Managing Health Care Waste Disposal

Guidelines on How to Construct, Use, and Maintain a Waste Disposal Unit

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Section I

The Waste Disposal Unit: Using the De Montfort Incinerator

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1.1 Health care waste management

Health care waste management (HCWM) has been described as "a process to help ensure proper hospital hygiene and the safety of health care workers and communities. It includes planning and procurement, construction, staff training and behavior, proper use of tools, machines and pharmaceuticals, proper disposal methods inside and outside the hospital, and evaluation."[1] Health care waste management systems enable health care waste to be managed responsibly, without harming the community or the environment.

1.2 Components of an HCWM system

An HCWM system is comprised of: i) hardware, including equipment such as categorized waste containers, ash and needle pits, incinerators, transport, needle cutters, etc.; ii) management personnel, to plan, direct, supervise and control; and iii) a process that systematizes the segregation and routing of waste from its point of generation to final disposal, whether through destruction, transformation or recycling.

1.3 Purpose of HCWM systems for primary health facilities

HCWM is required in primary health facilities to minimize the risk of contamination of patients, health workers and the general public through infectious waste. Recent studies indicate that as much as 33 percent of Hepatitis B virus (HBV) and 42 percent of Hepatitis C virus (HCV) infections arise from direct or indirect exposure to infectious waste[2]. Many recent studies have reported a convincing link between unsafe injections and the transmission of hepatitis B and C, HIV, Ebola and Lassa virus infections and malaria. Five studies attributed 20 to 80 percent of all new hepatitis B infections to unsafe injections, while three implicated unsafe injections as a major mode of transmission of hepatitis C.[3]

Good HCWM also improves hygiene and operational efficiency in primary health facilities, in addition to reducing the environmental pollution that arises from poor waste segregation and destruction practices.

HCWM ensures:

- Safe containment of infectious and non-infectious waste at the location where the waste is produced;
- Separation of waste into categories so that it is processed appropriately;
- Safe and prompt transport of contained waste to a point of temporary storage prior to processing, and
- Proper processing of waste according to WHO-recommended practices.

A Waste Disposal Unit is only one element of an HCWM system, and must be used as an integral part of the system for it to be effective.

[1] "Health Care Waste Management", *At a Glance Series*, World Bank, June 2003.
[2] WHO Website, Unsafe injection practices -a plague of many health care system http://www.who.int/injection_safety/about/resources/BackInfoUnsafe/en/. Accessed on June 28, 2004.
[3] *Unsafe injections in the developing world and transmission of blood borne pathogens: A Review*, L. Simonsen, A. Kane, J. Lloyd, M Zaffran and M Kane, Bulletin of WHO, 1999: 77(10):789-800.

1.4 Focus of the current guidelines

The guidelines focus upon specifications, installation, and operation and maintenance procedures of a WDU: in this case, the De Montfort incinerator.

The guidelines:

- Target those seeking a general understanding of small-scale incineration, inclusive of management, environmental and economic considerations.
- Provides specifications of materials required to construct a WDU inclusive of a De Montfort incinerator, engineering drawings of each component, options for procurement, and a step-by-step construction guide. They also detail the maintenance practices to be observed.

The guidelines include in Section III a training plan, which describes how to train De Montfort waste disposal unit operators. An *Operator's Manual* is under development to assist with comprehensive understanding of the "Best Practices" required to ensure efficient disposal of waste.[4]

1.5 The WDU and its components

The central element of a WDU is the De Montfort incinerator. If built according to specifications, maintained properly, and operated according to "Best Practices", the De Montfort incinerator can dispose of infectious and non-infectious waste simply, quickly and with minimal environmental consequence.

A WDU is made up of several elements, as shown in Figure 1.1, to enable trained operators to safely process and dispose of infectious waste. These elements include:

- A De Montfort incinerator to burn waste and reduce it. The De Montfort destroys 6-7 kg per hour (or 6 safety boxes per hour) if used as per recommended practices.
- An ash/needle pit, where residual ash, glass, metallic parts, including needles, are safely deposited after incineration. Needles from a needle cutter may also be deposited in the pit. The ash/needle pit is large enough to store incinerated residues for at least ten years without being emptied. Residue from one incineration session weighs approximately 0.5 kg. A pit of 3.25m^3 stores ash from the burning of approximately 300 safety boxes per month over a period of twelve years.
- A shelter to protect the De Montfort incinerator, the operator and the waste being incinerated from rain. The shelter also protects the fuel, like wood or agro-residues, required to preheat the incinerator, and the operator's tools, protective clothing and records. Moreover, it supports the chimney that is four meters in height.
- A waste store to securely accumulate waste that is to be incinerated, and where tools, records and protective equipment can be kept. The store has the capacity to stock at least 200 safety boxes, if neatly stacked.

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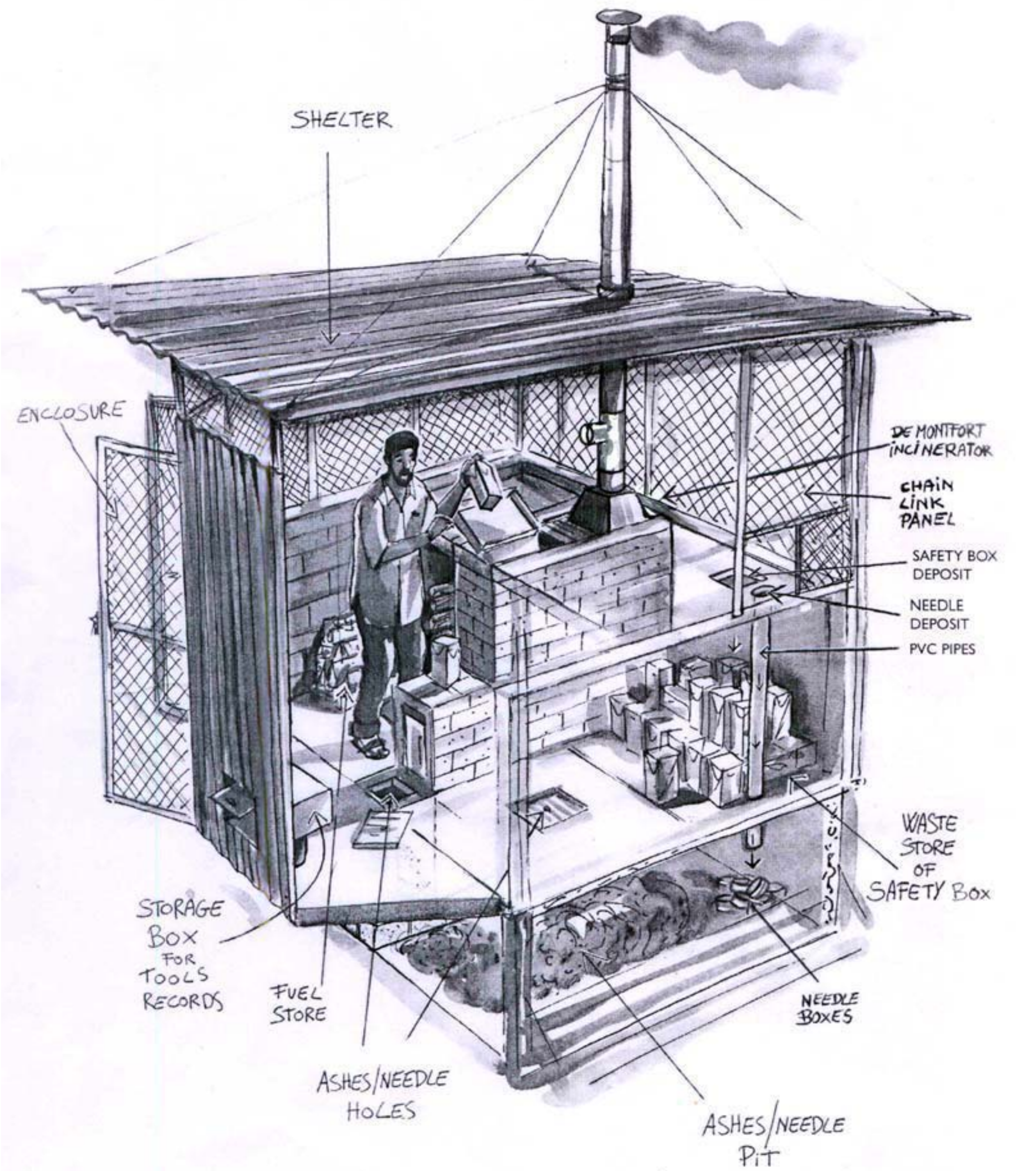
[4] Information on how to identify a Health Care Facility for installation of a WDU, and how waste should be collected, transported, and stored at a single location to justify the capital investment and amortisation of the equipment are provided in the training module *Safe Disposal of Syringes and Needles in the Context of Health Care Waste Management Systems*.
PATH, "Safe Disposal of Syringes and Needles," PowerPoint presentation at WHO Taskforce on Immunization (TFI), Luanda, 3-5 December 2003.
<http://www.afro.who.int/ddc/vpd/tfi2003/presentations/waste_management_safe.ppt>
(Accessed on July 8, 2004.)

- A fuel store to stock agro-residues or wood required to preheat the incinerator. The store has enough capacity to stock waste for at least five incineration sessions, both for pre-heating and supplementing medical waste.
- A storage box to keep tools, protective clothing and records.
- An enclosure with a lockable door to prevent access by children and unauthorized persons as well as scavenging animals and birds.
- A safety box deposit hole to allow the health worker to drop the safety box into the enclosed protected area when the incinerator operator is not present.
- A needle container deposit hole**,** which allows the health worker to empty the needles safely into the ash/needle pit when the incinerator operator is not present.

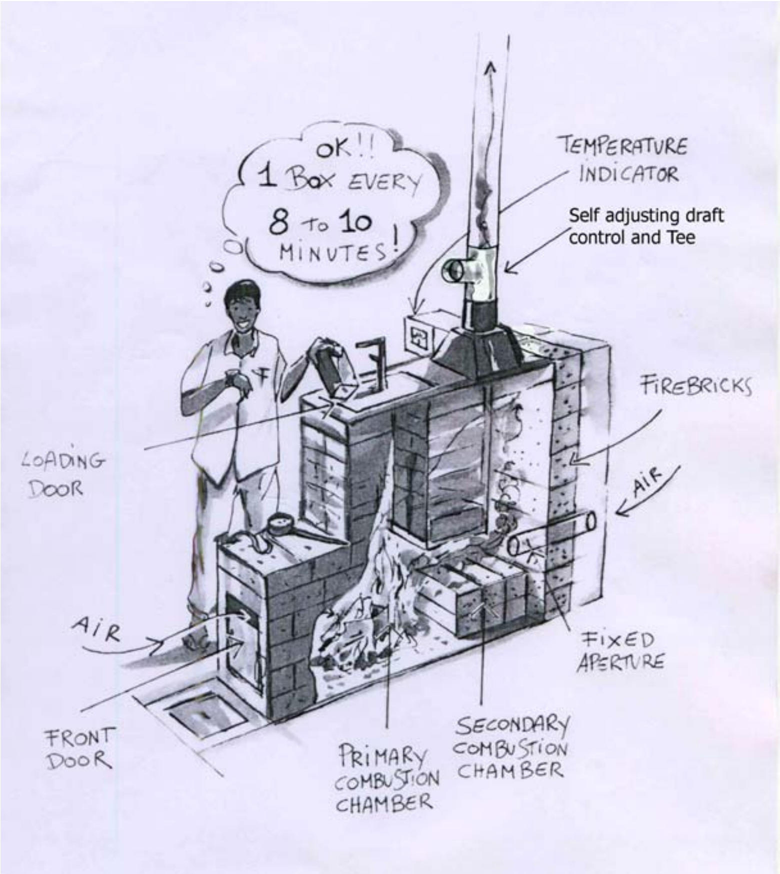
Figure 1.1 Components of the WDU



1.6 How the De Montfort works

The incinerator is made of firebricks and prefabricated metal components, which can be manufactured locally or imported. The structure is assembled and built at the site using mortar of Portland or refractory cement. No specialized tools are required.

Figure 1.2 How the De Montfort functions



The incinerator comprises primary and secondary combustion chambers. The burning zone of the primary chamber is accessible through a door at the front, which lets in air, allows the operator to light the fire, and also allows her/him to remove the ash. The medical waste is dropped in through a loading door above the primary chamber. The secondary chamber, which is inaccessible to the operator, is separated from the primary chamber by a brick column with an opening at the bottom to induce a cross draught during operation. Additional air is drawn into the secondary chamber through a small opening in the lower section of the rear wall of the secondary chamber. This air mixes with the partially burnt flue gas from the primary chamber and causes secondary combustion. A self-adjusting draught control for regulating heat output and burn time is mounted at the base of the chimney and controls the flue gases in the chimney. A stove pipe thermometer mounted at the neck of the chimney indicates when the medical waste should be loaded. A 4 meter-high chimney mounted above the secondary combustion chamber releases the flue gases into the atmosphere. (See Figure 1.2.)

1.7 Operating principles

Waste is warmed, dried and melted in the primary combustion chamber, before being burnt at the grate in the primary combustion chamber. Partially burned flue gas and particulates are drawn from this primary area into the secondary chamber, where additional air induces secondary burning before the flue gases are evacuated into the atmosphere through the chimney. All pathogens thus pass through two high temperature zones: one at the grate, and one in the secondary burning zone.

1.7.1 The burning cycle

The burning cycle contains three phases:

1) Preheating period: The primary chamber is loaded, lit and the temperature indicated on the stove pipe thermometer brought to approximately 600^0 C in 20 to 30 minutes by burning non-medical waste, i.e., firewood, coconut shells, etc., which is supplemented by kerosene or diesel fuel as may be necessary.
2) Medical waste disposal: Once the temperature in the primary chamber has reached 600^0 C, the safety boxes containing only syringes, or intermixed with small bags of infectious, waste, are loaded at a rate that maintains a constant and good, but not fierce, fire in the grate (approximately 6 kg/hr of safety boxes).
3) Burn down/close down period: Eight to ten minutes after the entire medical waste has been loaded, an additional 1 kg to 2 kg of non-medical waste is added to ensure that complete burning occurs.

1.7.2 Operating temperatures

The right operating temperatures should be maintained. This means:

- The temperature in the secondary chamber, which is displayed on the stove pipe thermometer, should be maintained between 600^0 C and 900^0 C by controlling the waste-loading rate.
- Temperatures above 900^0 C should be avoided since this increases velocities and burning in the chimney, which induces dense black smoke and reduces gas residency time.
- Temperatures below 600^0 C should also be avoided since toxic emissions (dioxins and furans) increase at lower temperatures.

1.8 Destruction capacity

1.8.1 Types of waste

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 the following material:

1) Sharps, including syringes with needles attached, razor blades, scalpels and any other sharp objects which may be contaminated, like glass, but excluding vials (unless open) or ampoules.
2) 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. [5]
3) Non-infectious waste, which does not include polyvinyl chloride (PVC) plastic bags, may be destroyed if it cannot be transported to a municipal waste disposal facility or if no alternative environmentally sound solution for disposal is available. (One can easily distinguish between PVC and polypropylene since PVC sinks in water, while polypropylene floats. This can be demonstrated to the ward personnel responsible for placement of waste in containers.)

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[5] Auto-disable and disposable syringe bodies where a needle cutter or needle remover has removed the needles should not be incinerated if disinfection and recycling can be practiced consistently and reliably.

The De Montfort should **not be used** to destroy:

1) Waste containing broken thermometers, IV fluid bags, PVC plastic bags, closed glass vials[6] and ampoules, or
2) Wet waste.

1.8.2 Waste in safety boxes

Used syringes in 5 (liter) WHO-approved safety boxes are the most common waste to be destroyed, especially during immunization campaigns. A safety box filled with used syringes weighs approximately 800 gm to 1400 gm. Safety boxes in primary health facilities sent for incineration typically weigh anything between 800 gm[7] and 1000 gm[8].

Figure 1.3 Types of Waste

1.8.3 Mixed waste

If temperatures indicated on the stove pipe thermometer are strictly adhered to, mixed waste comprising safety boxes of syringes and small sacks of infectious or non-infectious, non-sharp waste can be destroyed.

1.8.4 Rate of destruction

The Rate of Destruction is a measure of the rapidity with which waste is loaded into the incinerator. References to the rate of destruction differ considerably[9]. Average rates of destruction monitored at 14 sites in Kenya, 12 sites in Burkina Faso, which were in regular use by operators, ranged anywhere between 12kg and 9 kg of safety boxes per hour, respectively. If waste is loaded at the rate of 6-7 kg per hour, and stove pipe temperatures are maintained between 600 ^{0}C and 900^{0}C, then smoke emissions reduce considerably.

Recommended Rate of Destruction: 1 safety box every 8 to 10 minutes

If burning is fierce and waste is loaded rapidly, then internal temperatures increase, which may cause toxic emissions to reduce, but the levels of black smoke increase.

A careful balance between the rate of loading the incinerator and maintaining the incinerator operating temperature is required to minimize levels of visible smoke emissions and toxic emissions.

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[6] Open glass vials may be incinerated. Ref IT Power India test report, Incidence of Vial Explosions in the De Montfort Incinerator.

[7] Average weight of 94 safety boxes measured in Burkina Faso, Rapid Assessment of the WDU, PATH, June 2003.

[8] Average weight of 34 safety boxes measured in Kenya, Rapid Assessment of the WDU, PATH, June 2003.

[9] An emissions test in May 2003 on a De Montfort incinerator by Professor Jim Picken concludes that optimal burning rate combining high temperature levels with low smoke levels is achieved at 6 safety boxes/hr (6 kg-7 kg per hour).

1.9 Emissions: importance of controlling the waste-stream

Incinerators can produce toxic emissions such as carbon monoxide (CO), dioxins (polychlorinated dibenzo-para-dioxins or PCDDs), and furans (polychlorinated dibenzofurans or PCDFs). Carbon monoxide is produced by poor and incomplete combustion. These emissions can be reduced by good design and good operating procedures. Dioxin and furan emissions occur through burning of chlorine-containing wastes, e.g., PVC and other plastics. In general, since exposure to dioxins and furans is mostly through food intake (WHO 2001), the emissions from incinerators should not be allowed to blow across cultivated land. Emissions are minimized by good waste segregation practices to eliminate inclusion of PVC waste, and appropriate practices for high-temperature incineration. Incinerators are, however, estimated to emit a significant fraction of the global emissions of dioxins and furans.[10]

1.9.1 The World Health Organization position

From an environmental perspective, incineration of health care waste is not the ideal solution for health care waste disposal. Nevertheless, it is often the most viable option for developing and transitional countries. In these countries especially, there is a significant disease burden associated with poor management of health care wastes, since options for waste disposal are limited. There is also the issue of costs. Incineration of health care wastes may therefore be the preferred interim solution for disposing of health care waste. In situations where incineration presents itself as the best option, care needs to be taken to ensure that exposure to toxic air pollutants associated with burning is reduced to the minimal. One way in which this could be done is to limit the incineration of health care and other wastes to less-densely populated areas, e.g., rural areas.[11] As less polluting waste disposal technologies become available and resources permit, incinerators will gradually be replaced with safer waste treatment/disposal alternatives.

The WHO has found it inappropriate to recommend acceptable limits for dioxin and furan emissions in the proximity of small-scale incinerators. This is mainly because: most small-scale incinerators, including the De Montfort, do not meet the already existing but widely diverse standards: 0.1 ng toxic equivalency (TEQ)[12] 13/m3N to 5 ng TEQ/m3N for new incinerators in Europe and 10 ng TEQ/m3N for incinerator facilities already in use in Japan.[14] Further, there are a number of technology barriers. Small-scale incineration cannot be equipped with emission reduction and control devices, since such devices are unaffordable on a small scale. However, new generation, gas/electric-powered, small-scale incinerators for destruction of safety boxes are now commercially available.[15] These meet the European Union environmental norms, but are only suited for use at locations with regular electricity and gas supply.

Until countries have access to environmentally safe options for the management of medical waste, incineration may still be seen as the main option for such disposal. To make

[10] Medical waste incinerators were estimated to account for 21 percent of known sources of dioxin and furan emissions in the U.S. in 1987.
[11] This was a main recommendation from a WHO-organized and sponsored meeting on “Small Scale Incineration/Dioxin and Furan emissions”, 15 December 2003, WHO Geneva, Switzerland.
[12] TEQ is a calculated figured used to estimate the overall toxicity of multiple types (congeners) of dioxin-like chemicals at once.
[13] Toxicity equivalent at 40 hours per week.
[14] Source reference: Teruyoshi EHARA, Programme for the Promotion of Chemical Safety (PCS), WHO.
[15] Mediburner, Oulu, Finland.

incineration as safe as possible, "Best Practice" tools should be made available and enforced (e.g., pre-heating and not overloading the incinerator, or incinerating only at temperatures above 800° C). These guidelines are one element in the effort to reinforce a process of building "Best Practices."

WHO suggests that additional country assessments are necessary to gauge the national authorities' capacity to cope with the problem of health care waste. Such assessments will help lead to the development of appropriate health care waste management national policies and technologies.

1.9.2 Summary of dioxin emission estimates[16]

The available data related to emissions relevant to small-scale incinerators (without air pollution control equipment) appear to fall into three groups:

1) **Best practice:** Properly operated and maintained units which utilize sufficient temperatures, afterburners (secondary combustion chambers), and other features that limit dioxin/furan production. For such units, a reasonably conservative estimate of the emission concentration is 10 ng TEQ/Nm^3. [17] This limit may not be conservative for small brick-type units like the De Montfort design, which has a very short (<0.2 s) and variable residence time.

   Incineration for "Best Practices should not exceed 2hrs/day.

2) **Average practice tends to include**: Improperly designed, constructed, operated or maintained units that feature afterburners. Emissions from the SICIM Pioneer incinerator in Thailand, and United Nations Development Programme (UNDP) Class 2 tests range up to 600 ng TEQ/Nm_3, though most tests show lower emissions. Using a 500 ng TEQ/Nm_3 value may be conservative, however, given that the available data are admittedly scarce.

3) **Worst case equipment use**: Incinerators without an afterburner. The UNDP estimates an emission concentration of 4000 ng TEQ/Nm^3 for this simple technology.

1.9.3 Relative risks

For persons other than those with direct occupational exposure and contact with the ash residue, and if "Best Practices" are applied and incineration usage levels for waste disposal do not exceed 2 hrs/day, emissions represent less than 1 percent of the WHO provisional intake level for adults and children. As for the safety worker, sufficient precautions must also be taken to minimize exposure to toxins through consistent use of protective clothing, face masks and gloves.

To maintain risks at a small fraction of the WHO levels considered to be acceptable when "expected practices" are applied, utilization rates should not exceed one time per month, and each use should not exceed an hour.

If there is no provision for afterburning (secondary burning) when disposing of waste through drum burning or incineration, a "worst case" situation is likely. In this case, even if

[16]Batterman, Stuart. *Assessment of Small-Scale Incinerators for Health Care Waste*. Water, Sanitation and Health, Protection of the Human Environment, World Health Organization. For more information, contact S. Batterman at Environmental Health Sciences, University of Michigan, 109 Observatory Drive, Ann Arbor, MI 48109 USA

[17] Taken from the 90th percentile AP42 emission factor analysis.

incineration is undertaken only once a month for an hour, it may cause unacceptable intake and risk levels.

1.9.4 Measures to minimize emissions

To reduce emissions, adhere to the following Best Practices:

- 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, and 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 to maintain the burning temperature above 600^0 C.
- 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.

1.10 WDU management

Once an appropriate location to install the WDU has been identified, the other key management issues that need attention include budgetary provision, choice of site at the location, application of a "Best Practices" approach by the WDU operator, motivation of health care waste management personnel, and an effective supervisory mechanism for HCWM. The following sections discuss the issues related to installation, sustainable operation, and maintenance of a WDU.

1.10.1 Capital expenditure

Capital expenditure of WDUs comprise materials/fabrication costs, labor costs, and costs associated with management and training. Capital expenditure is generally borne by international donor agencies or central, state or provincial governments (See paragraph 1.11.1 for more details). Managers of WDUs at primary health facilities while not usually directly involved in mobilization of resources for capital expenditure, assume responsibility for assigning and coordinating personnel for training programs, HCWM supervising, and oversight of installation.

1.10.2 Operating budget and expenditures

In addition to the capital expenditure incurring on procurement and installation of the equipment and training, waste processing also requires financial resources to meet recurrent costs on personnel, fuels and maintenance. Health care facility budgets must include an annual provision for recurrent costs, and the management should carefully control the disbursements. During field evaluations it was observed that the absence of financial resources for recurrent costs is one of the most common reasons for failure of waste management programs. Some HCWM programs have successfully introduced a "burning fee" to offset or finance recurrent costs.

1.10.3 Siting

Siting is the process to determine where the WDU should be placed at a primary health facility. The location of the WDU can significantly affect the dispersion of smoke and particulates from the chimney, and the resultant exposure of workers and the public to toxins. Siting must also address issues of permission, ownership, access and convenience. A Best Practices approach should be adopted to find a location that, "to the maximum extent practicable, minimizes potential risks to public health and the environment."[18]

Experience with the De Montfort incinerators highlights the importance of good siting, and the importance of involving stakeholders, including medical personnel, nearby residents and incinerator operators, in the process of selecting the most appropriate site.

The following strategy should be adopted when selecting a site for the WDU:

- Involve individuals responsible for HCWM at the primary health facility in siting decisions.
- Involve health workers and members of the local community in the decision process.
- Respect national policies and regulations.
- Take guidance from a person or organization experienced in siting waste disposal units. This is mandatory.

The WDU should be built at a location where:

- It is convenient to use.
- It is NOT close to patients' wards and other occupied or planned buildings.
- There is low public presence/passage.
- Flooding does not occur.
- No flammable roofs or inflammable materials are stored within a radius of 30 meters.
- Prevailing winds blow smoke away from buildings and NOT across cultivated land.
- Security risk is minimized.

1.10.4 Procurement Strategy

The guidelines propose two options for procurement: a locally built WDU, where all the raw materials are sourced and manufactured locally, transported to the site, and assembled. (Such would be the case in India and South Africa). The other option is the "imported kit" option, where the parts are prefabricated, integrated with materials which may not be locally available (e.g., refractory brick and refractory cement), and imported as a pre-packaged kit which is then assembled at the site. Whatever option is adopted is an important management decision and will have substantial impact upon capital costs, workload of the local implementing agency, and—above all—good operational performance. Criteria for a decision making process to select the most appropriate option are listed in Section II, Paragraph 2.5.4.

[18] The US Environmental Protection Agency regulates the burning of hazardous waste in incinerators under 40 CFR Part 264/265, and in boilers and industrial furnaces under 40 CFR Part 266. U.S. Environmental Protection Agency, "Draft: Technical Support Document for HWC MACT Standards," February 1996, http://www.epa.gov/epaoswer/hazwaste/combust/tech/tsd_v2.pdf (Accessed July 7, 2004).

1.10.5 WDU operator

Several rapid assessments in 2003[19] of waste management practices and incinerator performance highlight management and incinerator operator constraints as critical factors in good HCWM. Major constraints identified were inconsistent design standard, inadequate quality control during installation, and inadequate operator training and motivation. The following operator-related measures should be adopted to ensure good WDU performance:

- Only a trained, qualified and equipped operator should operate the incinerator.
- The operator must be on-site while the incinerator is functioning.
- The operator must be motivated to follow "Best Practices."
- The WDU should be operated according to Best Practices to minimize emissions and other risks.
- Operators must have long-term contracts or be permanent hires.

Long-term or permanent operator contracts are the often the most difficult of the above points to address. WDU operation is usually not a full-time job, and frequently WDUs are operated by casual labor responsible for grounds maintenance. At some sites, casual laborers are rotated periodically in compliance with labor laws. This approach is strongly discouraged since training efficient operators is time-consuming and expensive; and operator knowledge and commitment are essential for good incineration practices. Operators should be contracted for longer terms or be on permanent payrolls.

In some instances, district-based cold chain maintenance technicians manage the WDUs. This practice is to be encouraged since cold chain technicians have a technical profile, habitually maintain records, and can recognize maintenance needs.

1.10.6 Supervision

Even if operators are well-trained, supervision is essential. Supervision provides quality control and recourse to improve other aspects of waste management, in particular segregation and disposal practices.

Every country should have a collaborative mechanism for developing a regulatory framework for HCWM, such as a national HCWM committee to develop and underpin national policies for handling, processing and destruction of infectious waste at all health facilities, including primary health facilities.[20]

Each primary health facility should designate an HCWM supervisor, with operational linkages (directly or indirectly) to the HCWM Committee. The responsibilities of the HCWM supervisors at these facilities include:

- Training all primary health facility staff in HCWM practices;
- Ensuring good waste segregation practices;
- Coordination and supervision of waste transportation, packaging, storage and handling;

[19] Based on studies of Burkina Faso, Kenya, Senegal, Benin, and Nigeria, and the Rapid Assessment of the WDU, PATH, June 2003.

[20] Recommendation offered to the Task Force on Immunisation (TFI) in an overview of GAVI/ITF workshops, Luanda, Angola 3-5 December 2003.

- Monitoring of waste processing at the WDU and other appropriate locations (municipal facilities);
- Supervision of the WDU operator; and
- Reporting.

1.10.7 Motivation

One of the key barriers to good HCWM is the absence of motivated operators and HCWM supervisors and the lack of effort to motivate them. Waste management, handling, and disposal are not generally considered ennobling tasks, hence special efforts need to be made to motivate personnel involved. One way of motivating the personnel is through schemes offering financial incentives for good performance. Good training and creating awareness in the community of the importance of good waste management can also improve motivation levels. (Training of operators is discussed in Section III.)

1.10.8 Maintenance

Maintenance is required for all processes that entail the use of technology. Maintenance of WDUs is no exception. (Issues of maintenance and planning are discussed in detail in Section IV.)

Supervision and control of maintenance quality are a management responsibility and are just as much a part of WDU management responsibility as budgetary provision. Usually, maintenance responsibility is outsourced under an Annual Maintenance Contract (AMC), in which case there is scope to include performance guarantees in the contract agreements for services. In some countries, the maintenance responsibility is assumed directly by the maintenance infrastructure of the ministries of health. Operating policies will determine the approach adopted. Economic and quality of service considerations should be the primary factors in selecting a maintenance option.

1.11 WDU Costs

In reviewing De Montfort economics, costs directly relating to the WDU and its operation are considered, and not the costs of transport, packaging and management which are part of general HCWM costs and not specific to WDUs.

1.11.1 Capital costs

The capital cost of a WDU will vary from location to location, depending on the following factors:

- Whether the “Local Build” or the “Imported Kit” (which comprises prefabricated metallic components and other materials not readily available in many countries) option is chosen
- Material and labor costs and the profit margin required by the equipment manufacturer.
- The number of WDUs to be installed.
- The remoteness and accessibility of sites.
- The type of contractual approach adopted.
- The scope of services (maintenance contracts, performance bonds, etc.) defined in the supply agreement.

Table 1.1 provides indicative distribution of capital costs of WDUs for programs ranging from 5 to 100 WDUs.

Table 1.1 Estimated percentage of capital costs for manufacturing, constructing, and commissioning a WDU

Cost components	5 WDUs	100 WDUs
Materials/Fabrication	33%	47%
Labor	13%	25%
Management/Training	54%	28%

This distribution is based upon actual cost estimates obtained in India in 2004, where the total capital costs were USD 950 per WDU when 100 WDUs had to be constructed, and USD1800/WDU when only 5 WDUs had to be constructed. The economies of scale are due primarily to the management/training component; the materials and fabrication costs reduce by only 25 percent with large-scale production.

1.11.2 Recurrent costs

The WDU equipment is designed to operate for 10 years before total replacement. Financial provision to cover the recurrent costs of WDUs over a ten-year period should be made when planning a HCWM system. Typical recurrent costs include:

- Wood, coconut shell, or kerosene needed to preheat the incinerator and supplement burning of medical waste at each burn cycle. For one complete cycle (i.e. preheating, incineration, and cool down), about 8 kg of wood is required. It is assumed the wood is dry.
- Salaries, social benefits and performance incentives of the WDU operator and supervisor.
- Replacement of labor and worn out parts.

Retraining and quality assurance are necessary. Table 1.2 provides indicative percentage distributions of annual recurrent costs of WDUs for the first year when retraining occurs, and for other years over a 10-year life cycle. Figures presented assume a level of utilization of 120 safety boxes per month. [21]

Table 1.2 Estimated percentage distribution of recurrent costs for construction and commissioning a WDU

	First year recurrent costs		Second to tenth year annual recurrent costs	
Cost components	5 WDUs	100WDUs	5 WDUs	100WDUs
Parts and maintenance	14%	14%	20%	17%
Fuel	23%	30%	33%	34%
Salaries/benefits	34%	42%	47%	49%
Retraining	29%	14%	(offered annually)	(offered annually)

[21] The average utilization rate observed in Kenya was 58 safety boxes per month.

Recurrent costs in India are projected to be USD430/WDU per year for a HCWM program consisting of 5 WDUs in those years when retraining is conducted, and USD300 otherwise. For large programs of 100 WDUs, recurrent costs are estimated at USD 330 with retraining conducted, and USD 290 with retraining. No significant economies of scale are achieved with larger programs, except in years when retraining occurs.

1.11.3 Cost efficiency

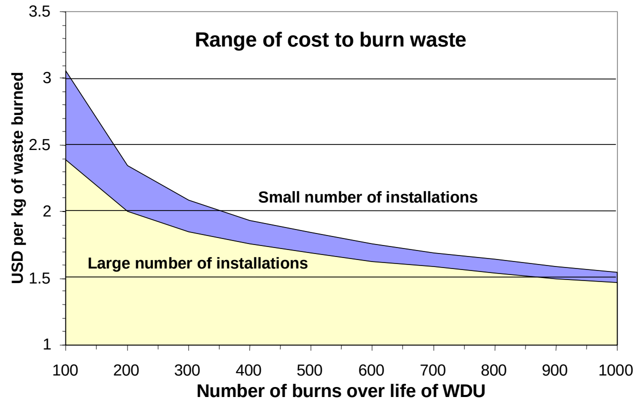
While capital and recurrent costs associated with setting up and operating a WDU are important from a budgetary perspective, it is ultimately the cost efficiency of destroying medical waste that is of greatest importance. The major factors that influence cost efficiency are:

- The level of utilization: (quantities of waste destroyed). To a large extent, this is dependent upon choosing an appropriate location for the WDU[22] and the HCWM practices; in particular; management, quality control, collection and transportation.
- Capital and recurrent cost: Although contingent upon locally available material and labor costs, these costs are also determined by good contracting practices and rigorous quality control.
- Life expectancy of the WD: Its duration is largely dependent upon the engineering design, component quality, installation standards, and operator practices.

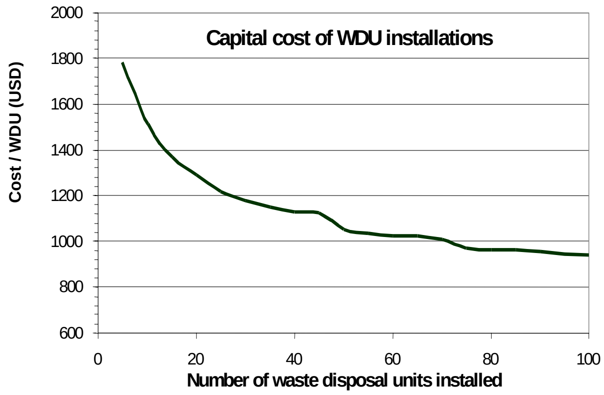
Based upon data gathered from India, Graph 1.1 and Graph 1.2 provide estimates of the:

- Link between the level of utilization of a WDU and the costs of burning waste over the operating life of the WDU; and
- Link between WDU capital cost to program size.

Graph 1.1 Level of utilization versus cost of burning waste



Graph 1.2 WDU capital costs versus program size



[22] *An Overview of GAVI/ITF Workshops during 2002-2003 for the WHO Task Force on Immunization (TFI)*, John S. Lloyd, Luanda 3-5 December 2003.

These charts provide a basis for decision-makers to estimate capital and recurrent costs, and cost efficiency of a planned WDU program. Annual maintenance costs are based upon 100 burns per year, each for a period of 2 hours, at a rate of loading of 6 boxes per hour. [23]

[23] The financial model may be requested via email at nvm@itpi.co.in or tjh@itpi.co.in.