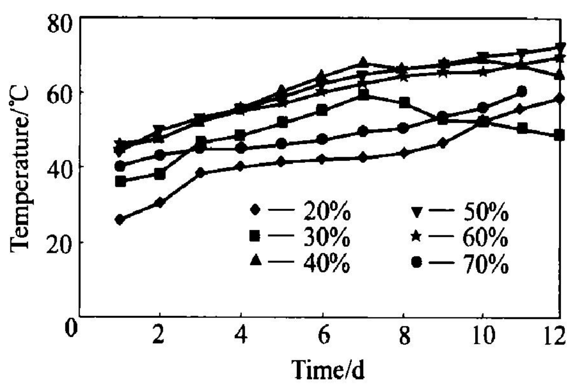

Fig. 2 Effect of moisture on temperature in composting

3.2 Effect of total organic matter on temperature

Fig. 3 shows the relation of total organic matter content to the average temperature of 10 d. When the total organic matter is lack (< 30%), the microbe can not assimilate enough nourishment to grow, and the heat emitted by decomposing the organic matter will be reduced. Then, the temperature will be relatively low and the thermophilic phase (50 − 55 ℃) can last for long time (⩽3d). When the total organic matter content is too high (> 70%), the circumstance for the composting will become adverse because the nutrient is too enough, the microbes grow quickly at the beginning, the ventilation rate can not be increased correspondingly, the oxygen in the MSW will be used up soon, and then the composting enters the anaerobic phase. From the peak value of the curve, it can be found that adjusting the total organic matter to 40% − 60%, the microbe will have enough nutrient and oxygen, the temperature will rise quickly and the thermophilic phase (50 − 65 ℃) can last for 5 − 7 d.

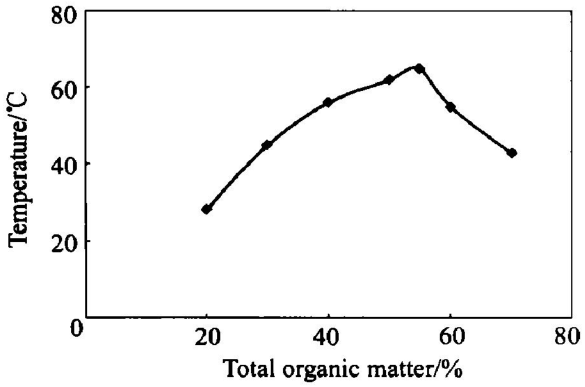

Fig. 3 Relation of temperature (average of 10 d) to total organic matter in composting

3.3 Effect of coal ash content on temperature

Fig. 4 shows the relation of coal ash content to temperature in composting when the moisture content is 45% and the ventilation rate is 0.05 $m^3/(min \cdot m^3)$.

It can be seen in Fig. 4 that, when the coal ash content is 0 − 45% in the MSW, the temperature increases slightly. There may be two reasons. Firstly, the coal ash absorbs some moisture in the experimental MSW, and then the evaporation loss of the moisture is reduced, resulting in the reducing of the loss of heat. Secondly, the coal ash can keep its original structure after absorbing the moisture by its rough porous structure. The organic waste in the experimental MSW will become denser by rotting after composting beginning, but the coal ash can maintain many pores for its special structure to keep the ventilation. Then, the decomposing of organic matter is accelerated and more heat will be emitted so the temperature increases.

When the coal ash content is above 45%, the average temperature of 5 d is 49.0 ℃, ranging from 45.0 ℃ to 57.5 ℃. When the coal ash content is 75%, the average temperature is 42.0 ℃, ranging from 36.4 ℃ to 55.0 ℃. The low temperature phase lasting for a relatively long time is harmful to disinfecting pathogens and to the aim of harmless treatment of composting. Adding excessive coal ash does not change the dominant bacteria species during composting, but decreases the population and the diversity of thermophilic bacteria species due to the high alkalinity and salinity caused by coal ash [16].

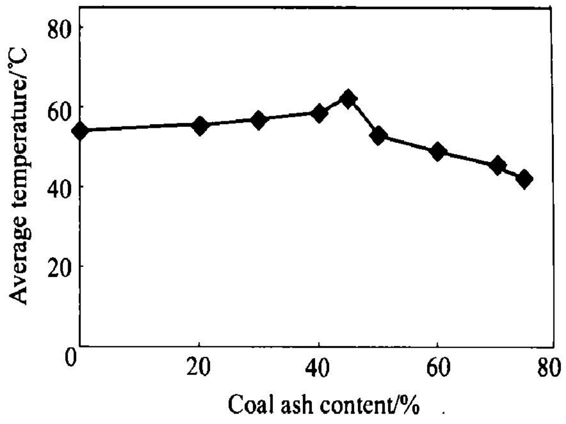

Fig. 4 Relation of average temperature of 5 d to coal ash content

The relation of the coal ash content to heat emitted during composting is shown in Fig. 5. The gross heat emitted during the composting process decreases with the increase of coal ash content. Increasing the coal ash results in the reducing of total organic matters and the heat emitted during composing the organic matter will be decreased correspondingly. When the coal ash content reaches up to 75%, the emitted heat is 1.61×10^4 kJ and the average temperature is 42 ℃, ranging from 36.4 ℃ to 55.0 ℃, which is hard to satisfy the condition for disinfecting pathogens. When the coal ash content is 70%, the emitted heat is 1.86×10^4 kJ and the average temperature is 46 ℃, ranging from 40.0 ℃ to 56.7 ℃. This situation will last for 4 − 5 d and can satisfy the condition for disinfecting pathogens.

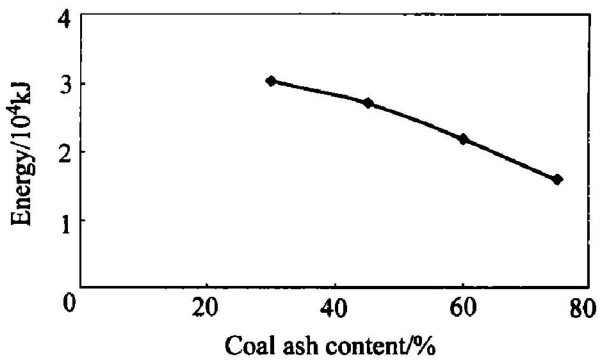

Fig. 5 Relation of energy to coal ash content

When there is no coal ash in the experimental MSW, the moisture of the experimental MSW will be relatively high, the temperature will begin to rise in 24 h, the ventilation become difficult and the leachate amount will be large. When the coal ash content is increased gradually, the leachate amount will be reduced obviously, the ventilation condition will be improved greatly and the temperature rise more quickly. The proper addition of the coal ash can improve the biological activity greatly in composting and enhance the nutrient value of the final composting product [17].

According to the above results, the coal ash content is suggested to be 40% − 60% during the aerobic composting of MSW, which is similar to the result of Fang's researches [18].

3.4 Effect of C/N ratio on temperature

The C/N ratio is important for the nutrient balance of the MSW composting, the decomposition rate of the MSW composting and the final quality of composting product [19]. When the C/N ratio is low, there will be no enough carbon, the temperature will rise quickly and the peak temperature will not be high. Nitrogen for the microbes might be lost by volatilization as ammonia into the atmosphere, which produces an unpleasant odor. Alternatively, composting with an excessive C/N ratio will have problems with slow, inefficient decomposition, which will last in the composting process [20].

Fig. 6 shows the effect of different experimental MSWs with different C/N ratios on the temperature. The ventilation rate is controlled at 0.05 − 0.20 $m^3/(min \cdot m^3)$. There are no obvious differences in the temperature between C/N of 20:1 and 35:1. When the C/N ratio is 20:1, the temperature rises comparatively slowly and does not keep enough time in the thermophilic phase. It can be seen that the C/N ratio of (25:1)−(35:1) is appropriate for the the MSW composting process.

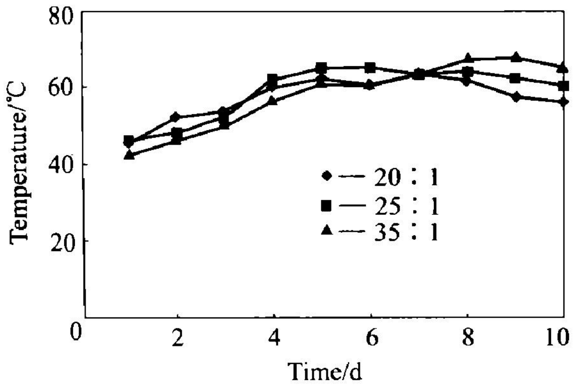

Fig. 6 Effect of C/N ratio on temperature in composting

3.5 Effect of ventilation rate on temperature

Aeration is an important factor in the decomposition of the MSW. In a ventilation system, oxygen often becomes a limiting factor for the composting [21]. In the aerobic composting, the main function of ventilation is to supply enough oxygen for the microbial activities to make the temperature rise to about 60 ℃ in the beginning phase of composting, and then to improve the volatilization to control the temperature.

Fig. 7 shows the effect of ventilation rates on the temperature of composting, in which the other factors are the total organic matter 46%, the moisture content 42% and the C/N ratio 25:1.

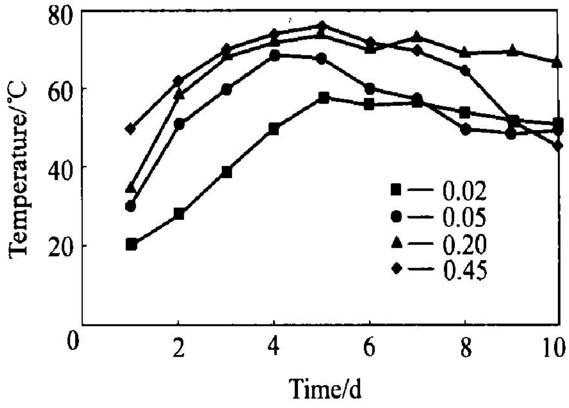

Fig. 7 Effect of ventilation on temperature in composting

When the ventilation rate is above 0.20 $m^3/(min \cdot m^3)$, the temperature rises very fast and then reaches up to 65 ℃. When the temperature keeps at 65 − 70 ℃ for a long time, some microbes will die and some microbes live in the form of spores. Then the decomposing of organic matter will be slowed down. Especially when the ventilation ratio is over 0.5 $m^3/(min \cdot m^3)$, the heat generated by the microbes will be dissipated rapidly, which will restrain the rising of temperature. And the temperature for the experimental MSW will decrease quickly in a week. Based on the above analyses, the ventilation rate is suggested to be 0.05 − 0.2 $m^3/(min \cdot m^3)$ in the MSW aerobic composting.

4 CONCLUSION

The existing of coal ash in the MSW has effect on the temperature and the emitting of heat in the composting process. In this study, the coal ash content is adjusted to optimize the technological parameters for the composting of MSW. The ideal technological parameters such as the moisture, the total organic matter, the content of coal ash, the C/N ratio and the ventilation rate are suggested to be 50% − 60%, 40% − 60%, 40% − 60%, (25:1)−(35:1) and 0.05 − 0.20 $m^3/(min \cdot m^3)$, respectively, when the composting of MSW can go on well to enter the thermophilic phase quickly and be kept on this phase for enough time to perform the harmless treatment of the MSW. The MSW composting with coal ash is proved to be feasible. The addition of coal ash inhibits biological activity in some degree but does not affect the compost maturity. In some cases, the nutrient value of the final product can be improved .

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