Comparison and analysis of several medical waste treatment technologies

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Abstract. Medical waste is a kind of special waste with great harm. Since the 1950s, the treatment of medical waste has attracted widespread attention from all over the world. At present, scholars at home and abroad are increasingly rich in research on medical waste treatment technology and have achieved certain research results. This article comprehensively compares and analyzes the technical influencing parameters, advantages and disadvantages of incineration treatment, pressure steam sterilization treatment, chemical treatment, microwave treatment, plasma treatment and other medical waste treatment methods, and emphasizes that high-temperature pyrolysis incineration treatment technology has reduced weight and is harmless. This is the current direction of domestic medical waste treatment research and development.

1. Introduction

Medical waste refers to waste that is directly or indirectly infectious, toxic, and other hazardous waste generated by medical and health institutions in medical treatment, prevention, health care, and other related activities. Medical waste is highly infectious, biologically toxic and corrosive. Untreated or incompletely treated medical waste is stacked arbitrarily, which can easily cause pollution of water, soil and air, and cause direct harm to the human body[1]. The problem of medical waste disposal has become a hot spot worldwide. Internationally, medical waste is regarded as a “top hazard” and a “fatal killer”. My country also lists it as the No. 1 hazardous waste in the "Hazardous Waste Directory".

2. Comparison of medical waste treatment technology

2.1 Sanitary landfill method

2.1.1 Principle
The sanitary landfill method is the ultimate disposal method of medical waste. Its principle is to bury the garbage in the ground and decompose it into harmless substances through the long-term decomposition of microorganisms. If the landfill system of medical waste does not have anti-seepage measures, various toxic substances, pathogens, radioactive substances, etc. will infiltrate the soil with rainwater, and harmful substances will enter the human body through the food chain, endangering human health[2]. Therefore, the sanitary landfill needs to be scientifically selected, and the anti-seepage
layer should be laid with clay, high-density polyethylene and other materials. It is also necessary to set up landfill gas collection and output pipelines. Therefore, the landfill treatment method must be very cautious. Strict pretreatment of medical waste according to relevant regulations\cite{3}.

2.1.2 Influence parameters

The landfill treatment method should be based on the characteristics of medical waste, select the site with geological conditions that meet the requirements, combine the soil and climate, and use the appropriate civil technology to determine the site construction scale.

2.1.3 Advantages and disadvantages

The advantages of the landfill treatment method are that the process is relatively simple, the investment is small, and a large amount of medical waste can be processed. The main disadvantages are the need for disinfection before landfilling, the reduction of waste volume, the large investment in landfill construction, the need to occupy a large amount of land, and produce a large amount of harmful gases such as methane, ammonia, hydrogen sulfide gas, nitrogen, carbon monoxide, etc., and also produce oxygen and hydrogen. And volatile organic compounds, long-term monitoring of soil and groundwater is required\cite{4}.

2.2 High temperature incineration method

2.2.1 Technical characteristics

Medical waste is mainly composed of organic hydrocarbons, contains more combustible components, has a high calorific value, and it is completely feasible to use incineration. Incineration is a chemical process of deep oxidation. Under the action of high-temperature flame, the medical waste in the incineration equipment is dried, ignited, and incinerated to convert it into residue and gas. The source of infection and harmfulness in medical waste The material can be effectively destroyed during the incineration process. The incineration technology is suitable for all kinds of infectious medical wastes. During incineration, the incinerator is required to have a high and stable furnace temperature, good oxygen mixing conditions, sufficient gas residence time and other conditions. At the same time, it is necessary to control the final flue gas and The residue is treated in a harmless manner.

2.2.2 Influencing parameters

The selection of incineration equipment must have suitable turbulence and mixing degree, and maintain the current moisture content in the waste. The filling condition of the combustion chamber, temperature and residence time, maintenance and overhaul are all important incineration parameters.

2.2.3 Advantages and disadvantages

The main advantages of incineration technology are that the volume and weight are significantly reduced, and the waste is obviously destroyed; it is suitable for all types of medical waste and large-scale applications; stable operation, good disinfection and sterilization and pollutant removal; potential heat energy can be recycled; technology is relatively mature\cite{5}. Disadvantages are mainly manifested in the high cost, serious air pollution, easy to produce dioxins, polycyclic aromatic compounds, polychlorinated biphenyls and other highly toxic substances and harmful gases such as hydrogen chloride, hydrogen fluoride and sulfur dioxide, which require a complete exhaust gas purification system; bottom Slag and fly ash are hazardous.

2.3 Pressure steam sterilization

2.3.1 Technical principles and characteristics

The principle of the pressure steam sterilization treatment method is that the sorted and crushed medical waste is operated for more than 20 minutes under the process conditions of 100kPa and 121°C,
and the pressure steam penetrates the inside of the object, so that the microbial protein is coagulated and denatured and killed; treatment The later medical waste is sent to a sanitary landfill or incinerated\textsuperscript{6}. This method is also suitable for the disinfection of contaminated work clothes, syringes, dressings, microbial culture media, etc., but it is not suitable for the treatment of pathological wastes, such as human tissues and animal carcasses, and the treatment efficiency of drugs and chemical wastes is not high.

2.3.2 Influence parameters
The main technical parameters of the pressure steam sterilization treatment are temperature, steam quality and action time. The size of the waste feed will affect the steam penetration, the treatment cycle time affects the completeness of the sterilization, and the incomplete air removal in the container can affect the sterilizer temperature.

2.3.3 Advantages and disadvantages
In contrast, the pressure steam sterilization technology has the advantages of low investment, low operating cost, easy detection, low risk of residues, good disinfection effect, and a wide range of suitable treatments. The main disadvantage is that the volume and appearance are basically unchanged; there may be air pollutant emissions, easy to produce odor, and can not handle formaldehyde, phenol, mercury and other substances.

2.4 Chemical disinfection

2.4.1 Technical Features
The essence of chemical disinfection is to mix the crushed medical waste with a certain concentration of disinfectant (sodium hypochlorite, peracetic acid, glutaraldehyde, ozone, etc.), and ensure that it has sufficient contact area and time with the disinfectant. It is decomposed and the microorganisms are killed during the disinfection process. The maximum contact between disinfectant and medical waste is the prerequisite to ensure the treatment effect. By using rotary crushing equipment to improve the degree of crushing, to ensure that the disinfectant can penetrate it\textsuperscript{7}. The chemical disinfection method is suitable for the treatment of liquid medical waste and pathological garbage, and it is also gradually being used for the treatment of medical waste that cannot be sterilized by heating or wetting.

2.4.2 Influence parameters
The main factors that determine the effect of chemical disinfection are the concentration and temperature of the disinfectant. The disinfectant with the corresponding pH value is selected according to the nature of the waste. The contact and mixing time of the waste and the medicine, and the recirculation of the fluid are also important factors.

2.4.3 Advantages and disadvantages
The advantages of chemical disinfection are simple and convenient process equipment and operation; good deodorization effect; rapid disinfection process with low one-time investment and low operating cost. For dry treatment, the waste volume reduction rate is high, and no waste liquid or waste water and waste gas are produced. The disadvantage is that dry waste has higher requirements on the crushing system and the pH value monitoring (automation level) of the operation process. Waste liquid and waste gas are generated in the wet waste treatment process, and most disinfectants are harmful to the human body. Not suitable for the treatment of chemotherapy waste, radioactive waste, volatile and semi-volatile organic compounds.
2.5 Electromagnetic wave sterilization method

2.5.1 Technical Principle
Electromagnetic wave sterilization methods include microwave and radio wave methods. Microwave sterilization uses 2450MHz high-frequency electromagnetic waves, while radio wave sterilization uses 10MHz low-frequency electromagnetic waves, which have stronger penetrating power than microwaves. The principle of electromagnetic wave sterilization is that it has the characteristics of being absorbed by water, fat, and protein. It uses the characteristics of selective absorption of energy by microbial cells and places it in the energy field of electromagnetic wave high-frequency oscillation, so that the liquid molecules of microorganisms can be The frequency of the electric field vibrates. This vibration causes the energy in the cell membrane to increase rapidly, resulting in high temperature, which eventually leads to the death of the cell, thereby killing the pathogens in the medical waste. The medical waste after electromagnetic wave treatment can be sanitary landfill as domestic waste. Electromagnetic wave sterilization has application examples in the United States, Australia, Germany and the Philippines.

2.5.2 Influence parameters
Whether it is microwave or radio waves, the factors that determine the sterilization effect are the output power and the actual field strength. According to the characteristics of the waste, the moisture content of the waste has a significant impact on the microwave treatment, and the exposure duration and waste mixing range also have a certain impact.

2.5.3 Advantages and disadvantages
The advantages of electromagnetic wave sterilization treatment method are reflected in the significant reduction in volume and good garbage destruction effect; the system is completely closed and the environmental pollution is small; it is fully automated and easy to operate. The disadvantage is that the cost of construction and operation is not low; the weight loss effect is not good after treatment, it will have a bad smell, and it is not suitable for the treatment of blood and dangerous chemicals.

2.6 Plasma method

2.6.1 Technical principles and characteristics
The plasma method is a new technology that the United States began to develop in the 1990s to treat hazardous waste. The plasma used for waste treatment is a gas cloud formed by the ionization of an inert gas, usually referred to as the fourth state of matter. The plasma system contains a large number of positive and negative charged particles and neutral particles. In the plasma system, an electric current is applied to make the inert gas, and the gas is ionized by applying energy to generate a glow discharge, which can reach a high temperature of 1200 ~ 3000 ℃ within 1/1000 seconds, so that the organic waste is rapidly dehydrated and heated. Decomposition and mitigation, produce mixed combustible gas such as hydrogen, carbon monoxide and alkanes, and then after secondary combustion, it can destroy the potential pathogenic microorganisms in the garbage. Plasma technology can turn medical waste into vitreous solids or slag, and the products can be directly landfilled for disposal.

2.6.2 Influence parameters
The main factors that determine the effect of plasma are the power of the equipment and the energy that can be provided. The higher the output energy, the faster the temperature conversion. In addition, the specified processing time period must be met. The characteristics of the waste have an impact on the electromagnetic wave.
2.6.3 Advantages and disadvantages
The advantages of plasma treatment technology are low exudation, high volume reduction, high
intensity, high disposal efficiency, can treat any form of medical waste, no harmful substances are
discharged, and the potential heat energy can be recycled. The disadvantage is that the construction
and operation cost is very high; the stability of the system is easily affected; the reliability needs to be
verified and improved.

2.7 High temperature pyrolysis incineration method

2.7.1 Technical Principle
The principle of the high-temperature pyrolysis method is to heat the organic components of medical
waste to 600-900°C under oxygen-free or oxygen-depleted conditions, and use heat to break the bonds
of the compounds, so that the large-molecular-weight organics are converted into combustible gases
and liquid fuels. And coke process. The gas produced by pyrolysis mainly contains hydrogen, methane,
carbon monoxide, carbon dioxide and other hydrocarbons and volatile organic compounds.

2.7.2 Influence parameters
The main factors of the high-temperature pyrolysis method are temperature and reaction time.
Maintaining a certain humidity of the waste and the size of the material have an impact on the
treatment efficiency. The molecular structure of the material determines the pyrolysis method.

2.7.3 Advantages
(1) "Treat thoroughly" The high temperature pyrolysis incineration method of medical waste burns
cracked gas and cracked coke. The combustible gas in the cracked gas is used as the fuel for pyrolysis
incineration, and its operating cost is much lower than that of conventional incineration. In addition,
the pyrolysis incineration method requires a smaller air coefficient, the amount of flue gas produced is
significantly reduced, and the required flue gas purification device is smaller, so the overall cost is
smaller than that of the conventional incineration method[10].

(2) "Less harmful substances produced" In the traditional incineration treatment method, due to
oxygen-enriched combustion, dioxins are easily produced under such conditions. The pyrolysis
method is carried out under the conditions of lack of oxygen and removal of acid gas such as chlorine,
which reduces the generation of dioxins, so the pyrolysis incineration method greatly reduces the
amount of dioxins generated by the traditional incineration method.

(3) "Wide range of application" High-temperature pyrolysis medical waste does not require
pretreatment, no classification, and can be directly put into the furnace for treatment, so there is no
obvious selectivity for the treated waste.

3. Analysis of comparative results of medical waste treatment technologies
From the analysis of the above several treatment technologies, it can be seen that high-pressure steam
sterilization technology and incineration technology are almost applicable to all kinds of medical
wastes. However, when using high-pressure steam sterilization technology, the hospital must purchase
a larger dedicated autoclave, and it will produce volatile toxic chemicals. Chemical disinfection is
often used to disinfect infectious liquid waste, but it is difficult to disinfect large amounts of waste.
Incineration technology has a wide range of treatment and can effectively destroy infectious and toxic
substances in medical waste. However, for the production of harmful substances such as dioxins,
suitable furnace types and advanced flue gas purification devices must be used. However, new
technologies such as microwave sterilization, dry heat treatment, plasma spray gun, radiation treatment,
electrothermal deactivation, liquid alloy treatment, and glass paste curing are rarely used in China, and
they are also immature technologies abroad and are difficult to implement. Relatively speaking, the
high temperature pyrolysis method has a wide range of applications, a high recovery rate of pyrolysis,
less pollution such as dioxins, and good economic benefits.
4. Conclusion

Based on the above analysis, it can be seen that the pyrolysis treatment technology of medical waste provides a new way for the diversification of waste treatment, which is in line with the development direction of solid waste treatment that is reduced, harmless, and recycled. This technology has the advantages of high energy recovery rate, low secondary pollution, and good comprehensive economic benefits. The research results are the first in China. The project has developed a relatively complete set of equipment for medical waste pyrolysis treatment and pyrolysis gas recovery, with reasonable design, high level of automation, small floor space, normal operation of the equipment, engineering application and market transformation conditions, and broad promotion Application prospects. The system uses the pyrolysis gas generated by the waste to realize energy circulation, reduces energy consumption and processing costs, and has good economic benefits.

References

[1] Huang Zhengwen, Zhang Bin, Ai Nanshan, Yu Bo. Comparative analysis of eight medical waste treatment methods[J]. Chinese Journal of Disinfection, 2008(03):313-315.
[2] Yu Bo, Zhang Bin, Huang Zhengwen. A review of several medical waste treatment technologies [J]. Guangzhou Environmental Science, 2009, 24(02): 1-5+20.
[3] Yu Bin. Analysis of the current situation and countermeasures of medical waste treatment in my country[J]. Resource Conservation and Environmental Protection, 2017(12): 48+51.
[4] Luan Yuanyuan. Discussion on the harmless incineration of medical solid waste[J]. Chemical Management, 2016(23):301.
[5] Luo Shuai, Zhang Xiangming, Wu Jiangbin, Li Long. my country's medical waste disposal technology and current situation[J]. Guangdong Chemical Industry, 2017, 44(01): 44-45.
[6] Chai Shouming, Wang Jianwei, Chen Libo, Yang Qianming. Research progress of thermal plasma hazardous waste treatment technology[J]. Modern Manufacturing Technology and Equipment, 2016(10): 4-10.
[7] Huang Yaoqiang. Research progress in medical waste treatment[J]. Forum on Primary Medicine, 2013, 17(07): 924-926.
[8] Niu Bo, Yu Fengqing. The hazards and disposal methods of medical waste[J]. Guangdong Chemical Industry, 2013, 40(11): 152-153+142.
[9] Li Hua, Xu Jian, Pan Minqiang, Shen Hong. Treatment technology and disposal status of solid medical waste in my country [J]. Journal of Hebei North University (Medical Edition), 2008(03): 72-74.
[10] Liu Yin. Analysis of the current situation of medical waste management [J]. Electronic Journal of General Stomatology, 2019, 6(05): 28+34.