

## Options for Healthcare Waste Management and Treatment in China

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**Abstract:** Healthcare waste management and treatment is one of the national priority tasks of China's Tenth Five-Year Plan. Numerous installations disposing medical waste have already operated the project or under construction to the operation in 2006. This paper focuses on the assessment of existing and future options to handle medical waste (MW). Internationally available and so far in China applied technologies and management practice are analysed, including the problems how to segregate medical waste streams at the source and to reduce the 'critical waste' to mainly infectious and aesthetically sensible materials. Non-hazardous MW can be managed and treated in analogue to municipal solid waste (MSW). In most of the European countries decentralised hospital incinerators have been, because of high operation costs and pollution problems, widely banned and replaced by pre-treatment technologies at the source and centralised incineration plants for hazardous MW. Information for adapting and further developing MW management solutions and treatment technologies in China and applying the most appropriate MWM practice is provided.

**Key words:** healthcare waste; management; incineration; gasification; mechanical biological treatment; non-incineration treatment; non-thermal treatment

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### 1 INTRODUCTION

Waste from the medical and healthcare sector, produced at all levels of medical and sanitary organizations in clinics, healthcare institutions and related education and research institutes contains a certain extent infectious and toxic waste, including infectious, pathological, pharmaceutical and chemical wastes. This waste is internationally and also in China legally recognized as 'hazardous waste', mainly because of its risk to cause acute or epidemic infections by the impact of pathogenic bacteria and viruses. Without proper management and treatment, infectious medical waste (MW) may cause serious environmental problems<sup>[1,2]</sup>. Every year China generates around 650000 tons of medical waste, ca. 2% of municipal solid waste (MSW), and this figure appears to be growing at about 19%~25% per year. The amount of MW per capita in China is at present about 8~10 times lower than that in western countries. MSW is only collected regularly in urban areas from about 25% of the Chinese population and only half of this waste is treated properly<sup>[3]</sup>. As MW emerges mainly in the cities (at least on county level) the collection rate is estimated to be much higher. The State Environmental Protection Administration of China (SEPA), responsible for MW,

plans that during the Tenth Five-Year Plan till the end of 2005 an increase of 100% in medical waste treatment and MW management (MWM) has to follow certain standardized procedures. Therefore the most relevant management options and treatment technologies used in the recent years should be discussed. Fortunately the awareness has increased to take care of sanitary disposal of medical waste and the selection of suitable treatment technologies in a more professional and scientific manner.

### 2 THE EUROPEAN APPROACH

In Europe MW management is focusing on segregation of the infectious and toxic waste stream (see Fig.1 and Table 1) which must be treated to prevent the spread of diseases. Imposing segregated practices within medical facilities and hospitals to separate biological and chemical hazardous waste will result in a clean solid waste stream, from which a major part can be recycled easily. If proper segregation is achieved through training, clear standards and thorough enforcement, then resources can be turned to the management of the small portion of the waste stream needing special treatment. The review of MW treatment technologies has found that cost-effective alternative technologies are available,

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which are safer and cleaner than incineration. Only about 10% of MW requires special treatment.

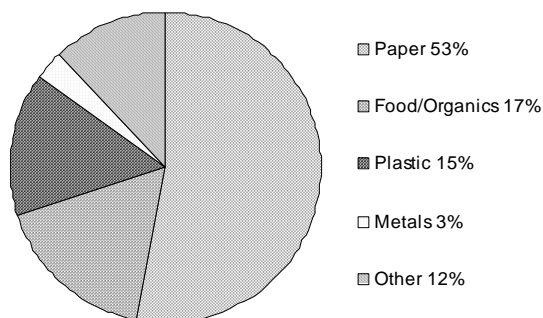


Fig.1 Average composition of hospital waste in EU, approximately 12% subject to special disposal

In Austria even only 8.5% of MW (total 35000 t/a) is considered to be hazardous (see Table 1) and subject

to special treatment, whilst more than 80% of the other MW from the healthcare sector is similar or no more hygienic risk than municipal solid waste according to EU and WHO view<sup>[4]</sup>. During the last 15 years the decentralised hospital incinerators have been closed down because of high operation and maintenance costs and air pollution problems. Pre-treatment technologies have been introduced at the source, and centralised incineration plants are used for the hazardous MW. For example in Austria, already 10 years ago, a countrywide collection logistic for hazardous MW (about 5% of the total MW), including the introduction of special one-way receptacles, a network of intermediate cold-storage facilities and a centralised disposal at the hazardous waste rotary kiln plant in Vienna was established.

**Table 1 Medical waste categories according to EU Waste Catalogue, WHO and China (2003)**

European Waste Catalogue (EWC)	WHO categories of healthcare waste	China (MOH, SEPA) Classification of Medical Wastes, 287-2003
18 01 01	Sharps	Sharps (pinhead, suture stitch, scalpel, bistouries, scissors, slide, glass test tube, glass ampoule, etc.)
18 01 02	Pathological waste	Pathological waste: 1. Human organs from operation and other processes; 2. Animal organs and bodies from medical experiments; 3. Human organs after pathological section.
18 01 03*	Infectious waste	Infectious waste: 1. Materials contaminated by blood and body fluid excrement; 2. Daily wastes from institutions where patients with contagious or suspected infectious diseases are treated; 3. Culture medium, specimen and culture of pathogen; 4. Discarded medical specimen; 5. Blood and blood serum; 6. One-time articles and instruments from medical treatment to be deemed as infectious wastes after use.
18 01 04	Non-risk or "general" healthcare waste	Wastes, their collection and disposal are not subject to special requirements in order to prevent infection (for example dressings, plaster casts, linen, disposable clothing, diapers).
18 01 06*	Chemical waste, waste with high content of HM	Chemicals consisting of or containing dangerous substances (See Chemical waste)
18 01 07	Chemical waste	Chemicals other than those mentioned in 18 01 06 Chemical waste from medical labs, disinfection reagents, mercury blood-pressure meters and thermometers
18 01 08*	Genotoxic waste	Cytotoxic and cytostatic medicines (See medicaments)
18 01 09	Pharmaceutical waste	Medicines other than those mentioned in 18 01 08 Medicaments: Antibiotics, non-prescriptive medicaments, cell toxic and inheritance toxic medicaments, medicaments that are suspected to cause cancer, vaccine, and blood products.
18 01 10*	Waste with high content of heavy metals	Amalgam waste from dental care
15 01 11*	Pressurized containers	Metallic packaging containing a dangerous solid porous matrix (for example asbestos), including empty pressure containers
National regulation [EU Proposal: COM (2003) 32 Final]		Radiological waste

Note: \* indicates the waste classified as hazardous.

### 3 NON-THERMAL DISPOSAL AND TREATMENT OF MEDICAL WASTE

Safe and reliable long-term diversified disposal of all kinds of waste by appropriate technologies is the target of integrated waste management. But landfilling and uncontrolled land disposal are still the most commonly used methods for waste disposal worldwide, including China. While sanitary landfill of medical waste should be carefully re-considered and an obligatory pre-treatment is to be anticipated in line with relevant regulations. The planning, design and operation of modern landfills involve the application of a variety of scientific, engineering and economic principles<sup>[5]</sup>, and if thermal treatment options are not available, MW can be co-disposed by sanitary landfilling under consideration of pre-treatment at the source (such as sterilization of infectious materials and separate collection of sharps) or at specific treatment plants by applying mechanical biological co-treatment (MBT) to MSW. Fully process controlled in-vessel technologies are to be used and a guaranteed 2 times in 3 days period of 65 °C (microbial self-heating system) to remove pathogenic germs must be ensured. MBT processing is not appropriate for highly infectious non-sterilized waste and the waste from surgery. Especially body parts from surgeries might be disposed alternatively in crematories.

Among non-incineration medical waste treatment technologies, chemical treatment systems have a well-documented history in disinfecting and sterilizing of medical devices.

Applying these methods to waste treatment, the material must first be shredded prior to exposure to agents such as sodium hypo-chlorite, chlorine dioxide, per-acetic acid, glutaraldehyde, quaternary ammonium compounds, etc., in order to bring all waste particles into direct contact with the chemicals<sup>[6]</sup>. Biological processes, employing enzymes to destroy organic matters, have no tradition in China and even only a few technologies are based on biological processes in western countries.

### 4 LOW-TEMPERATURE TREATMENT

Thermal treatment technologies inactivate pathogenic microorganisms and partly decompose toxic organic and hazardous substances. These technologies can be divided into low- and high-temperature treatments according to the operation temperatures<sup>[7]</sup>, as shown in Fig.2. Low-temperature treatment at the source such as pressure steam autoclaves and electromagnetic wave sterilization does not have tradition in China, but it is going to be introduced as an option to process the MW prior landfilling. Mechanical biological treatment plants do exist in China and they could be used to remove pathogens during the haemophilic decomposition phase (mainly suitable for pre-treated infectious waste or EWC 180104 in Table 1). Due to the hygienic risks and aesthetic problems, China Regulations for Disposal of Hazardous Waste, following the international trend and recommendations, does not allow MW landfilling anymore, though in some specific cases where no other means are available, sanitary landfilling including special consideration during dumping can be seen as an tolerable interim solution.

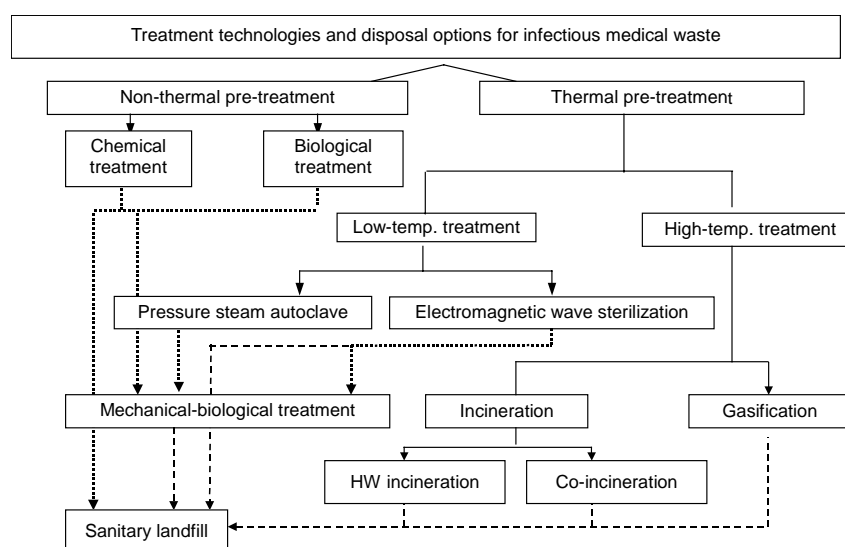


Fig.2 Disposal and treatment technologies for infectious healthcare waste in China (overview)

## 5 HIGH-TEMPERATURE TREATMENT BY INCINERATION

Incineration and gasification are the relevant high-temperature treatment technologies and they are the most employed methods for MW treatment in China. China's plan is to increase the medical waste incineration capacity to 0.4 Mt/a during the period of the Tenth Five-Year Plan. More than 100 centralized medical waste high-temperature treatment plants will be in operation at the end of 2005.

Central incineration plants fully equipped with 4 or 5 step flue gas cleaning facility provide numerous advantages: (1) there is no need for pre-treatment, (2) no separation required, (3) no grinding of feedstock material, (4) a volume reduction of 80%~90% (due to

the high organic content) takes place, (5) undefined waste may have no negative effect the environment, (6) heat recovery can be applied for large-scale installations, and (7) there is long lasting experience regarding technology and operation. The disadvantages of incineration plants are: (1) high investment and operation costs, and (2) the risk of negative impact on the environment, such as acid gases (HCl, NO<sub>x</sub>), particulate emissions and solid residues (fly ash, bottom slag, and sludge from flue gas cleaning) containing heavy metals and dioxins. The costs for the pollution control system are high (50%~65% of the total investment). Suitable ranges and characters of each waste treatment technology are listed in Tables 2 and 3<sup>[8-11]</sup>.

**Table 2 Suitable ranges of different disposed and treatment technologies**

Technology	Type of waste					
	Infectious	Pathological	Sharps	Pharmaceutical	Genotoxic	Chemical
Incineration	O	O	O	O	O	O
Plasma	O	O	O	O	O	O
Chemical treatment	O	O	O	×	×	×
Steam autoclave	O	O	O	×	×	×
Electromagnetic wave	O	×	O	×	×	×
MBT treatment	O	×	×	Small part	×	×
Electromagnetic wave	O	×	O	×	×	×
Sanitary landfilling	O	×	×	Small part	×	×

**Table 3 Comparison of commonly used medical waste treatment methods**

Treatment	Influential factor	Advantage	Disadvantage
Incineration	Turbulence and mixing, feedstock moisture and manner, temperature and residence time, maintenance and repair	For all waste types, undefined waste, acceptable, heat recovery potential for large systems	High investment and operation cost, suitable for larger installations, air pollution control, site difficult to find, secondary hazardous waste
Gasification	Temperature control and chamber operation, residence time of waste in the chamber	Lower investment cost compared to incineration, simple flue gas technology, use of the pyrolysis gas	Not suitable for low calorific waste, skilled plant operation required
Steam autoclave	Temperature and pressure, steam penetration, size of waste, length of treatment cycles, sealing condition of high-pressure kettle	Low investment cost, low maintenance cost, ease of biological tests, low hazard residues	Appearance and volume of waste unchanged, not suitable for all types of waste, possible air emissions
Microwave	Waste composition and moisture, duration of exposure, turbulence and mixing, microwave strength	Undefined waste, significant volume reduction, undefined waste	High investment cost, not suitable for all waste types, possible air emissions
Mechanical-chemical	Type of waste, temperature, pH, high investment cost, chemical contact time, mixing condition, type of processing (cycle or flow trough)	Significant volume reduction, size of feedstock not critical, short treatment time, waste deodorization	High investment cost, not suitable for all types of waste, possible air emissions, need to store chemical agents

## 6 MEDICAL WASTE INCINERATION APPLIED IN CHINA

Incineration technologies for MW treatment are various and can be classified into direct incineration, co-incineration, pyrolysis and gasification. Direct incineration systems have only one combustion chamber in which organic volatile components and fixed carbon combust. These techniques have numerous advantages

such as simple construction, easy operation and relatively low investment, but the flue gas is highly polluted. There are three basic types of furnaces: small-scale chamber, rotary kiln and grate type incinerators. Hangzhou Hazardous Waste Treatment Centre (Dadi Company) uses two parallel-connected incinerators and introduces the flue gas from both into a 3-step flue gas treatment system (quenching chamber, dust precipitation, and desulphurization). The system

has operated well since 1998.

Gasification or so-called controlled air oxidation is occasionally used to treat medical waste abroad. In China gasification is particularly seen as a more environmentally friendly treatment option as the concentration of pollutants in the "fuel gas" is much lower compared to incinerator flue gas. Volatile organic waste is decomposed at a low oxygen-level in the first chamber, the low temperatures and the undersupply with oxygen avoid the volatilization of heavy metals, it is not supportive to generate dioxins, and the  $\text{NO}_x$  formation is limited. The combustible fuel gas can then be burned completely in the second chamber under excess-air condition by avoiding the generation of dioxins, and with a simple pollution control system the pollution emission standard can be met<sup>[12]</sup>. There are various basic types of gasification systems: horizontal controlled air oxidation systems, vertical pyrolysis gasifier, two-stage incinerators, electric incinerator, and plasma incinerator. Gasification technology has developed quickly in medical waste treatment field and gradually become the alternative technology to conventional incineration in China.

A 15 t/d rotary kiln medical waste gasification system, designed by Junbang Company is being built in Beijing. Shenyang Medical Waste Incineration Plant, Liaoning, uses a two-stage gasification incinerator developed by Shenyang Environmental Science Research Institute, which has been successfully operated for about two years. Taiyuan (Shanxi) is using an experimental vertical gasification reactor, which was set in operation 1999.

## 7 DISCUSSION ON MEDICAL WASTE TREATMENT TECHNOLOGY IN CHINA

Though the National Environmental Protection Act and the targets of the China Tenth Five-Year Plan requests centralized treatment of MW, the practical performance is still stepping behind. Suitable technology has to be chosen not to produce new sources of waste, and to cover the demand, at latest after a new case of epidemic disease, the problem might get evident again. So it is vital to build management, logistic and integrated treatment systems highly practicable and apply technologies on the basis of compulsory treatment targets. Following western experience the infectious part of the waste should be limited to the necessary amount by segregated collection at the sources (from infectious departments, surgery, laboratories, pathology).

Non-incineration technologies should be applied to the best possible extend, but while choosing medical waste thermal treatment, the following aspects should be fully considered.

**Collection logistics.** One-way containers tightly closed and with sufficient strength should be used to prevent bursting under normal handling conditions before delivered to the incineration plant. The containers may not be cylindrical to avoid rolling on the incinerator grate. MW should be transported by authorized companies, equipped with cleaning and disinfections facilities, using special labeled vehicles authorized for medical waste transport to permitted transfer stations and treatment facilities, as required by the state law.

**Type of feeding system.** The feeding system must consider the infectious potential of medical waste. The MW is usually collected in bags or better in the before mentioned closed one-way plastic receptacles. Considering the size of the receptacles the waste feed hopper should directly after unloading provide the waste to a closed storage area or directly to the combustion unit. A sealed storage connected with the hopper may be considered.

**Incinerator type.** The furnace is the key element of the whole incineration technology, which influences the emission load of the flue gas. According to the experience of developed countries and the measures suggested by WHO, two combustion chambers are needed. The temperature of the first one should be higher than  $850^\circ\text{C}$ , and that in the second ( $1050\pm 50^\circ\text{C}$ ) to completely burn out the flue gas during at least 2 seconds. The residence time of MW in the first chamber must not be less than 1 h. Direct incineration of HW is mainly suitable for those cities which do not have the possibility for MSW or hazardous waste co-incineration.

**Co-incineration.** Cities, which have one MSW incineration plant, may co-incinerate the MW. At present, most domestic waste incinerators in China are using grate type furnaces. To treat MW by incinerators designed for domestic waste is an economic and efficient possibility recommended by WHO. China's Hazardous Wastes-Pollution Control Standards for Incineration requests for such kind of medical waste incineration (incineration requirements as mentioned above) including pollution control technology<sup>[13]</sup>. If MW is incinerated, the particle size of the waste will determine the residence time in the grate to ensure a complete burning out of the substance to achieve an ignition loss of the bottom ash below 5% DS.

Successful examples of this application are operated in Nova Scotia, Cape Breton, Canada, and Zhuhai, Guandong, China.

**Air pollution control technology.** The proper design of flue gas cleaning systems to prevent harmful air pollution from MW incineration is a critical and essential part of the design for an incineration system. At the same time the lack of trust in function and operation of this system is a main reason for the public to oppose against medical waste incineration technology. The air pollution control system must contain a bag house precipitator, a quenching system and an activated carbon absorber that reduces air pollutants in the flue gas and ensures to meet the related emission standards.

## 8 CONCLUSIONS AND SUGGESTIONS

Management, disposal and treatment technology for health care wastes in China are still behind the status of developed countries. The installations and the development of new projects often lack scientific experience, professional management and clear operation standards. EU experience may help to improve the situation by carefully adapting to the Chinese conditions. Choosing and implementing an appropriate treatment technology to replace the existing landfilling practice is only one aspect to solve China's medical waste problems. Increased environmental awareness after SARS event has induced the enactment of the required legislation to build up an appropriate management of medical waste. According to western standards the first priority for introducing an integrated medical waste management system should be source segregation of different types of waste in order to minimize the quantities in infectious waste required for hygienic disposal and to achieve waste minimization through recycling. Collection receptacles, transport logistics and transfer stations are required to deliver the critical waste to authorized central disposal plants. SEPA still follows the strategy to dispose the unsorted MW to avoid illegal utilization of infectious secondary raw materials (such as contaminated infusion tubes) to be illegally merchandised by hospital staff. But it is suggested to apply this strategy only to hazardous MW and to provide sufficient training and control to introduce the new MW management practice. The cost for HW disposal has to be covered by a daily fee per patient of ¥3 RMB, which is related to app. ¥2000 RMB/t) already to be collected by the EPBs.

According to WHO suggestions both MSW

co-incineration plants and hazardous waste incinerators can be used when the present state of the art technology is applied<sup>[14]</sup>. To reduce manipulation and transportation risks non-incineration technologies from developed countries can be employed for disinfection, but they have to be adjusted to the Chinese conditions. As interim solutions in the areas where no specific technology is available to treat healthcare waste, existing MBT plants (depending on the technology) and controlled landfill disposal can help to cover local needs.

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