PRACTICAL ACTION
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technical brief

HEALTH-CARE WASTE MANAGEMENT IN DEVELOPING COUNTRIES

This brief gives an overview on healthcare waste treatment options, focussing on incineration, one of the options most used for the treatment of healthcare waste. It highlights advantages and drawbacks of the use of incineration in comparison to other treatment options, as well as discussing the different kinds of incineration that can be found in low and middle income countries. It also describes 'De Montfort' incinerators, built in order to represent a cheap but effective treatment option. Their application in several developing countries is also discussed and contrasting opinions are reported.

Introduction

Healthcare waste (HCW) includes all the waste generated by hospitals, healthcare centres, research facilities and laboratories. In addition, it includes the waste originating from "minor" or "scattered" sources, such as that produced in the course of healthcare undertaken in the home (dialysis, insulin injections, etc.) (WHO, 1999). According to The World Health Organization (WHO), health care waste can be classified into eight main categories briefly presented in Table 1 (Ahmed, 1997).

Improper disposal of health-care wastes, syringes and needles that are scavenged and reused may lead to significant numbers of hepatitis B, hepatitis C, HIV and possibly other infections – such as, gastric, lung or eye infections - in the developing world (Batterman, 2004). WHO (2011) estimates that in 2000 injections with contaminated syringes caused 21 million hepatitis B virus infections (32% of all new infections); 2 million hepatitis C virus infections (40% of all new infections); and 260,000 HIV infections (5% of all new infections). In some countries (e.g., India and Pakistan), contaminated disposable needles are often scavenged, repackaged, sold and reused without sterilization. Inappropriate disposal of chemical and pharmaceutical waste causes poisoning and injuries – mainly burns.

Several groups of people are most at risk from poorly managed health-care waste:

- Health workers.
- Patients & visitors to healthcare waste establishments.
- Waste handlers.
- Scavengers retrieving items from dumpsites or uncontrolled collection points.
- Children who may come into contact with contaminated waste and play with used needles and syringes, e.g., if waste is dumped in areas without restricted access.

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HAZARDOUS	Category	Examples
NO	General Waste	Domestic waste, packing material, non-infectious animal waste, bedding, wastewater from laundries, etc.
MAYBE	Chemical Waste	Discarded solid, liquid and gaseous chemicals, for example generated from diagnostic and experimental work, cleaning, housekeeping and disinfecting procedures.
YES	Pathological Waste	Tissues, organs, body parts, human foetuses, animal carcasses, blood and body fluids.
YES	Radioactive Waste	Solid, liquid, and gaseous materials contaminated with radionuclides: for example, from radiotherapy or laboratory research, contaminated glassware, packages, etc.
YES	Infectious Waste	Waste suspected to contain pathogens: laboratory cultures, tissues, excreta, etc.
YES	Sharps	Needles, syringes, scalpels, blades, saws, glass, nails and any other item that could cause a cut or puncture.
YES	Pharmaceutical Waste	Pharmaceutical products, drugs and chemicals that have been returned from wards, have been spilled or outdated or contaminated, or are to be discarded because they are no longer required.
YES	Pressurized containers	Gas cylinders, gas cartridges, aerosols cans; they may explode if incinerated or accidentally punctured.

Table 1: Categories of healthcare waste

Health-care waste treatment options

Incineration

Incineration is one of the most used options for healthcare waste treatment. Incineration is a high-temperature dry oxidation process that reduces organic and combustible waste to inorganic, incombustible matter and results in a very significant reduction of waste volume and weight. But it can generate significant emissions containing atmospheric pollutants and may produce odours, as described later.

Different types of incinerators can be used, ranging from single-chamber furnaces to highly complex rotary kilns. Advantages and drawbacks of the three types of incinerator most commonly used in low-income countries, namely drum / brick incinerator, single-chamber incinerator and pyrolitic incinerator, are presented in Table 2, as well as the categories of healthcare waste they are adequate for.

Type of incinerator	Advantages	Drawbacks	Adequate for
Pyrolitic incineration 	- Very high disinfection efficiency. - Low cost models available.	- Incomplete destruction of cytotoxics. - Relatively high investment and operating costs.	- All infectious waste - Most pharmaceutical waste. - Most chemical waste.
Single-chamber incineration 	- Good disinfection efficiency. - Drastic reduction of weight and volume of waste. - The residues may be disposed of in landfills. - No need for highly trained operators. - Relatively low investment and operating	- Significant emissions of atmospheric pollutants. - Need for periodic removal of slag and soot. - Inefficiency in destroying thermally resistant chemicals and drugs such as cytotoxics.	- General healthcare waste - Infectious waste BUT significant emissions

	costs.		
Drum or brick incineration 	- Drastic reduction of weight and volume of the waste. - Very low investment and operating costs.	- Destroys only 99% of microorganisms. - No destruction of many chemicals and pharmaceuticals. - Massive emission of black smoke, fly ash, toxic flue gas, and odours.	- General healthcare waste - Infectious waste BUT it should be used only in case of emergency

Table 2: Types of incinerator commonly available in low-income countries (WHO, 1999; modified)

Criteria for decision making
Various factors should be considered before implementing an incinerator and in order to choose a technology that is appropriate to the context. The following ones are some of the questions decision makers should try to answer:

- What is the available space?
- Where is the incinerator going to be located?
- How much HCW is generated?
- What is the waste composition?
- Is the waste separated?
- What is the system of HCW management in place?
- What are the options available for the final disposal of waste?
- Who is going to be in charge of the incinerator?
- What are the investment and operation costs likely to be?
- How will the ashes be dealt with?
- How will needles be dealt with?
- Are the materials to build the incinerator locally available?
- Are the technical skills for operation and maintenance of the incinerator locally available?
- Are there specific regulations concerning HCW?
- What is the opinion of local community and staff on the system to be adopted?

Other processes
A variety of non-incineration treatment technologies, including several low cost options are available or under development. Common processes in low-income countries include autoclaving, chemical processes and containment processes (WHO, 2005).

Autoclaving
Autoclaving is an efficient wet thermal disinfection process. Typically, autoclaves are used in hospitals for the sterilization of reusable medical equipment. They allow for the treatment of only limited quantities of waste and are therefore commonly used only for highly infectious waste, such as microbial cultures or sharps. Research has shown that effective inactivation of all vegetative microorganisms and most bacterial spores in a small amount of waste (about 5– 8 kg) requires a 60-minute cycle at 121°C (minimum) and 1 bar (100 kPa); this allows for full steam penetration of the waste material.

Chemical processes
Chemical disinfection is an efficient process, but it is usually costly because the prices of disinfectants are high. For safe operation it requires trained technicians provided with adequate protective equipment and is therefore not recommended for treating all infectious healthcare waste. However, the process can be useful in specific cases, such as disinfection of recyclable sharps or disinfection of stools from cholera patients.

Containment processes
Containment processes deal with waste disposal phase and can be characterized by different levels of complexity. When waste are to be landfilled in municipal disposal sites, the presence of an established system for rational and organized disposal of waste, engineering works completed to prepare the site to retain its wastes more effectively and rapid burial of healthcare waste are

the minimum requirements to be followed. In addition, it is recommended that healthcare waste is deposited in a shallow hollow excavated in the mature municipal waste or in specially constructed small burial pits. Burying inside the premises of the healthcare facilities is also often practiced in low and middle-income countries. Encapsulation is another containment process, which involves filling containers with waste, adding an immobilizing material, sealing the containers and disposing of them.

Advantages and drawbacks of these three categories of treatment are illustrated in Table 3.

Category	Treatment or disposal method	Advantages	Drawbacks
Wet thermal process	Autoclaving	- Efficient. - Environmentally sound. - Relatively low investments and operation costs.	- Qualified operators essential. - Inadequate for wastes not designed as recyclable items and for waste that is not easy penetrated by steam. - Capacity for treating limited quantity of waste.
Chemical process	Chemical disinfection	- Highly efficient disinfection under good operating conditions. - Some chemical disinfectants are relatively inexpensive. - Drastic reduction in waste volume.	- Highly qualified technicians essential - Comprehensive safety measures necessary. - Inadequate for pharmaceutical, chemical, and some types of infectious waste.
Containment processes	Landfilling in municipal disposal sites	- Low cost. - Relatively safe if access is restricted. - Effective biodegradation of the biological components of healthcare waste.	- Conditions for safe landfilling seldom met and difficult to assess. - Access restrictions not always guaranteed.
	Safe buying inside premises	- Low cost. - Relatively safe if access is restricted and natural infiltration is limited.	- Risk of pollution. - Difficult to prevent access and scavenging.
	Encapsulation	- Low cost. - Simple and safe. - Also applicable to chemicals and pharmaceuticals.	- Not recommended for non-sharp infectious waste.

Table 3: Advantages and drawbacks of other treatment processes

Other treatment options, such as solar-powered autoclave-style sterilizers, boiling chambers with mechanical grinders and compactor or enhanced recycling technologies are currently under research and testing (Batterman, 2004).

'De Montfort' incinerators

'De Montfort' incinerators were designed by the *Innovation Technology Centre* – now called *Applied Sustainable Technology Group* - at De Montfort University (Leicester, UK). The objective was to meet a need for cheap but effective healthcare wastes incinerators which could be built in almost any developing country, but would meet the criteria of a temperature of above 800°C with a residence time of over 1 second (Picken, 2007). As described in the *Guidelines on How to Construct, Use, and Maintain a Waste Disposal Unit* (WHO et al, 2005), The incinerator comprises primary and secondary combustion chambers (see Figure 1) and it is made of firebricks and prefabricated metal components, which can be manufactured locally or imported. Information about construction details – namely, on guidelines, materials, tools and standard problematic areas – are provided on 'De Montfort' website [http://www.mw-incinerator.info].

technical brief

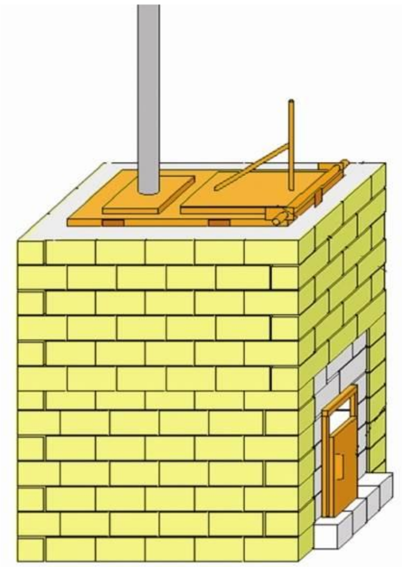

Figure 1: Representation of Mark 8a De Montfort (WHO et al., 2005)

The 'De Montfort' incinerator has the capacity to destroy any medical or domestic waste, which is combustible. However, it should only be used to destroy sharps (including syringes with needles attached, razor blades, scalpels and any other sharp objects which may be contaminated, like glass, but excluding vials or ampoules), infectious non-sharp waste (like tissues and materials, or equipment which has been in contact with blood or body fluids, including swabs, bandages and any other waste which may be contaminated) and non-infectious waste (just if it cannot be transported to a municipal waste disposal facility or if no alternative environmentally sound solution for disposal is available). On the contrary, the 'De Montfort' should not be used to destroy waste containing broken thermometers, fluid bags, PVC plastic bags, closed glass, vials and ampoules or wet waste. Box A summarizes what De Montfort' incinerator can and cannot do.

Box A: What De Montfort incinerator does and what it does not do

Does:
It reduces all waste added to ash and flue gases. This includes dressings, wet or dry, plastics, organic matter, etc. Used hypodermics can be added, but needles may not all be reduced though they will be sterilised and denatured. Care should be taken when removing ashes in this case. Small glass sharps will normally be part melted and rendered safe. When properly operated, the flue gases emitted will have been held at a high temperature (800°C) for at least one second and should be almost harmless.

Does not do:
It will not render all flue gases smoke free and will not meet clean air requirements in all situations with all loads. If this is your requirement, you will need to buy a much more expensive incinerator and have it professionally installed and operated. It will not operate automatically without attention. When burning waste, particularly infectious waste, an operator must be in constant attendance. It is not suitable for short sharp burns with no warm up period. For this sort of operation you need a low thermal capacity incinerator, probably made of stainless steel and gas heated. It is not suitable for operation in a closed room. Smoke will be emitted whenever the loading door is opened. A roof may be fitted to protect the operator from rain, but only minimum walls.

De Montfort University has developed different models of incinerator (Picken, 2007). They are all variations of the same basic design, namely the Mark 1 incinerator. It can burn 12 kg/h of waste and it has now been superseded by the Mark 8a, which is more robust and reliable and cheaper to build.

The various models are characterized by different designs and/or capacities. Table 4 shows a brief overview of the main characteristics of the available models.

Model	Capacity	Remarks
Mark 1	12 kg/h	Basic model; now superseded by Mark 8a
Mark 2	12 kg/h	Larger combustion chamber compared to Mark 1; only used for experimental purposes
Mark 3	50 kg/h	Designed for large hospitals (up to 1000 beds); now superseded by Mark 9
Mark 5	50 kg/h	Higher chimney compared to Mark 3; design currently under modification
Mark 7	12 kg/h	Specifically designed for use in emergency situations
Mark 8 and 8a	12 kg/h	Similar to Mark 7, but with a brick-built body. Mark 8a recommended for most applications

Table 4: Capacity and remarks for the different models of 'De Montfort' incinerator

The construction and implementation of Mark 8a 'De Montfort' incinerators in Hargeisa (Somaliland) is illustrated in Box B.

Operation and maintenance

As described by WHO et al, 2005, some operator-related measures should be adopted to ensure a good performance of the incinerator. Only a trained, qualified and equipped operator should operate the incinerator, the operator must be on-site while the incinerator is functioning and must be motivated to follow best practices. It is underlined that operators must have long-term contracts or be permanent hires, since training efficient operators is time-consuming and expensive, and operator knowledge and commitment are essential for good incineration practices. Even if operators are well-trained, supervision is essential. Each primary health facility should designate a supervisor for healthcare waste management, responsible for instance for the training of all primary health facility staff in healthcare waste management practices, the control on segregation practices, the coordination and supervision of waste transportation, packaging, storage and handling, the monitoring of waste incineration practices. Detailed information on operation practices is available at http://www.mw-incinerator.info/en/401_operation.html.

Regular maintenance is needed to ensure that the system will continue to work properly and to prolong the life span of the incinerator. Before each operation, it must be checked that all the ash has been completely cleared from the grate and floor of incinerator and that the loading door closes properly onto the sand seal in an air-tight manner. As well as regular maintenance, annual inspections and rectifications are of the utmost importance to guarantee that the incinerator performs well. They concern the chimney, top sand seals, ash door and brickworks. Checking and rectifying practices are presented at http://www.mw-incinerator.info/en/402_maintenance.html.

Box B: Implementation of De Montfort incinerators in Hargeisa, Somaliland

Hargeisa is the capital city of Somaliland, a self-declared independent Republic situated in the north-west of former Somalia. Three Mark 8a 'De Montfort' incinerators were implemented in three of the main hospitals situated in Hargeisa: General Group Hospital and TB Hospital are public structures, with a total capacity respectively of about 300 and about 200 patients, whereas Edna Adan Hospital is a non profit charitable hospital able to host 69 patients. The activities were conducted within SISDISC project, which run between 2008 and 2009, was led by Cesvi, an Italian NGO, and funded by European Commission and Italian Cooperation Agency.

Fig. B.1 – Old incinerator used at General Group Hospital before the intervention

At the beginning of the project the practices for waste collection and disposal presented relevant differences in the three facilities, but a common feature was that the segregation of hazardous and non-hazardous wastes was done properly only in some departments. At General Group Hospital and TB Hospital hazardous waste, collected by means of wheelbarrows, were subjected to burning in old incinerators (see Fig. B.1), which were poorly constructed and not opportunely repaired when they broke down. At Edna Adan Hospital sharps and infectious waste were collected and stored within the hospital premises until the arrival of waste collectors employed by the municipality.

Fig. B.2 – New De Montfort incinerator built at General Group Hospital

The three incinerators were built between February and June 2009 by local enterprises under the supervision of the Italian NGO leading the project (see Fig. B.2). Specific trainings were elaborated and delivered in order to explain how to correctly operate and maintain the incinerators. Initially, the availability of the appropriate construction materials was the main technical issues faced. The construction of the incinerator at TB Hospital began using firebricks, as defined by the company in charge of the building. They flaked off, so it was decided to line the facility with a layer of cement and to use local stones, called *deber*, for the other two facilities.

The constraints linked with operation and maintenance of the incinerators did not affect all the hospitals in the same way.

Major constraints were usually identified in the operation phase: irregular de-ashing procedures, misuse of safety gears and ineffective separation of HCW were observed. These operative constraints are all ascribable to some of the more common reasons, such as the lack of supervision within the hospitals and the fact that trainings were successful initially but were not repeated.

As regards the perception of the local stakeholders, the participants of the trainings on the correct procedures for the operation of the incinerators showed a good interest and a high comprehension of the explained activities. The user acceptance appeared high and the patients of the hospitals witnessed about an overall improvement of hygienic conditions of the three structures.

Source: Di Bella et al., 2011

Further considerations

Other experiences

Different opinions have been reported about the use of 'De Montfort' incinerators. Whereas the incinerator has been enthusiastically adopted and used in many developing countries, there is a body of opinion, which believes that emissions from the chimney can do such damage that other means of disposal must be used. Some national authorities take an intermediate position insisting on either using a very tall chimney to disperse the gases (e.g. India), or that the incinerator conforms to a standard such as the *Best Practical Environmental Option*, developed in South Africa (Picken, 2004).

Some comments about the implementation of De Montfort incinerators in low and middle income countries are briefly summarized below. (Batterman, 2004)

- Kenya: Some 44 De Montfort type incinerators were constructed in 2002, of which 55% were in intermittent or regular use at the time of the study. Tests and interviews were conducted at 14 sites (Adama, 2003). Only 1 of 14 sites had an operator with 'near to adequate' skills, fewer than 40% of health facility managers demonstrated any level of commitment, many technical defects were observed in the equipment, and most incinerators were operated improperly (Taylor, 2003).
- Tanzania: A total of 13 'De Montfort' incinerators were constructed in 2001 and 2003, and all were in use. Of these, less than 40% had trained operators, 70% had low smoke disturbance and 60% had safe ash disposal (Adama, 2003).
- Burkina Faso: Where utilized, equipment was poorly operated and under-utilized, i.e., the expected number of syringes incinerated fell short by about two-thirds (Adama, 2003).
- India: Eight 1 to 2 year-old 'De Montfort' incinerators at hospitals in India were surveyed by HCWH (2002). This survey indicated visible smoke from the stack; smoke emission from the chamber door and air inlets; commingling of sharps and non-infectious waste, despite some source segregation; large quantities of unburned materials (sometimes plastics, syringes, glass, paper and gauze) in the ash; deficient ash disposal practices; siting in all cases near populated areas (e.g., playground, orphanage, hospital staff quarters, a primary school, town center) and a lack of operator training. A comment coming from another hospital in India is provided here below.

Comments from India

"We have built 9 medical waste incinerators at our hospitals in India of the design developed by Prof. J. D. Picken of the De Montfort University. These incinerators cost us about US$1,000 each to build. This is about 1/10th the cost of commercial incinerators available, all of which use large amounts of external fuel or electricity. The design and building technique need to be followed precisely for success, and we have found it important to train one person to oversee the building of all of the incinerators. When operated correctly they are very effective in reducing medical waste to clean fine ash while putting out very little visible smoke. They only need renewable fuel (wood, coconut husks, heavy garden waste, paper and other dry household waste, etc.) to start and, once up to operating temperature, the medical waste itself becomes the fuel to drive the incineration process. It is actually amazing to see. Careful adherence to the design and careful operation are keys to making this simple, yet effective, incinerator work very well."

T. A. M, July 2002
Source: Picken, 2011

Emissions and their monitoring

Referring to environmental effects, incinerators can produce toxic emissions such as carbon monoxide (CO), dioxins (polychlorinated dibenzo-para-dioxins or PCDDs), and furans (polychlorinated dibenzofurans or PCDFs).

Incinerator emissions and associated risks may be reduced by implementing emission standards, operational controls and enhanced management practices, such as (Batterman, 2004; WHO, 2005):

- Rigorously segregate waste so that no PVC (IVs, etc.) waste is incinerated.
- Ensure that the incinerator is built according to recommended dimensions, using appropriate materials, that it is functioning properly and the chimney is clear of excessive soot.
- Ensure that the incinerator is preheated adequately and that supplementary fuel is added whenever necessary.
- Load the incinerator according to the recommended "Best Practices".
- Minimize burning in the chimney through correct loading practices and regulation of the self-adjusting draft control in the chimney. This increases the gas residency period.
- Adopt rigid quality control measures.

Moreover, a gauge temperature should be installed on the chimney in order to control the temperature during the operation phase. As well as temperature, other parameters to be carefully monitored and recorded are smoke levels, loading rates, usage of fuel and type of waste incinerated. For the control of the temperature, if a gauge is not available, a visual guide can be followed:

- If a good strong flame is visible through the secondary air hole, the temperature should be more than 600°C at this point.
- If the smoke is dense white, grey or black, poor combustion is occurring because the temperature is either above or below what is required.
- If temperatures are too high, the chimney glows red.

Inexperienced operators should not be assigned to operate incinerators that do not have a working temperature gauge fitted.

Moreover, at least once per year analyses on the concentration of CO, PCDDs and furans in the smoke should be conducted requiring the assistance of a specialized external expert.

Conclusions

Healthcare waste includes all the waste generated by hospitals, healthcare establishments, research facilities and laboratories. In low-income countries, healthcare waste (HCW) rarely receives attention; rather, it is handled as part of the municipal waste stream and disposed at the dumping sites in the city, making it freely accessible to rag-pickers who are then exposed to serious health hazards.

Incineration is one of the options most used for the treatment of healthcare waste. It has advantages and disadvantages, it is reduces organic and combustible waste to inorganic, incombustible matter and results in a very significant reduction of waste volume and weight but can generate significant emissions containing atmospheric pollutants and may produce odours.

Several different types of incinerator are available, suitable for different categories of waste and provided with different treatment efficiency.

The 'De Montfort' incinerator is a small-scale double chamber incinerator. Several models of the 'De Montfort' incinerator are available and they have been implemented in a number of low and middle income countries. The success or failure in the implementation of this technology is strongly linked with proper construction, operation and maintenance of the incinerator itself. These issues can be frequently linked with the lack of opportunely trained and supervised personnel responsible for the operation of the incinerator, together with inefficient practices of segregation of the healthcare waste stream.

External Links and References

This brief uses material from:

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Sources of Further information

WASTE – Netherlands
WHO Healthcare waste
Bio-Medical Waste Management film by Toxics Link
Biomedical Waste Treatment (India)
Medical Waste (Cambodia)
Eco-Scan Medical Waste (Kenya)
Medical Waste Disposal Unit – Liberia
4 tons of medical waste dumped at local landfill (USA)
Medical Waste Disposal (Kenya)
Hospital Waste to Non-Hazardous Building Blocks

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