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Analysis of Cooperative disposal of Medical Waste Treatment and Municipal Solid Waste Incineration

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Abstract. The main technologies and existing problems of medical waste disposal are introduced. The technical process for the cooperative disposal of medical waste treatment and municipal solid waste incineration as well as its advantages is studied. The cooperative disposal of both can effectively reduce the system investment and operation cost.

1. Introduction

Medical waste refers to the wastes produced in the medical, preventive, health care and other related activities which have directly or indirectly infectivity, toxicity and other hazardous characteristics ^[1]. Medical wastes in China are classified into infectious wastes, traumatic wastes, pathological wastes, chemical wastes and pharmaceutical wastes. They are listed in the national hazardous waste list due to their serious infectivity and toxicity. The amount of medical wastes generated in China has reached 721 thousand tons in 2016, and the disposal rate is nearly 100%. However, there are many problems existing in the operation of disposal facilities.

The medical waste disposal can be divided into the incineration technology and non-incineration technology ^[2]. For the incineration, the pyrolysis method is suitable for the plant with daily capacity less than 10 tons, while the rotary kiln incineration is suitable for large-scale disposal center. However, there are many problems in operation such as high investment, high operating cost and secondary pollution ^[3-6]. Furthermore, the flue gas is difficult to reach the emission standard, especially the dioxin. The non-incineration method mainly includes steam disinfection, chemical disinfection and microwave disinfection. The advantages of non-incineration are quite distinct, such as low investment, low operating cost, intermittent operation, strong adaptability, less secondary pollution, no dioxin pollution and the stable sterilization effect. Hereinto, steam disinfection is widely used because of its mature technology and low safety risk. At present, the incineration and non-incineration disposal facilities in China account for 50% respectively. The incineration technology is mainly pyrolytic incineration, while the non-incineration technology is mainly steam disinfection.

According to the technical specification for steam-based centralized treatment engineering on medical waste in China, the medical waste after steam disinfection must be crushed and destroyed. If the sterilization effect meets the standard requirement, the solid waste can be regarded as the general municipal solid waste (MSW) for final disposal, not the hazardous waste. Therefore, medical waste can be handled using mature steam disinfection in coordination with MSW. It can make full use of high-temperature steam generated from MSW incineration, send solid waste and odour to MSW



incinerator, and send the wastewater to MSW leachate treatment system. The coupling of these two waste treatments can effectively reduce the system investment and operation cost.

2. Medical waste steam disinfection

2.1. Steam disinfection principle

The principle of steam disinfection is as follows: medical waste is fed into the high-temperature steam treatment pot through a special hand barrow, and the air in the treatment pot is absorbed by vacuum process. Then the medical waste is sterilized with high temperature steam (steam temperature ≥ 134 °C, sterilization time ≥ 45 min). The latent heat released by steam is used to cause the protein denaturation and coagulation of pathogenic microorganisms, and hence achieves the harmless and safe disposal. After the treatment, the medical waste is cooled, dried and crushed.

2.2. Steam disinfection process

According to the sequence of steam disinfection and crushing, the process can be divided into three forms:

(1) First steam disinfection, then crushing

The advantage is that medical waste after steam disinfection meets a higher level of hygiene standard, which can reduce the risk of the subsequent crushing. This process is widely used, however the high steam treatment pot usually has high pressure and requires vacuum to drain out the bad conductor-air before steam disposal. This process has high requirements for the equipment and demands strong vacuum pumping capacity.

(2) First crushing, then steam disinfection

The package of medical waste is destroyed by crushing, making the medical waste directly exposed to high temperature steam and increasing the contact opportunity, so the sterilization effect is easier to guarantee. However, the problem is that the risk of crushing unsterilized medical waste is high, and it is easy for operators to infect and cause disease.

(3) Steam disinfection and crushing at the same time

There is generally a stirring device in the steam pot when steam disinfection and crushing are carried out at the same time. In the process of steam disinfection, the package is destroyed and the waste is directly exposed to the steam. On the other hand, the stirring makes the heat transfer more uniform and the effect of steam disposal is significantly improved. However, the domestic medical waste has complex components and the classification is not good, resulting in a high rate of equipment failure and high maintenance cost.

At present, the widely used and most mature form is that first steam disinfection, then crushing. The detailed process is shown in Figure 1 and related process parameters are listed in Table 1.

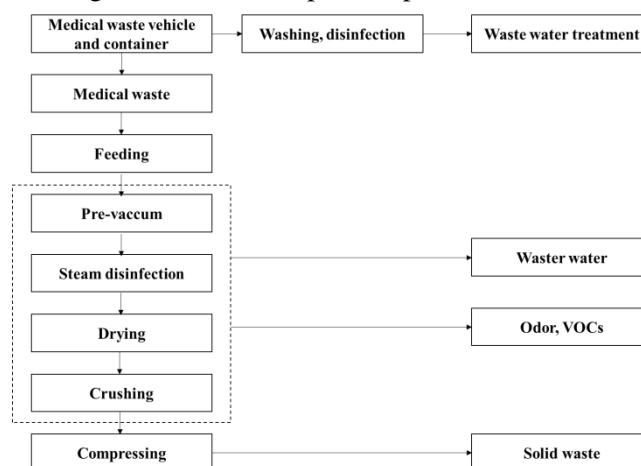


Figure 1 Steam disinfection process

Table 1 Steam disinfection process parameter

Item	Unit	Parameter
Daily capacity	t/d	≤ 10
Daily operation time	h	≥ 16
Annual operation time	d	330
Volume reduction rate	%	60~80
Time per batch	min	74
Batch per day	Times	13
Vacuum	MPa	≥ 0.09
Steam pressure	kPa	≥ 220
Steam temperature	$^{\circ}\text{C}$	≥ 134
Sterilization time	min	≥ 45
Steam temperature fluctuation	$^{\circ}\text{C}$	$\leq \pm 1$
Sterilization efficiency	%	> 99.99
Steam pressure	MPa	0.3~0.6
Steam pressure fluctuation	%	≤ 10
Non-condensable gas in steam	%	≤ 5
Steam superheat	$^{\circ}\text{C}$	≤ 2

2.3. Secondary pollution control

The secondary pollution in the steam disinfection process is mainly waste gas and waste water. The waste gas is the most difficult to deal with, mainly field odour. The exhaust gas mainly comes from the vacuum process, storage facilities and crushing process. Lowering temperature drying can effectively control the odour through the condensation of organic gases, and then through activated carbon and filter membrane treatment the discharge standard can be reached.

The waste water mainly comes from the condensate produced in the steam disinfection, medical waste leachate, the condensate produced in the waste gas treatment, the vehicle and container washing. The waste water is usually collected for disinfection using sodium hypochlorite, and then discharged into the plant sewage treatment.

3. MSW incineration

MSW incineration projects include the garbage reception and feed system, waste incineration, auxiliary fuel system, heat recovery, flue gas purification, leachate treatment, slag storage and delivery, automatic instrument control system and so on. The specific process can be found in Figure 2.

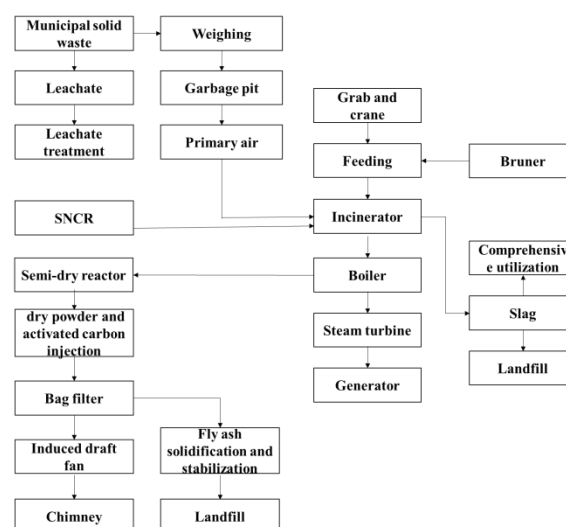


Figure 2 MSW incineration process

The garbage after weighing is transferred into the storage pit. The garbage is put into the feed hopper through the crane grab, then dropped into the feeding grate through the chute, and finally evenly fed into the incinerator. The air required for combustion can be divided into the primary air and secondary air. The primary air is taken from the garbage storage pit to maintain its negative pressure and to ensure that the odour in the pit cannot escape. The secondary air is sucked from the atmosphere and fed into the furnace by secondary fans, which produces strong turbulence to guarantee the complete combustion and facilitate the burning of carbon particles in the fly ash. Through the drying, combustion and burn-out area, the combustible composition has been completely burned and the ash has fallen into the slag extractor. The ash is transferred to the ash storage pit and then transported for comprehensive utilization or landfill.

The boiler absorbs heat from high temperature flue gas with water as working medium, and generates 4.0 MPa, 400 °C steam for steam turbine generator. The generated electricity is supplied for the plant equipment and regional power grid.

When the flue gas leaves the boiler its temperature drops to 200 °C, and subsequently it enters the flue gas purification system. Each incinerator is equipped with a set of flue gas purification system, “semi-dry rotary spray tower + dry powder injection + activated carbon adsorption + bag filter” is adopted, and the denitrification system is set up in the proper position of the incinerator chamber. The flue gas first enters the reaction tower and is fully mixed with the lime slurry. As the chemical reaction takes place, the acid gas is removed. Activated carbon is sprayed into the gas between the reactor and the bag filter to adsorb heavy metals and dioxins. After the dust and reaction products are removed from bag filter, the flue gas is sent to the chimney through the induced draft fan and discharged to the atmosphere.

The leachate is treated by a combination of “physicochemical pre-treatment, high efficiency anaerobic reactor, MBR, nano-filtration membrane system, reverse osmosis system”. After the treatment, the effluent is reused as the supplementary water for circulating cooling, while the left concentrated liquid is used for lime slurry preparation, thus achieving the zero emission of waste water.

4. Cooperative disposal of medical waste treatment and MSW incineration

Through analysis, medical waste treatment and MSW incineration can be coordinated in solid waste, steam, waste gas and waste water. The specific process is shown in Figure 3.

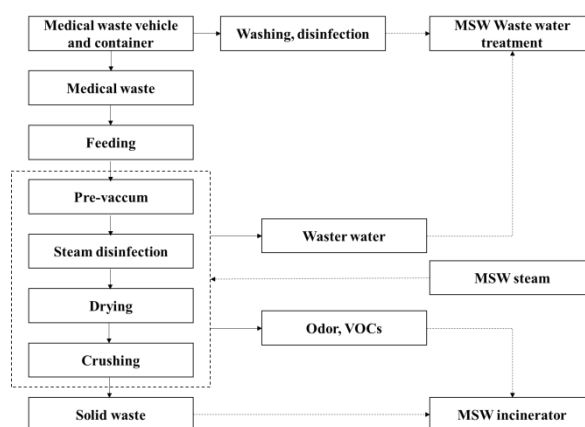


Figure 3 The cooperative disposal process of medical waste treatment and MSW incineration

4.1. Cooperative disposal of solid waste after steam disinfection

After steam disinfection, the volume of medical waste is reduced by 60%, but the weight is nearly the same. After drying, the water content is reduced to about 20% and the calorific value is in the range of 3000~6000 kcal/kg. After the steam disinfection, the hazardous medical waste can be regarded as the general MSW, and directly sent to the garbage pit without the need to be crushed and destroyed. As

the medical waste has a high calorific value, it must be fully mixed with MSW before incineration to avoid the fluctuation of operation conditions.

The daily capacity of medical waste is generally less than 10 tons, which is extremely smaller than MSW daily capacity such as 350 or 750 tons. The cooperative disposal will not affect the stable operation of MSW incinerator.

4.2. Cooperative disposal of waste gas and waste water

For the waste gas treatment, the operation condition of MSW incinerator should be fully considered. When the MSW incinerator is in operation, waste gas from medical waste steam disinfection can be collected and sent directly to the garbage pit on the premise of maintaining its negative pressure, and then sent to the incinerator. When the incinerator is in maintenance or the negative pressure of garbage pit cannot be maintained, the waste gas from medical waste steam disinfection and MSW garbage pit should be sent together to the deodorizing system of the incineration project.

Due to the limited and controllable quantity of pathogenic bacteria, the waste water from medical waste steam disinfection can be sent directly to the MSW leachate treatment system for cooperative disposal.

4.3. Energy use

The steam required for medical waste steam disinfection can be directly provided by MSW incineration system without the need for a separate steam boiler. The electricity needed by the equipment can be directly supplied by the steam turbine and no external purchase is required.

Through the cooperative disposal, medical waste steam disinfection system can be simplified and the synergistic benefit of the system can be improved.

5 Analysis of system investment and operation cost

The medical waste steam disinfection system can eliminate steam boiler unit, crushing unit, odour treatment unit and sewage treatment unit, which can effectively reduce the plant area. After accounting, the equipment investment can be saved by 1.5 million RMB (about 37.5%) when the 5 t/d medical waste steam disinfection are cooperated with MSW incineration.

Table 2 shows the direct operation cost of medical waste (5 t/d) under non-cooperative and cooperative conditions. With cooperative disposal, the direct operation cost of medical waste per ton is reduced from about 863 RMB to 184 RMB, saving about 79%. It can effectively reduce the investment and operation cost, and thus improve the economic benefit.

Table 2 Direct operation cost of medical waste steam disinfection system (RMB per ton)

Item	5 t/d	
	non-cooperative	cooperative
Water bill	3	3
Electricity bill	30	30
Steam bill	396	0
Disposal cost for medical waste after steam disinfection	250	0
Waster waster disposal cost	26	0
Maintenance	28	21
Sum	863	184

6. Conclusion

The cooperative disposal of medical waste steam disinfection and municipal solid waste incineration can effectively reduce the investment and operation cost, reduce the area occupied, and provide a new

mode for kinds of solid waste. In order to give full play to the advantages of collaborative disposal, more concerns should be considered on the system design, construction, operation and management.

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