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Sustainable management measures for healthcare waste in China

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ABSTRACT

This paper discusses actions aimed at sustainable management of healthcare wastes (HCW) in China, taking into account the current national situation in this field, as well as the requirements deriving from the Stockholm Convention on Persistent Organic Pollutants and the WHO recommendations. By the end of 2005, there were 149 low-standard HCW disposal facilities in operation in China, distributed throughout different areas. According to the *National Hazardous Waste and Healthcare Waste Disposal Facility Construction Plan*, 331 modern, high-standard, centralized facilities will be built up in China in municipal level cities. Although incineration is still the main technical option for HCW disposal in China, it is expected that, especially for medium and small size facilities, non-incineration technologies will develop quickly and will soon become the main technical option. The basic management needs – both from the point of view of pollution control and final disposal – have been defined, and a system of technical and environmental standards has been formulated and implemented; however, there are still some shortages. This is particularly true when considering the best available techniques and best environmental practices developed under the Stockholm Convention, with which the present technological and managing situations are not completely compliant. In this framework, the lifecycle (from generation to final disposal of wastes) of HCW and holistic approaches (technology verification, facilities operation, environmental supervision, environmental monitoring, training system, financial mechanism, etc.) towards HCW management are the most important criteria for the sustainable and reliable management of HCW in China.

1. Introduction

In China, healthcare wastes (HCW) are defined as wastes characterized by infectious, toxic, and other hazardous properties deriving directly or indirectly from medical treatment, prevention, health protection, and other related activities in healthcare institutions (PR China State Council, 2003). According to Chinese legislation, HCW are classified, based on their properties and the production source, as infectious waste, pathological waste, sharp objects, chemical waste, and pharmaceutical waste (PR China MOH, SEPA, 2003).

With the rising awareness of the environmental implications of waste disposal, the management and disposal of HCW are gaining more and more attention by the scientific community and by general society. It is well known that inappropriate treatment and final disposal of the wastes can result in negative impacts upon both public health and the environment (Diaz et al., 2005).

The present amount of HCW generated yearly in China – one of the largest developing countries with a population of 1.3 billion persons – is 650,000 tons. This amount will reach 680,000 tons by the end of 2010 (PR China State Council, 2003). The environmentally sound management and disposal of HCW must be carried out with the goal of protecting the environment and human health.

The problem of sustainable management of HCW has become more important and challenging since the ratification of the Stockholm Convention on Persistent Organic Pollutants (hereafter referred to as the Stockholm Convention) by China, as reflected in the PR China National Implementation Plan for the Stockholm Convention on Persistent Organic Pollutants (NIP) list of priorities (PR China National Implementation Plan, 2007).

Incineration has until now been the most widespread adopted technology for the disposal of HCW, as it also neutralizes the infectivity of the wastes, which is the most hazardous medical waste property. However, if not correctly operated, incineration may lead to high levels of PCDD/PCDFs and heavy metal emissions. In the last 10 years, the enforcement of stricter PCDD/PCDFs emission standards by many countries significantly reduced the release of these substances into the environment (WHO, 2005). HCW incineration is recognized as a key PCDD/PCDFs release source by the Stockholm

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Convention. This fact is also confirmed by the China PCDD/PCDFs inventory reported in the NIP, where in 2004 PCDD/PCDFs emission from HCW incineration is reported to have contributed 1.18 kg/a for a total figure of over 10.24 kg (PR China, 2007).

Under Article 5 and Annex C of the Stockholm Convention, parties are to promote in some cases and require in others the use of best available techniques (BAT), and shall promote the application of best environmental practices (BEP). The BAT/BEP guideline refers to incineration as the main waste disposal process over the last 50 years, and may still be a suitable option for waste disposal, provided that proper technology and processes are adopted to minimize their risk (UNEP Chemicals, 2006).

The BAT/BEP guideline describes and recommends the proper design and operation parameters for different classes of incinerators, such as fixed and fluidized bed, and rotary kiln. The main requirements concerning waste minimization, collection, classification, storage, transportation, treatment and final disposal of HCW are also indicated (UNEP Chemicals, 2006). Concerning the reduction of PCDD/PCDFs release, although the BAT/BEP guideline does not establish a compulsory limit, it classifies different combinations of primary and secondary measures as BAT/BEP, which allow reaching an emission value of PCDD/PCDFs falling within a range of 0.01–0.1 ng I-TEQ/Nm^3 (at 11% O2) (UNEP Chemicals). In other words, it can be said that the achievable limits of 0.1 ng I-TEQ/Nm^3 for PCDD/PCDFs is the minimum BAT/BEP guideline requirement (Chen et al., 2007).

Non-incineration technologies, also called alternatives to incineration, are sterilization (steam, advanced steam, dry heat), microwave treatment, alkaline hydrolysis, biological treatment or in certain cases landfill disposal. These are also described by the BAT/BEP guideline, and for new facilities being built, these alternative technologies should be considered as the preferred options. In China, especially for small size HCW incinerators, application of BAT is often difficult, given the high costs associated with building, operating, maintaining, and monitoring such facilities. When considering proposals to construct new HCW disposal facilities, consideration should be given to alternatives such as activities that minimize the generation of medical waste, including resource recovery, reuse, recycling, waste separation, and to promoting products that generate less waste (UNEP Chemicals).

Actually, the BAT/BEP guideline contains important indications not only on the technological side, but also on waste management issues. Only the proper combination of these two aspects may allow a substantial reduction of PCDD/PCDFs generation associated with waste disposal, in the case of both incineration and non-incineration technologies.

The policy of the World Health Organization (WHO) to promote effective non-incineration technologies for the final disposal of HCW, in order to avoid both the disease burden from unsafe HCW management and potential risks from dioxins, furans, and co-planar PCBs, are the following (WHO, 2005):

- Prevent the health risks associated with exposure to HCW for both health workers and the public by promoting environmentally sound management policies for HCW;
- Support global efforts to reduce the amount of noxious emissions released into the atmosphere to reduce disease and defer the onset of global climate change;
- Support the Stockholm Convention;
- Support the Basel Convention (1989) on hazardous wastes and other wastes;
- Reduce the exposure to toxic pollutants associated with the combustion process through the promotion of appropriate practices for high temperature incineration.

In China, the Stockholm Convention entered into force on November 11, 2004. This means that China must apply BAT and promote BEP in new sources in priority source categories, and complete PCDD/PCDFs release reduction demonstrations in selected existing sources in the priority sectors by November 11, 2010 (UNEP Chemicals, 2001). Furthermore, the WHO policy and objective are in good agreement with the Stockholm Convention. How to eliminate the health risks associated with exposure to HCW and reduce noxious emissions released into the atmosphere during the process of HCW incineration is a common concern of international society.

Based on the above considerations and on the analysis of the existing policy, regulation, and standard system, sustainable management measures and proposals for HCW in China are discussed and proposed in this paper.

2. Management situation

2.1. Generation, disposal of HCW

HCW generation in China is extremely high, and it is increasing rapidly. The generated amount is estimated to be 650,000 tons per year, an average of 1,780 tons per day. Based on the 5% increase of sickbeds in medical institutions, the generated HCW amount is expected to reach 680,000 tons per year, an average of 1,870 tons per day, in 2010.

There are presently a total of 149 facilities for HCW in operation, of which 85 (57.1%), 33 (22.1%), and 31 (20.8%) of the facilities are located in the east, middle, and west of China, respectively. The disposal capacity in the east of China is 775.91 tons per day, 58.5% of total disposal capacity; the disposal capacity in the middle of China is 318.44 tons per day, 24.0% of total disposal capacity; and the disposal capacity in the west of China is 233.08 tons per day, 17.5% of total disposal capacity (Sun et al., 2007a).

The distribution of disposal facilities and the disposal capacity for HCW in China are presented in Table 1. This table shows that the geographic distribution is not evenly balanced in the different regions of China. There are more facilities available in the east of China than in the middle and west of China together. Moreover, the exiting facilities in all regions in China cannot meet the disposal requirements of the generated HCW (Sun et al., 2007a).

According to the *National Hazardous Waste and Healthcare Waste Disposal Facility Construction Plan* (hereafter referred to as the National Plan), 331 centralized HCW disposal facilities (300 HCW-dedicated disposal facilities and 31 HCW and hazardous waste disposal facilities) are needed in municipalities across the country to ensure the safe disposal of HCW. The implementation of the National Plan will allow for a better distribution of the facilities. The geographical distribution of facilities and of the disposal capacity foreseen by the National Plan in China is shown in Fig. 1. From this figure it is also possible to see that the 331 disposal facilities will be built in all regions in municipalities crossing 31 provinces (not including Hong Kong, Macao, and Taiwan).

The National Plan has been developed following four main principles: (1) a reasonable distribution of centralized disposal plants is the starting point for suitable HCW management, while the instal-

Table 1
The Distribution of Disposal Facilities and Disposal Capacity for HCW in China.

Region	Disposal facilities layout		Disposal capacity layout	
	Layout number	Layout percentage (%)	Disposal amount (tons)	Disposal percentage (%)
East of China	85	57.1	775.91	58.5
Middle of China	33	22.1	318.44	24.0
West of China	31	20.8	233.08	17.5
Total	149	100	1327.43	100

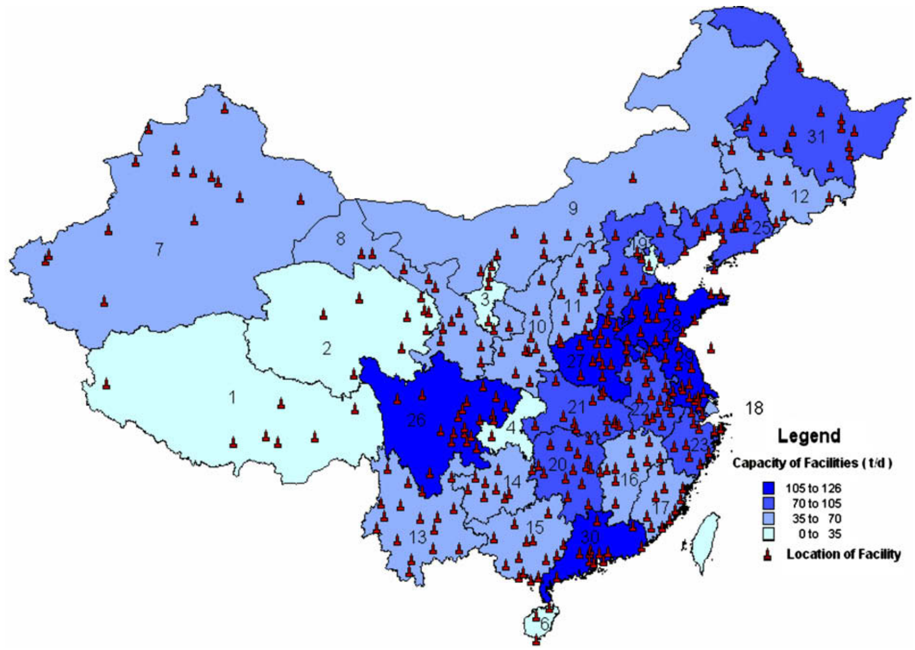

Fig. 1. Geographical Distribution of Facilities and of the Disposal Capacity foreseen by the National Plan in China, Province: Tibet (1), Qinghai (2), Ningxia (3), Chongqing (4), Tianjin (5), Hainan (6), Xinjiang (7), Gansu(8), Inner Mongolia (9), Shanxi (10), Shananxi (11), Jilin (12), Yunnan (13), Guizhou (14), Guangxi (15), Jiangxi (16), Fujian (17), Shanghai (18), Beijing (19), Hunan (20), Hubei (21), Anhui (22), Zhejiang (23), Hebei (24), Liaoning (25), Sichuan (26), Henan (27), Shandong (28), Jiangsu (29), Guangdong (30), Heilongjiang (31).

lation of decentralized disposal capacity will gradually follow; (2) it is necessary to consider the need to install centralized HCW and hazardous waste disposal facilities together; (3) advanced, practical, mature, and reliable techniques for obtaining safe treatment and avoiding secondary pollution must be adopted; and (4) disposal facilities should be functionally complete (PR China State Council, 2004).

The feasibility study and environmental impact assessment of the HCW disposal facility construction project will be commissioned by the owner of the project and approved by the provincial Development and Reform Commission (DRC) and the provincial Environmental Protection Bureau (EPB), respectively, and will then be submitted to SEPA to recheck. The feasibility study report for the HCW disposal facility construction project will be revised according to the results of the rechecking, and submitted to the National Development and Reform Commission (NDRC) by SEPA for approval of national investment. The capital investment funded by the central government is 35%, 60%, and 70% of the total project capital investment in the east, middle, and west of China, respectively; the other funding will be raised by the owner of project. The preliminary design and construction process will be carried out at the local level according to administrative purview. The checking and acceptance of the construction project should be approved by the provincial DRC and EPB under the supervision of NDRC and SEPA.

For the east of China, a disposal capacity of 830 tons per day – 40.2% of the whole country's disposal needs – is foreseen, with 96 disposal facilities. For the middle of China, the plan foresees 628 tons per day – 30.4% of the country's capacity – with 105 disposal facilities. The planned disposal capacity for the west of China is 510 tons per day, i.e., 29.4% of the country's capacity, with 103 disposal facilities. It is expected that the distribution of disposal facilities and disposal capacity for HCW in China will meet the recent and near future demand for disposal capacity (PR China State Council, 2004).

By the end of 2007, 73 HCW projects foreseen by the National Plan have been authorized and will be in operation within a 3-yr period. By the end of 2008, a further 63 facilities will be completed. These projects account for 41% of the total of 331 National Plan projects. Moreover, considering that due to their poor techniques and technical conditions, over 50% of the existing 149 disposal facilities will soon be dismantled and reconstructed using the investment of the National Plan, the situation of HCW management in China will improve quite rapidly. The final implementation progress of the National Plan will continue for the period of the next 5 yr due to different situations of different regions in China.

2.2. Technical application and facilities operation of HCW disposal

Presently, incineration is the most widespread technology used for HCW disposal. However, for several reasons it is expected that non-incineration technologies will be the predominant technologies for future small and medium size disposal facilities.

Table 2 summarizes the main advantages and shortcomings of the different technologies for HCW in China. The main advantages of incineration technologies are technical maturity, versatility in accepting different type of wastes, waste volume and weight reduction, capability to produce unrecognizable residues, very high disinfecting power, heat recovery potential for large systems, availability of operational standards and specifications, and more (Akter, 2000).

The above advantages easily explain the success of incineration technologies. However, due to increasing environmental awareness and recent technology developments, the use of non-incineration technologies like high temperature steam-based autoclave, microwave, and chemical treatment have progressively increased. There are several drivers for the increasing use of non-incineration technologies, which may be of utmost importance to China. First, many incineration facilities, built decades ago, have to be renewed or dismantled in order to meet stricter standard limits and pollution control requirements. In the course of their replacement, the construction and operation cost of non-incineration technologies may represent a significant advantage compared to the incineration option. Second, the need to fulfill the Stockholm

Table 2
Main advantages and shortcomings of the different technologies for HCW in China (Akter, 2000).

Type	Factors	Advantages	Disadvantages	Pollutants emission	Scope can be treated
Incineration/ pyrolysis-gasification	• Turbulence and mixing • Moisture content of waste • Filling combustion chamber • Temperature and residence time • Maintenance and repair	• Mature and widely used technology • Volume and weight reduction • Unrecognizable waste • Complete disinfection • Heat recovery potential for large system • Broad applicability, acceptable for all waste types • Large scale system of waste • Related standards and specifications completed	• Public opposition • High investment and operation costs • High maintenance cost • Expensive control equipment required to reduce emissions • Skilled operator needed • Bottom and fly ash may be hazardous	PCDD/PCDFs SO_2, HCl, NO_x, Heavy metals, etc.	Acceptable for all waste types
High temperature steam-based	• Waste characteristics • Temperature and pressure • Steam penetration • Size of waste load • Length and number of treatment cycles • Degree of vacuum in the chamber	• Low investment cost • Low operating cost • Ease of biological tests • Low hazard residue • PCDD/PCDFs emission free	• Appearance, volume unchanged • Not suitable for all waste types, chemical waste and pharmaceutical waste can not be treated • Possible incomplete disinfection	Microorganisms, Odour, VOCs and others	Infectious waste, Pathological waste, Sharp objects
Microwave	• Moisture content of waste • Microwave strength • Duration of exposure • Extent of waste mixture	• Unrecognizable waste • Significant volume reduction • Absence of liquid discharge • PCDD/PCDFs emission free	• Mod-High investment cost • Not suitable for all waste types, chemical waste and pharmaceutical waste can not be treated • Possible incomplete disinfection	Microorganisms, Odour, VOCs and others	Infectious waste, Pathological waste, Sharp objects
Chemical	• Concerns for chemicals, temperature, • pH • Chemical contact time • Waste and chemical mixing • Recirculation vs flow-through	• Significant volume reduction • Unrecognizable waste • Rapid processing • Waste deodorization • PCDD/PCDFs emission free	• Mod -High investment cost • Not suitable for all waste types, chemical waste and pharmaceutical waste can not be treated • Possible incomplete disinfection • Need for chemical storage	Microorganisms, Odour, VOCs and others	Infectious waste, Pathological waste, Sharp objects

Convention requirements for the new plants will represent an incremental investment and operational cost due to the need to adopt up-to-date air pollution control systems, the burden of this incremental cost will prove uneconomic for small facilities. In these cases, centralization or adoption of non-incineration technologies will be the only viable options. Third, the public acceptance of incineration is quite low, making it much easier to get non-incineration technologies approved, although non-incineration technologies may also have environmental problems. Fourth, due to the extremely strict requirements for selecting sites for the construction of incineration facilities, there may be insurmountable social and economic constraints. The adoption, in western countries, of non-incineration technologies, characterized by low investment and operational costs, production of non-dangerous residue, and zero PCDD/PCDFs emissions, has often allowed the above mentioned problems to be avoided. For the same reasons, these technologies may prove very successful in China, especially in regions where the centralization of disposal plants may present logistical complexities (Health Care without Harm, 2001; Malkan, 2005).

However, no single technology offers a panacea to the complexity of medical waste disposal. Each technology has its advantages and disadvantages, and for non-incineration technologies, it is still necessary to determine which technology best meets the local waste management needs while minimizing the impact on the environment, enhancing occupational safety, and protecting public health (Health Care without Harm, 2004).

According to the information of the Nationwide General Investigation on Hazardous Waste Disposal Facilities in 2004 (Sun et al., 2007b), among the existing 149 HCW disposal facilities in operation, there are 147 incineration facilities. Therefore, incineration is presently the mainstream technology employed in China. The application of non-incineration technologies in China is less widespread than in developed countries. SEPA issued technical and environmental standards in the field of non-incineration technologies only in 2005, including three engineering and technical specifications for the construction and operation of chemical disinfection, microwave, and high temperature steam-based technology. Notwithstanding the existence of these standards, knowledge in this field, both on the administrative and technical sides, is still scarce in China, and the non-incineration technologies, policies, regulation, and standards are still at an early stage. Despite an increasing application of non-incineration technologies in some cities in China, incineration is still the most widely used HCW disposal technology in the country. Concerning environmental standards for incineration, while most western countries adopted a PCDD/PCDFs emission standard below 0.1TEQng/Nm^3 years ago, China still follows the 0.5TEQng/Nm^3 limit value established by the *Standard for Pollution Control on Hazardous Waste Incineration,* including for newly-built HCW disposal projects. This standard should be changed in the near future in order to fulfill the Stockholm Convention requirements.

It is also necessary to increase the capability to evaluate the suitability of the air pollution control system (APCS) of the incinerator, in all stages of design, construction, and operation. Moreover, China has not yet developed an integrated system for the evaluation and authorization of new disposal technologies and techniques. Due to the lack of evaluation and supervision for operation processes and phases, some facilities have exceeded the emission limit value for a long time. A lot of HCW disposal facilities operate without an effective disposal plan and in the absence of daily monitoring data. Additionally, environmental protection departments very often lack the capability to measure secondary pollutants, and to supervise and control the effectiveness of disposal plant operations, rendering them unable to identify and solve environmental problems.

Most of the existing HCW disposal facilities are not equipped with on-line continuous monitoring equipment. In the majority of the healthcare waste disposal facilities, the release concentration of PCDD/PCDFs is not measured. The actual amount of waste disposed by several HCW disposal facilities is well below their design capacities. In this situation, the quality of HCW disposal cannot be assured, resulting in a severe increase in the environmental risk.

As far as standards for building or operating HCW disposal facilities are concerned, many differences do exist from city to city and from province to province, creating a large uncertainty in the waste management market. In this situation, it is hard to guarantee the quality level of the equipment. Wide differences also exist in the pricing system, as every city has its system established using different criteria, based for instance on the weight of waste or on the number of hospital sickbeds. These differences may result in different disposal efficiencies, charging standards, and operational constraints.

Finally, several existing HCW incinerators have emission values exceeding the regulatory limit, with an evident impact on the environment.

As was already said, among the 147 incineration facilities, over 50% will be dismantled and reconstructed. However, most of the disposal facilities funded by the National Plan are still under construction.

2.3. Legislation and regulation framework of HCW management

The definition of the Chinese HCW policy, regulation, and standard system started about two decades ago. The Chinese HCW policy, regulation, and standard system was first defined in the 1990s; since then, several improvements have been established, as shown in Table 3. The National Plan was issued by the State Council in 2004 after the outbreak of Severe Acute Respiratory Syndrome (SARS) in 2003. In order to implement the National Plan, SEPA and the MOH enacted a series of regulations and standards. The overall disposal capacity foreseen by the National Plan, together with the significant regulatory effort, testifies that Chinese HCW management and disposal entered a completely new stage of development. However, the situation of the Chinese HCW policy, regulation, and standard system is still affected by the following obstacles and hindrances impeding sound environmental management of HCW:

(1) The existing HCW management system needs to be more systematic, as it does not cover the whole management process of HCW. There is the need for a regulatory system covering waste collection, classification, storage, transportation, treatment, and disposal with a lifecycle perspective. The lack of systematic and specific management standards and monitoring result in an ineffective HCW management and disposal process. On the industry side, the lack of specific technical guidance and market-based incentive mechanisms is a significant barrier against the development of an environmentally sound HCW disposal industry.

(2) The potential for technology innovation is still low, and management tools for supporting technology development, verification, and auditing differs greatly from other developed countries. Today, both the total capacity and technological level of domestic HCW incineration technology need improvement; as already said, many incineration facilities operate without or with an inadequate APCS. As a consequence, the PCDD/PCDFs emissions of most of them exceed the existing regulatory limit value. As far as non-incineration technologies are concerned, China is still at an early stage and lacks the research and development capability required for establishing technologies tailored to its specific situation. For these reasons, it is still very difficult to satisfy the basic demand for HCW disposal in a way capable of ensuring the technical requirements for protecting the environment at a local and global level. It is therefore imperative to establish a coherent system of standards or specifications to be applied in the permitting procedures.

(3) Limited supervision methods and an incomplete supervision management mechanism exist. The lifecycle management of HCW relies on the functions and interactions of several agencies and institutions. The effectiveness of the HCW management depends not only on the capability of individuals or institutions, but also on the implementation of an effective system of regulations, standards, and a suitable supervision and control scheme. However, the current Chinese HCW management still lacks a complete system for the supervision of law enforcement, as well as persistent, comprehensive, and regulated supervision and management methods. These inefficiencies bring hidden troubles for safety management in the HCW disposal process.

(4) Monitoring methods are incomplete and there are deficiencies in the overall monitoring ability. Monitoring aims at appraising whether a specific parameter, which may be an indicator of technological performance and management effectiveness, meets the requirement of standards and specifications. However, presently, among domestic disposal facilities in operation, there is a general lack of monitoring methods or monitoring capability (in terms of institution and management) for several parameters such as PCDD/PCDFs from incineration disposal, efficiency of disinfection, and the concentration of VOCs from non-incineration treatment. As far as on-line monitoring is concerned, although the environmental protection authorities have developed generic regulations or standards for the on-line monitoring of key parameters including incineration temperature, key gas pollutant emissions, and basic operation parameters, the practical implementation of these standards is not so effective.

Table 3
Main HCW laws, regulations and standards in China.

Type	Title	Issue time	Issue agency	Application
Law	Law of The People's Republic of China on Environmental Protection	December, 1989	SCNPC[a]	Principal law of environmental protection in China
Law	Law of the People's Republic of China on the Prevention and Control of Environmental Pollution by Solid Waste	April, 1996 Revised in Apr, 2005	SCNPC	Special law for Chinese solid waste environmental management, applicable to the hazardous waste pollution prevention and control in China
Law	Law of the People's Republic of China on infectious disease control and prevention	September, 1989	SCNPC	Special law for prevention, control and elimination of infectious disease and protection of human health
Regulation and rules	Healthcare Waste Management Regulation	June, 2003	SC[b]	Special administrative regulation for Chinese HCW management
Regulation and rules	Hazardous Waste Operation Permit Management Rules	May, 2004	SC	Stipulated hazardous waste disposal facilities must acquire the permit issued by Environmental protection agency of related level, applicable to HCW
Regulation and rules	Hazardous Waste Movement Manifest Management Rules	October, 1999	SEPA[c]	Special for hazardous waste transportation management in China, the transfer manifest required during the process of hazardous waste transportation for the enterprises, applicable to HCW
Regulation and rules	Healthcare Organization Medical Waste Management Rules	October, 2003	MoH[d]/ SEPA	Stipulated HCW classification, collection, transportation, temporary storage and related methods for healthcare institutions, as well as stipulations of specific measures to be taken to address HCW
Regulation and rules	Administrative Punishment Rules for Medical Waste Management	June, 2004	MoH/ SEPA	Stipulated administrative punishment for violations of HCW management provision
Regulation and rules	Medical Waste Category	October, 2003	MoH/ SEPA	One of important basis of HCW management process, stimulated five categories of HCW as infectious waste, pathological waste, sharp objects, chemical waste and pharmaceutical waste
Standard	Incineration Pollution Control Standard of Hazardous Waste (GB18484-2001)	November, 2001	SEPA/ SATQS[e]	Stipulated hazardous waste site selection, technical performance, atmospheric emission limit, slag disposal principle and relevant environment monitoring, etc. for the incineration process
Standard	Storage Pollution Control Standard of Hazardous Waste (GB18596-2001)	December, 2001	SEPA/ SATQS	Stipulated the requirement of hazardous waste package, storage, facility site selection, design, operation, safety and protection, monitoring and enclosure, etc.
Standard	Landfill Pollution Control Standard of Hazardous Waste (GB18598-2001)	December, 2001	SEPA/ SATQS	Stipulated environment requirement for safe landfill of hazardous waste, including landfill site selection, engineering design and construction, operation, enclosure and monitoring, etc.
Standard	Concentrated Disposal Technical Specification on Medial Waste (tentative)	December, 2003	SEPA	Stipulated technical requirement for HCW disposal, personnel training and safety protection requirement, contingency prevention and response measures, as well as the special requirement to the HCW during the period of serious disease spreading
Standard	Special Standard of Packaging Material, Container and Caution Mark for Medical Waste	November, 2003	SEPA/ MOH	Stipulated the requirement of package bag and container (barrel), mark of sharp device for HCW management and disposal
Standard	Technical Specifications for Centralized Incineration Facility Construction on Medical Waste (HJ/T177-	January, 2004	SEPA	Special regulatory document for construction and operation requirement for centralized incineration facilities for HCW, stipulated the general engineering design, system component and operation management.
Standard	Technical specifications for Chemical Disinfection Centralized Treatment Engineering on Medical Waste (On Trial) (HJ/T2 28-2006)	February, 2006	SEPA	Special regulatory document for construction and operation requirement for centralized chemical disinfection facilities for HCW, stipulated the general engineering design, system component and operation management
Standard	Technical specifications for Microwave Disinfection Centralized Treatment Engineering on Medical Waste (On Trial) (HJ/T2 29-2006)	February, 2006	SEPA	Special regulatory document for construction and operation requirement for centralized microwave disinfection facilities for HCW, stipulated the general engineering design, system component and operation management
Standard	Technical Specifications for Steam-based Centralized Treatment Engineering on Medical Waste (On Trial) (HJ/T276-2006)	August, 2006	SEPA	Special regulatory document for construction and operation requirement for centralized high temperature steam-based facilities for HCW, stipulated the general engineering design, system component and operation management

[a] SNCNPC Standing Committee of National People's Congress.
[b] SC State Council, MoH: Ministry of Health.
[c] SEPA State Environmental Protection Administration.
[d] MoH Ministry of Health.
[e] SATQS State Administration of Technical and Quality Supervision.

(5) There is a lack of financial resources and sound financial schemes in waste management. At the moment, HCW management is mainly promoted by the government, and the enthusiasm of all of the sectors has not been mobilized yet. The market mechanism – still at a very early stage in the HCW management field – does not play the role of an economic lever in aspects such as law enforcement, standards establishment, incentive schemes, and so on. Moreover, the financial resources required by management, supervision, monitoring, research and development, and facility construction and operation are uncertain, so the impact on HCW management caused by financial difficulties is significant.

(6) The qualification of the personnel and their management ability is insufficient and public environmental awareness needs to be substantially increased. The fulfillment and implementation of policies, regulations, and standards need a substantial availability of personnel familiar with the technical and regulatory aspects. As China only recently started the implementation of the HCW management system, most

of the personnel engaged in this field come from other fields or are at their first employment experience. Only a few of them attended specific professional training to be competent with respect to the requirements of their relative posts. Moreover, the fulfillment of policies, regulations, and standards also needs a proper background, but the public currently knows very little about the harm of HCW and the management and disposal process of HCW, so it is necessary to improve the public environmental consciousness.

3. Management measures of HCW

The essential aim of China is to fulfill the Stockholm Convention by reducing PCDD/PCDFs produced when processing and disposing of HCW, in order to protect human health and the environment. According to the the BAT/BEP guideline, as well as to the current situation in HCW management and disposal in China and abroad, sustainable waste management is the most widespread term in the management and technical level for HCW, and is based on four different requirements:

(1) Environmental desirability, referring to the capability of the waste management and technology options to safeguard public health and the environment;
(2) Economic effectiveness, referring to the cost-effectiveness of each management and technology option in use, considering also the economic value of the waste;
(3) Social acceptability and equity, referring to the level of support and acceptance of the waste management and technology options in use by the local community, and to the effectiveness of a community involvement approach in waste management;
(4) Administrative diligence, referring to the administrative capability to ensure with continuity that good measures and policies will be carried out and will be sustained in the long term (Chung and Carlos, 2003).

In order to satisfy the criteria listed above, several aspects of the HCW management system must be considered:

(1) Correctly understanding the idea of BAT/BEP of HCW disposal, promoting the implementation of lifecycle and holistic management, and solving the problem of matching between technologies and management. Only when good technology is matched to a well–oriented policy and management method is it possible to achieve the best benefit. In other words, the adoption of BAT/BEP must be based on the lifecycle of HCW and supported with the tools and approaches of holistic management.

Lifecycle management stands for a management embracing the whole process of HCW treatment, including collection, classification, packaging, storage, transportation, treatment, and disposal. Due to the complex and heterogeneous composition of HCW, many different disposal technology stages may be needed, including pre-treatment. Incineration and non-incineration methods are associated with their specific requirement for flue gas emission and control. That is to say that flue gas emission issues currently associated with HCW are directly related to waste generation patterns and disposal methods.

From the viewpoint of waste minimization, a reduction in the use of material, substitution with products which do not generate PCDD/PCDFs during their disposal, or the collection and segregation of waste should be adopted whenever possible. Considering waste disposal, the adoption of the correct technology or process option and the proper operating practice, including continuous waste feeding, proper storage, and transportation should all be considered in the lifecycle.

The process of holistic management is a management system based on the lifecycle of HCW and the application of technology. The sequence of the process is this: first, the technical authentication which is the precondition of technology application; second, engineering construction which includes the construction criteria and the specification of a systemic allocation of the technology application; third, facility operation which regulates and guides the managers and workers to operate the facility; then, supervision and management which give the methods and tools to supervisors from the government, e.g. environmental protection and health sectors; and finally, environmental monitoring, which provides the methods of environmental monitoring for the operation of the facility and for supervision by government agencies. As an environmental management organism, it is necessary to have a managing and technical training system, as well as an economic operation mechanism for the construction and operation of facilities such as charge policy, revenue policy, and so on. They are the human resource drive and economic resource drive, respectively, of the whole holistic management system. Generally, effective operation of holistic management comprised of the above factors will promote the achievement of lifecycle management.

The relationship among waste lifecycle components and holistic management for HCW are presented in Fig. 2, which shows that: (a) the lifecycle management concept should be embodied and enforced by holistic management; (b) HCW holistic sound management needs balanced policies, regulations, and standards designed with a lifecycle perspective; and (c) the BAT/BEP requirement also needs to be formulated taking into account the lifecycle and holistic management of HCW.

(2) Managing the application of incineration technology, taking into account the specific conditions of China. As was already stated, incineration technology is the main technology option for HCW disposal in China. Unfortunately, the facilities for waste disposal and their operations very often face difficulties in fulfilling the existing regulations and standards, not to mention the even stricter standards required by the Stockholm Convention. In addition, it should be considered that more than 150 disposal facilities for HCW foreseen by the Nation Plan intend to adopt incineration technology.

The results of the research show that the emission factors for the incineration of HCW were strongly influenced by the characteristics of the incinerated waste, and directly affected by the type of waste incinerated, by waste classification, by segregation methodology, and by waste management methodology. For China it is then very important, at this stage, to enhance some management options like a green procurement system for hospitals, waste minimization (source reduction), and recycling programs. The substitution of hazardous solutions and materials with non-hazardous solutions and materials whenever possible – for instance, the purchasing of medical tools that are PVC-free, or a prohibition on the use of plastic films containing PVC for HCW packaging – must also be implemented. These countermeasures are all capable of reducing the emission of toxic pollutants like PCDD/PCDFs and heavy metals during the disposal processes. The segregation of HCW should be carried out as rigorously as possible to minimize atmospheric emissions (Alvim-Ferraz and Afonso, 2005; Tsakona et al., 2007).

(3) Properly managing non-incineration technologies for HCW disposal, following the international trend. Non-incineration disposal technologies may be the correct alternative technology in China for replacing medium and small size treatment facilities while at the same time fulfilling the BAT/BEP requirements foreseen by the Stockholm Convention. However, it must be considered that, besides the scale of the disposal plant, some wastes (like chemical waste, pharmaceutical waste, and some pathological waste) are preferably disposed of using incineration; for this reason, control of the classification, collection, packaging, and tempo-

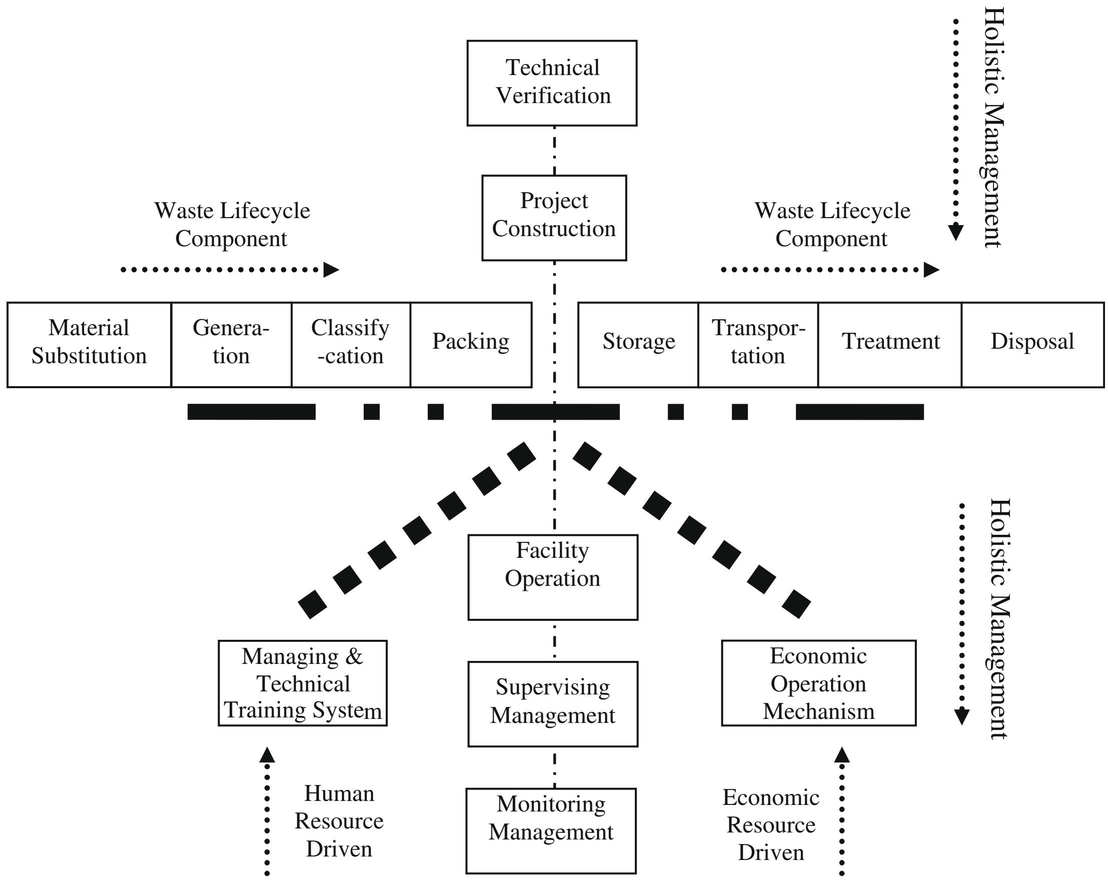

Fig. 2. Relationship among waste lifecycle component and holistic management for HCW.

rary storage of HCW is key for an overall management of HCW which includes both incineration and non-incineration technologies.

It is therefore important to encourage the application of non-incineration technology, while at the same time strengthening the capacity to manage and control these technologies which may present different monitoring and management technologies. For instance, in order to monitor the effectiveness of chemical disinfection and microwave treatment technology, in China monitoring of VOCs, odor and the microorganism *B .subtilis* ATCC 9372 are required, while in the case of high temperature steam-based technology, the count of *B. stearothermophilus* ATCC 7953 is the required method.

The lifecycle and holistic management concepts should become the key idea of the whole management and application process of non-incineration technologies.

(4) Strengthening the HCW managing and technical training system. The gap in the knowledge of environmental impacts of healthcare products and services underscores the need for increased understanding among health professionals of integral links between human health and environmental health in the lifecycle management from generation to final disposal of HCW (Kaiser et al., 2001). The training system should include training methods, content, and teaching material of management and technology related to the collection, storage, transportation, and disposal of HCW. In order to enhance the level and effectiveness of HCW management, China should change and improve the training methods and content of HCW management within medical institutions, as well as compile teaching material on management and training suitable for China's medical institutions and different HCW disposal plants. In addition, the country should increase the availability of funds for training institutions and teachers in order to provide the foundation and conditions for the establishment of regular management and technology training. Based on the above mentioned factors, the managing and technological level of the managers, operators, and supervisors will all advance through the establishment and operation of the training system.

(5) Strengthening waste management awareness and enhancing public participation. HCW management and disposal are environmental problems that have wide scope and incidence. Therefore, for promoting Stockholm Convention implementation in China's HCW, it is also important to actively promote management and technology training, improve environmental education and extend public participation in order to promote the development of a correct HCW management consciousness and course of actions.

4. Conclusions

HCW management is one of the most important parts of the implementation of the Stockholm Convention in China. In order to forge ahead with the development of related activities in this field, it is imperative to explore the mode of management and disposal that meets the requirement of the Stockholm Convention as well as satisfying China's needs, in order to contribute to sustainable and environmentally sound management. In terms of the regulatory aspects of HCW in China, it is very important to set up a lifecycle and holistic management system, as it is the only way to ensure the application of different types of technologies and the promotion of environmentally safe management. As far as technical aspects are concerned, on one hand it is important to improve research and to develop and promote PCDD/PCDFs-reducing technologies; on the other hand, non-incineration technologies should be promoted and replicated with the purpose of realizing a standardized system for HCW management in China. In addition, awareness and training also need to be enhanced, and a market-oriented co-financing mechanism for the construction and operation of HCW disposal facilities should be encouraged to promote BAT/BEP implementation the in HCW field.

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