Environmentally Responsible Management of Health Care Waste With a Focus on Immunization Waste

OCTOBER 2002

Working Draft

This document is in draft format in order for HCWH to receive input and comments from colleagues and peers. HCWH welcomes comments and suggestions on this document.

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Health Care Without Harm (HCWH) is a broad-based, international coalition consisting of 350 organizations in 38 countries and including community groups, environmental justice advocates, physicians, nurses, patients, scientists, religious institutions, and labor representatives. The mission of HCWH is to reform the environmental practices of the health industry without compromising safety. The efforts of HCWH include:

- advocating for policies to eliminate the indiscriminate incineration of medical waste,
- changing purchasing and materials management practices of hospitals and purchasing groups,
- promoting policies and procedures that work toward the minimization of waste volume and toxicity,
- researching and advocating safer waste disposal alternatives, and
- educating the broader public about dioxin, mercury, and endocrine-disrupting chemicals and the health care industry's contribution to these problems

Please go to www.noharm.org for more information on HCWH.

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NOTE: Parts of Chapter 4 are drawn from the WHO guide, Safe Management of Wastes from Health Care Activities, particularly Chapter 8 (Pruss, et al., 1999); and the UNICEF guide, Management of wastes from immunisation campaign activities: Practical guidelines for planners and managers <HCWM_IA_en_v4.doc . Draft version 3>. They have been modified to coincide with the authors' experience and emphasis on non-incineration treatment technologies. The authors acknowledge and recognize the value of the materials herein cited for their systematic thinking and careful approach to planning.
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Introduction

The management of wastes from health care facilities and immunization programs has been elevated to a serious public health issue by a number of international non-governmental organizations (NGOs) in recent years. In particular, as a result of the new massive immunization programs underway and anticipated globally, millions of single-use syringes will be generated. There is a recognized need for programs and protocols for safe handling, treatment, and disposal to accompany the roll-out of these efforts.

The World Health Organization (WHO) has been studying the issue since the publication of its guide on safe management of wastes from health care activities in 1999 (and the establishment of a special web resource <www.healthcarewaste.org>). The World Bank Group, the International Finance Corporation, the Inter-American Development Bank, and other major global funders of health care programs and infrastructure have all released initial guidance notes on health care waste management since 2000.

A coalition of international NGOs, scientists, and medical professionals, Health Care Without Harm (HCWH) advocates for safe handling, treatment and disposal of medical waste. HWCH works to discourage antiquated approaches to waste management that produce harmful environmental and public health impacts, and replace them with innovative thinking and approaches that makes the best use of technology and management skills to solve this problem.

Of particular concern to HCWH is the continued reliance on combustion technology for “solving” the health care waste problem. There has been extensive documentation of the serious environmental degradation related to the use of incinerators, as well as incinerators’ health impacts on health workers and surrounding communities. Medical waste incinerators are a leading source of dioxins and mercury in the environment. Dioxin, one the most toxic substances known, is a by-product formed when chlorine-containing products are manufactured or burned. Polyvinyl chloride (PVC) plastic is a major source of chlorine in medical waste. Mercury is used throughout hospitals in patient and laboratory thermometers, blood pressure devices, dilation and feeding tubes, and batteries. Once constructed and in use, medical waste incinerators are commonly used to burn all hospital waste. This is especially true of rural areas in developing countries where proper training and systems are not in place. Section two of this paper will discuss the environmental and health problems associated with medical waste incinerators.

The recent innovation of a small-scale incinerator called De Montfort that can be locally manufactured and is being promoted as an “appropriate technology,” is in fact a step backwards in waste management efforts in the “low-resource” areas where it is being promoted. The De Montfort incinerator has serious operational deficiencies from an environmental standpoint and can lead to management deficiencies that undermine good waste management practices. Ironically, promotion of these incinerators as part of global public health initiatives may require special exemptions or exclusions from environmental regulations thereby exacerbating the trend of dumping obsolete and polluting technologies that are no longer used in more industrialized countries. Moreover, incinerators undercut environmental laws and international conventions to protect public health and the environment and hamper the deployment of cleaner alternatives. Data analysis and field study results of the De Montfort incinerators are also discussed in section two.

HCWH advocates for safe handling, treatment, and disposal of medical waste.
Proponents of the De Montfort incinerator (and other low-cost combustion technologies) argue that they are meeting a need in poor rural communities that would not be able to afford high-tech incinerators. This assumes that developing countries have only these options: inexpensive low-tech incinerators or costly high-tech incinerators. Many cleaner alternatives now exist to safely treat and dispose of medical waste. Section three of this report will focus on low-cost alternatives which can be manufactured locally and offer a solution to medical waste problems in low-income developing countries at costs lower than those of low-cost incinerators.

The planning for waste management should not happen as an afterthought of the planning of global immunization campaigns or major investments in building new health care infrastructure. Waste management is a basic public health concern and needs to be integrated from the beginning of project planning. Waste management is a process, not a technology, and its various components or planning, training, management systems, technology, equipment and disposal sites need to be given comprehensive attention if they are to provide a sustainable and flexible solution for today and tomorrow. Various waste management strategies and processes are discussed in section four.
Critique of Incineration

Before the 1950s, incinerators were single-chamber open hearths or enclosed oven-type units that operated at low temperatures. Little was known then about their health effects but visible smoke and concerns about environmental pollution led to the development of afterburners. Recognizing the importance of high temperatures to improve combustion efficiencies, incinerator designers added temperature controllers and auxiliary burners in the chamber. But these steps were not sufficient to reduce pollution. By the late 1950s and early 1960s, manufacturers realized that residence time (the time that combustion gases are exposed to high temperatures and turbulent mixing with air) was a significant factor in reducing pollutant emissions. This led to the development of a secondary combustion chamber with the afterburner to provide a longer residence time at high temperatures. Thus, beginning in the 1960s, three basic incinerator designs came into common use for medical waste: multiple chamber, dual-chamber controlled-air, and dual-chamber rotary kiln incinerators.

Since the 1950s, the medical waste composition also changed from mostly cellulose waste (gauze, swabs, paper, etc.) to more heterogeneous waste streams with larger percentages of disposable materials resulting in a significant increase in the use of plastics and composite materials, and a large increase in components with hazardous materials (e.g., batteries, mercury and other heavy metals). Among the consequences of this change were more chlorinated organics and metals, a higher caloric content in the waste, the need for more controlled temperature and airflow, and higher levels of toxic emissions. Therefore, by the 1970s, regulatory authorities began requiring the addition of air pollution abatement devices such as neutralizing scrubbers and fabric filters. In the last decade, more data on the health effects of incinerator emissions have been published prompting countries to promulgate more stringent regulations in an effort to protect human health and the environment.

The promotion in developing countries of incineration, an obsolete polluting technology that undermines activities to protect health and the environment, is a major step back. Increasing the use of incineration makes it more difficult for countries to enforce or strengthen environmental regulations, and impedes the deployment of newer and cleaner technologies for treating medical waste.

2.1 Environmental Impact of Incineration

In the last decade, government authorities and environmental advocates have come to realize that medical waste incinerators release into the air a host of pollutants including highly toxic dioxins and furans, metals (such as mercury, lead, and cadmium), particulate matter, acid-forming gases, and carbon monoxide; see Table 2.1. Hydrogen chloride, which is formed when chlorinated plastics common-

<table>
<thead>
<tr>
<th>TABLE 2-1 TYPICAL POLLUTANTS FROM MEDICAL WASTE INCINERATORS</th>
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<tbody>
<tr>
<td><strong>POLLUTANT</strong></td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>Dioxins and furans</td>
</tr>
<tr>
<td>Other organic compounds</td>
</tr>
<tr>
<td>Heavy metals</td>
</tr>
<tr>
<td>Acid gases</td>
</tr>
<tr>
<td>Carbon monoxide</td>
</tr>
<tr>
<td>Pathogens</td>
</tr>
<tr>
<td>Particulate matter</td>
</tr>
<tr>
<td>Bottom ash residues</td>
</tr>
</tbody>
</table>
ly found in medical waste are incinerated, readily forms hydrochloric acid in contact with moisture and is corrosive and toxic to plants.

2.2 Health Effects of Incineration

Incinerator emissions have serious adverse consequences on health workers, local communities near and far, and the environment. Pollutants from incineration include Persistent Organic Pollutants (POPs) such as dioxins and furans, which are especially dangerous because they bioaccumulate, biomagnify, resist decomposition and are capable of being transported great distances threatening public health and ecosystems around the world. Very low concentrations of dioxins, for example, have been linked to cancer, immune system disorders, diabetes, birth defects, and other health effects. Mercury is associated with nervous system disorders particularly affecting developing fetuses and small children. Medical waste incinerators are a leading source of dioxins and mercury in the environment.

Lead at low concentrations can cause anemia and reduced IQ in children. Chronic exposure to cadmium has been associated with progressive lung diseases, heart disease, anemia, and other health problems including lung cancer. Chronic exposure to carbon monoxide at low concentrations may aggravate heart conditions.

Since many hospitals and health care clinics are situated within the cities, towns, and rural communities they serve, on-site incinerators are often found adjacent to homes, schools, marketplaces, and other centers of activity, providing a large receptor population for toxic pollutants.

Various epidemiological studies on incinerators in general have indicated significant links between incinerator emissions and:

- higher blood levels of dioxins, furans, toluene, lead, and cadmium
- higher levels of mercury in the hair
- increased risk of cancers, especially stomach, colorectal, liver, and lung cancers
- higher prevalence of hypertension
- excessive deaths from ischemic heart disease and lung cancer.

Table 2-2 summarizes some epidemiological studies published since 1988.

2.3 Other Problems Associated With Incineration

Poor operation and maintenance of incinerators amplify the level of pollutants emitted. Lack of training, staffing, and financial resources results in many incinerators operating under the poorest conditions. Since incinerators are subjected to high temperatures and acid gases, one often finds incinerators with rusty or broken chimneys and doors, cracked or damaged refractories, clogged air vents, etc. This generally indicates that the optimal levels of oxygen needed for combustion are not met and that pollutant by-products of incomplete combustion are released at high levels. Incinerator operators are often low-skilled workers with little or no training on operating principles, maintenance, inspection, repair, or diagnosis and correction of poor combustion conditions.

Worker safety is another critical issue. Many incinerator operators are not provided with training and personal protection equipment. Hence, operators are exposed to heat, dense smoke (especially with poorly maintained incinerators where the smoke comes out of doors and vents instead of the stack), and ash particles stirred up during ash removal.
### TABLE 2-2 SUMMARY OF EPIDEMIOLOGICAL STUDIES ON ADVERSE HEALTH EFFECTS ASSOCIATED WITH INCINERATION

<table>
<thead>
<tr>
<th>STUDY SUBJECTS</th>
<th>CONCLUSIONS REGARDING ADVERSE HEALTH EFFECTS</th>
<th>REFERENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residents from 7 to 64 years old living within 5 km of an incinerator and the incinerator workers</td>
<td>Levels of mercury in hair increased with closer proximity to the incinerator during a 10 year period</td>
<td>P. Kurttio et al., Arch. Environ. Health, 48, 243-245 (1998)</td>
</tr>
<tr>
<td>Residents living within 10 km of an incinerator, refinery, and waste disposal site</td>
<td>Significant increase in laryngeal cancer in men living with closer proximity to the incinerator and other pollution sources</td>
<td>P. Michelozzi et al., Occup. Environ. Med., 55, 611-615 (1998)</td>
</tr>
<tr>
<td>Residents living around an incinerator and other pollution sources</td>
<td>Significant increase in lung cancer related specifically to the incinerator</td>
<td>A. Biggeri et al. Environ. Health Perspect., 104, 750-754 (1996)</td>
</tr>
<tr>
<td>People living within 7.5 km of 72 incinerators</td>
<td>Risks of all cancers and specifically of stomach, colorectal, liver, and lung cancer increased with closer proximity to incinerators</td>
<td>P. Elliott et al., Br. J. Cancer, 73, 702-710 (1996)</td>
</tr>
<tr>
<td>10 workers at an old incinerator, 11 workers at a new incinerator</td>
<td>Significantly higher blood levels of dioxins and furans among workers at the old incinerator</td>
<td>A. Schecter et al., Occup. Environ. Medicine, 52, 385-387 (1995)</td>
</tr>
<tr>
<td>122 workers at an industrial incinerator</td>
<td>Higher levels of toluene, lead and cadmium in the blood and higher levels of tetrachlorophenols and arsenic in urine among incinerator workers</td>
<td>R. Wbitzky et al., Int. Arch. Occup. Environ. Health, 68, 13-21 (1995)</td>
</tr>
<tr>
<td>53 incinerator workers</td>
<td>Significantly higher blood and urine levels of hexachlorobenzene, 2,4/2,5-dichlorophenols, 2,4,5-trichlorophenols, and hydroxypyrene</td>
<td>J. Angerer et al., Int. Arch. Occup. Environ. Health, 64, 266-273 (1992)</td>
</tr>
<tr>
<td>37 workers at four incinerator facilities</td>
<td>Significantly higher prevalence of urinary mutagen/promutagen levels</td>
<td>X.F. Ma et al., J. Toxicol. Environ. Health, 37, 483-494 (1992)</td>
</tr>
<tr>
<td>56 workers at three incinerators</td>
<td>Significantly higher levels of lead and erythrocyte protoporphyrin in the blood</td>
<td>R. Malkin et al., Environ. Res., 59, 265-270 (1992)</td>
</tr>
<tr>
<td>86 incinerator workers</td>
<td>High prevalence of hypertension and related proteinuria</td>
<td>E.A. Bresnitz et al., Am. J. Ind. Medicine, 22, 363-378 (1992)</td>
</tr>
<tr>
<td>176 incinerator workers employed for more than a year from 1920-1985</td>
<td>Excessive deaths from lung cancer and ischemic heart disease among workers employed for at least 1 year; significant increase in deaths from ischemic heart disease among workers employed for more than 30 years or followed up for more than 40 years</td>
<td>P. Gustavsson, Am. J. Ind. Medicine, 15, 129-137 (1989)</td>
</tr>
<tr>
<td>Residents exposed to an incinerator</td>
<td>Reproductive effect: frequency of twinning increased in areas at most risk from incinerator emissions</td>
<td>O.L. Lloyd et al., Br. J. Ind. Medicine, 45, 556-560 (1988)</td>
</tr>
</tbody>
</table>
Ash disposal is another serious problem. Ash residues from incinerators incapable of completely destroying needles pose needle-stick hazards. The ash may also contain broken glass as well as leachable metals and organic compounds. Some studies show that a significant portion of the overall dioxin formed in incinerators is found in the ash or slag. Despite the hazards of incinerator ash, it is often improperly discarded in open dumps or on the grounds of the hospital or health center.

Because incinerators are seen as a convenient way of discarding waste, incinerators tend to be used for the burning of all waste from health care activities, including non-infectious recyclable or compostable materials, chlorinated plastics such as PVC, and waste containing heavy metals such as mercury thermometers and batteries. Moreover, incinerators that may have been designed or installed for specific infectious waste streams, such as immunization waste, may end up being used for all other wastes. In cases where incinerators have been reserved for just “special hazardous waste” the field experience of waste assessments in a number of countries have documented that mercury, hazardous pharmaceutical and a variety of other hazardous chemical wastes are added to the incinerator waste stream because practitioners know it should receive “special treatment.”

In the last decade, the growing acceptance by health care providers of their environmental responsibilities has fostered greater support and implementation of waste segregation and waste minimization programs as key elements of a safe and effective waste management system. Unfortunately, the perception that incinerators are a convenient disposal method for all waste without regard for their environmental and health effects leads to the burning of all health care waste and undermines the move towards better waste management practices.

### 2.4 Incineration, Stockholm Convention on POPs, and Environmental Regulations

In May 2001, the final version of the Stockholm Convention on Persistent Organic Pollutants (POPs) was adopted and is now in the process of ratification. Annex C of the Stockholm Convention deals with the unintended production of POPs. Among the POP chemicals are dioxins and furans. When the Stockholm Convention takes effect, countries will be required to develop and implement action plans within two years to address the release of dioxins and furans.

The Convention specifically targets medical waste incinerators among processes that have “the potential for comparatively high formation and release of these chemicals to the environment.” Article 5 of the Convention makes it clear that some measures will have to be taken to further reduce releases of dioxins and furans from incinerators with the goal of their “ultimate elimination.” A high priority will be given to the use of alternatives. According to the Stockholm Convention, countries will have to “promote and, in accordance with the implementation schedule of its action plan, require the use of best available techniques” which include technologies. Countries will be best served in preparing for compliance by identifying and actively pursuing cleaner technologies to replace medical waste incinerators.

Furthermore, international agencies should encourage all countries to enforce their environmental laws and support the adoption of more stringent measures to protect public health and the environment in keeping with international standards and covenants. Weaker environmental standards in some developing countries have led to the dumping of banned or unsafe technologies in these countries. For example, in an effort to justify the purchase of obsolete Austrian incinerators that do not meet European standards, some Philippine officials have sought to delay the implementation of an incinerator ban in the Philippines. Since many small incinerators cannot meet many environmental standards, promoting their use in developing countries would entail special exemptions or immunity from compliance thereby undermining the enforcement of environmental regulations.
2.5 Case Study: The De Montfort Incinerator

The De Montfort incinerator was developed by the Innovative Technology Group at De Montfort University in Leicester, UK in order to address the problem of medical waste in developing countries, particularly in rural areas. The design and building instructions for this small-scale incinerator are available to the public. In the last few years, well-respected international organizations—such as Medicins Sans Frontieres, World Health Organization, Salvation Army, and United Nations Children’s Emergency Fund—have promoted or funded the construction of hundreds of these incinerators around the world especially in low-income developing countries.

Despite the good intentions of De Montfort engineers and these international agencies, it is important to assess whether the De Montfort incinerator is really a solution or an approach that makes a serious problem even worse.

2.5.1 Analysis of Existing Data

Complete combustion means converting all hydrocarbon waste into water and carbon dioxide. Because complete combustion is not achieved in an incinerator and because of the presence of other chemicals such as chlorine and metals, incinerators release unwanted pollutants including “products of incomplete combustion” such as carbon monoxide, toxic organic compounds, and smoke formed by small, unburnt particles suspended in air.

Operational problems observed during field tests of the De Montfort incinerator in Zimbabwe and Nepal were reported at a WHO meeting. At a test site at a hospital in Murewa, Zimbabwe, the burning of plastics resulted in visible smoke indicating incomplete combustion. The De Montfort incinerator was not used after the test because of the cost of wood fuel and the need for an operator. Other tests were conducted at hospitals in Nepal.

The tests showed that plastic material—which would melt, drop through the grate, and burn in the ash pan—tended to obstruct the flow of gases through the grate thereby resulting in products of incomplete combustion. When expired or unwanted pharmaceuticals were burned, ointments containing petroleum jelly were found to produce dense black smoke. These clearly indicate the inability of the incinerator to achieve high combustion efficiencies at all times.

Incineration of large quantities of syringes from immunization campaigns manifested further problems. When incinerating boxes of syringes, there was “little other material to separate the boxes” and “nothing to hold the diesel fuel” while it burned. For immunization waste, the De Montfort designer then suggested alternating loads of wood and syringes to maintain the temperature, placing absorbent material such as straw between the boxes of syringes when using diesel fuel, or using a burner or welding torch in the combustion chamber.

As shown by the tests, the following requirements are needed for good operation:

■ A “generous supply of wood,” diesel oil, or other supplementary fuel source
■ No wet material should be thrown directly into the grate
■ The grate and flue should be cleared whenever the rate of burning decreases
■ The load may have to be pushed down if it is too compact
■ The chamber must be kept full by loading about every 15 minutes with a “well judged” mix of materials.

As the report concludes: “All this means virtually continuous manning to achieve satisfactory operation, and some hospitals feel they cannot afford this expense.”
A set of laboratory tests was conducted in South Africa for De Montfort University and the South African Collaborative Center for Cold Chain Management. The resulting report noted the highly variable performance of the incinerator due to variable energy in the wood fuel and the potential for blockage of the air intake ports. The De Montfort also used a large amount of fuel during operation; the high consumption of fuel could be unacceptable or unavailable for rural communities. When researchers first attempted to light the incinerator using kindling and paper, large amounts of smoke were emitted. Liquified petroleum gas was then used to reduce the amount of smoke released by the incinerator into the laboratory. It should be noted that the tests done in South Africa were taken at temperatures below the recommended temperatures. In many of the tests conducted, there was little or no information about the amounts and composition of the waste load used.

Despite strong indications that the De Montfort incinerator released significant amounts of products of incomplete combustion, comprehensive emission testing has never been done. However, the available data from limited tests indicate that the De Montfort incinerator does not meet many environmental standards.

In order to achieve as close to complete combustion as possible, an incinerator must have a high combustion temperature, the right amount of air, sufficient mixing and a long enough “residence time” in the incinerator, the proper feed rate, and an ideal waste composition. For this reason, measurements of combustion temperature, residence time, carbon dioxide, and carbon monoxide are important since they give indications of the level of combustion achieved.

### 2.5.1.1 Combustion Temperatures

Many regulations require the combustion temperature to be above 850 °C to ensure good combustion of organic compounds. The temperature in the secondary or combustion chamber is most crucial. Secondary chambers promote mixing and add more heat so as to get as close to complete combustion as possible.

As shown in Table 2-3, the De Montfort incinerator is not capable of maintaining a combustion temperature above 850 °C at all times. Moreover, temperatures in the De Montfort's secondary chamber generally do not reach 1000 °C which is the minimum required in many regulations. Under European standards, the combustion temperature should be at least 1100 °C if the waste contains more than 1% chlorinated organics, which is often the case with medical waste. Even more disturbing, secondary chamber temperatures in the De Montfort can drop as low as 400 °C, temperatures at which dioxins and furans are known to form.

The ability to control temperature within a specified range (typically 850 to 1,000 °C) is just as important. Whenever a waste load is placed in the incinerator, temperatures tend to drop. It is during these periods that many pollutants are emitted. Temperature control is usually done by means of auxiliary burners which automatically fire supplemental fuel whenever the temperature falls below a limit. Since the De Montfort incinerator does not have any temperature controller nor auxiliary burners, it cannot keep the temperatures within a narrow range, as shown in the data in Table 2-3. Measurements of the De Montfort incinerator showed that when fluids and wet wood were added, the temperature in the secondary chamber dropped to within the range of temperatures where dioxins and furans are formed. In the following table, the De Montfort data are compared to some regulatory standards.
2.5.1.2 Residence Time

Residence time (also called the dwell time or retention time) is an important design parameter for incinerators. It is a measure of the time that off-gases or gaseous by-products are exposed to combustion temperatures and turbulent mixing with air, generally referring to the time in the secondary or combustion chamber. The higher the residence time, the greater the extent of destruction of organic compounds and of any microorganisms in the off-gas and hence, the lower the pollutant levels. Conversely, the lower the residence time, the higher the level of pollutants emitted.

In research commissioned by the U.S. Environmental Protection Agency (USEPA), the secondary chamber residence time was identified as the single most important factor in achieving low emission levels. Thus, many medical waste incinerator manufacturers have focused on secondary chamber residence time as the key component of their design efforts to meet emission limits. The Midwest Research Institute, which conducted the study for USEPA, found that new incinerators built in the U.S. from around 1993 already had residence times of 2 seconds, while those built before that period were designed with 1-second residence times. As early as 1977, experiments with incinerators using biological test spores resulted in the recommendation of a minimum residence time of 2 seconds at high temperatures to assure total destruction of all pathogens.

As shown in Table 2-4, the residence time in the De Montfort incinerator is less than 1 second accounting for both chambers and the stack. When accounting only for the volume in the critical secondary chamber, one estimates about 0.1 second or 0.05% of the time required by many environmental standards. Moreover, as already noted, these extremely short residence times correspond to exposures to low temperature conditions in the De Montfort, not the high temperatures required in many standards.

<table>
<thead>
<tr>
<th>OPERATING PARAMETER</th>
<th>DE MONTFORT DATA</th>
<th>INDIAN STANDARDS</th>
<th>SOUTH AFRICAN STANDARDS</th>
<th>OTHER STANDARDS OR GUIDELINES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Chamber Temperature</td>
<td>600 - 1000 ºC after 45 min</td>
<td>800 ± 50 ºC</td>
<td>= 850 ºC</td>
<td>&gt; 760 ºC</td>
</tr>
<tr>
<td></td>
<td>402 - 830 ºC after 125 min</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>449 - 873 ºC after 100 min</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secondary Chamber Temperature</td>
<td>400 - 800 ºC after 45 min</td>
<td>1050 ± 50 ºC</td>
<td>=</td>
<td>&gt; 870 ºC</td>
</tr>
<tr>
<td></td>
<td>600 - 817 ºC after 125 min</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>661 - 899 ºC after 100 min</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>600 - 900 ºC after 30 min</td>
<td></td>
<td></td>
<td>≥ 850 ºC or ≥ 1,100 ºC</td>
</tr>
</tbody>
</table>

(b) Test 1 as reported in: "Tests of The Enlarged De Montfort Incinerator (Mark 3)," in www.appsci.dmu.ac.uk/mwi/low/7.htm
(c) Test 2 as reported in: "Tests of The Enlarged De Montfort Incinerator (Mark 3)," in www.appsci.dmu.ac.uk/mwi/low/7.htm
(d) "Laboratory Assessment of the De Montfort Small-Scale Medical Waste Incinerator for Rural Applications," report prepared by CSIR for De Montfort University and the South African Collaborative Centre for Cold Chain Management, December 15, 1999 [excepts of the report provided by D.J. Picken].
2.5.1.3 Combustion Efficiency

Combustion efficiency is another indicator of complete combustion or conversely, the level of organic emissions coming out of the incinerator. Organic emissions refer to unburned organic compounds that are a result of incomplete combustion and include many toxic pollutants. Combustion efficiency is computed using the measured values of carbon dioxide and carbon monoxide. As noted in one study, the De Montfort’s combustion efficiency did not comply with South African standards and the organic emissions were higher by a factor of at least 20. These results were based on tests conducted at conditions below the recommended temperatures. When air intakes were blocked, which apparently occurred frequently, the organic emissions were 400 times higher than the limits under South African standards.

<table>
<thead>
<tr>
<th>TABLE 2-4 RESIDENCE TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPERATING PARAMETER</td>
</tr>
<tr>
<td>Residence Time</td>
</tr>
</tbody>
</table>

(a) Residence time in the primary and secondary chambers and stack is estimated at a maximum of 1 second in “Laboratory Assessment of the De Montfort Small-Scale Medical Waste Incinerator for Rural Applications,” report prepared by CSIR for De Montfort University and the South African Collaborative Centre for Cold Chain Management, December 15, 1999 [extracts of the report provided by D.J. Picken]; secondary chamber volume is estimated at 13% of the total internal volume based on construction notes for the Mark 1 De Montfort incinerator (“Low-Cost Medical Waste Incinerator: Manufacturing, Operation and Maintenance Instructions,” Information Services, The Schumacher Centre for Technology and Development, Warwickshire, UK, June 13, 2002).

<table>
<thead>
<tr>
<th>TABLE 2-5 COMBUSTION EFFICIENCY</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPERATING PARAMETER</td>
</tr>
<tr>
<td>Combustion Efficiency</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

(b) During first batch load of first test reported in: “Laboratory Assessment of the De Montfort Small-Scale Medical Waste Incinerator for Rural Applications,” report prepared by CSIR for De Montfort University and the South African Collaborative Centre for Cold Chain Management, December 15, 1999 [extracts of the report provided by D.J. Picken].
(c) Hot incinerator conditions and when air intakes are not blocked, as reported in: “Laboratory Assessment of the De Montfort Small-Scale Medical Waste Incinerator for Rural Applications,” loc. cit.
(d) Combustion efficiency when air intakes are blocked, as reported in: “Laboratory Assessment of the De Montfort Small-Scale Medical Waste Incinerator for Rural Applications,” loc. cit.
2.5.1.4 Air Pollutant Emissions

Table 2-6 tabulates the results of stack emission tests and compares them with different regulatory standards. Fine particles arise from an incinerator due to incomplete combustion, the suspension of non-combustible materials, and condensation of vapors. Hence, particulate matter includes char (unburned particles), fly ash, condensed metals, soot, and other toxic substances. Table 2-6 shows that the De Montfort incinerator does not meet Indian standards for particulate matter and most likely would not meet more stringent standards for total dust or particulate matter in Europe or the United States.

Opacity is a measure of the density of smoke from an incinerator and gives an indication of the effectiveness of the incineration process. Many regulations limit opacity to no more than 20%. U.S. environmental regulations limit opacity to 10%. Measurements of the De Montfort incinerator indicate opacities as high as 45%. Measurements also show a high percentage (68%) of soot in the particulate emissions. The report attributed this to the low combustion efficiencies especially during blockage of air inlets by the waste during burning.

Because of incomplete information, it was not possible to draw conclusions about other pollutants. For example, several reports gave carbon monoxide concentrations but since it was not clear whether standardized corrections were made, it was difficult to compare them with regulatory limits (see Table 2-6).

Tests for metal emission were also reported. Chromium emissions, for example, exceeded the European standards. Higher chromium emissions would be expected depending on the amount of needles in the waste. Stainless steel used in needles contains chromium as well as varying amounts of manganese and possibly nickel, molybdenum, niobium, and other heavy metals depending on the type used. However, the detection limits for almost all other metals measured were too high to determine whether or not the metal emissions complied with South African or the more stringent European and U.S. standards. For example, the tests could not provide an accurate measurement below the detection limit of 1.2 mg/Nm$^3$ for cadmium. So all one could conclude was that the emission level was somewhere below that value. But since the South African regulatory limit for cadmium is 0.05 mg/Nm$^3$, one cannot determine whether the limit was exceeded or not.

Comments were made in the report that metals such as arsenic, lead, and cadmium were not expected in the waste. However, in addition to discarded metal objects, metals can be present as fillers and additives in plastics and rubber material, as ingredients in inks and pigments used in paper and plastic, and as components of chemicals used in clinical laboratories. For example, significant concentrations of arsenic, lead, cadmium, and chromium are found in rubber material and syringes used in health care facilities; cadmium is found in rubber caps used with blood collection tubes; and lead is found in orange and red-colored plastic bags, latex and vinyl gloves, and sharps containers.

Tests were conducted for dioxins on a modified De Montfort incinerator. The test procedures for metals and dioxins, however, would likely not have been accepted in some countries. The European Union requires a ceiling of 0.1 ng/m$^3$ for dioxins and furans. The proponents concluded that “the flue gas was found to contain virtually no dioxins or furans.” This conclusion is misleading since the sampling time and the detection limits of the test method were not mentioned. Unfortunately, this misleading conclusion has been used by others to claim that the De Montfort incinerator does not produce dioxins or furans. And yet those same tests showed that the temperatures inside the secondary chamber and the residence time (which is critical in the destruction of organic compounds) do not meet the high temperatures and residence time requirements needed to minimize the formation of dioxins and furans.
## 2.5.1.5 Pollution Control Equipment

Because medical waste incinerators emit many pollutants harmful to public health and the environment, incinerators require air pollution control devices to reduce emission levels. The devices are added on to the incinerator before the stage where exhaust gas leaves the stack. Many types of pollution control equipment are used alone or in combination, including wet or dry scrubbers with or without a neutralizing alkali, fabric or baghouse filters, cyclone separators, electrostatic precipitators, and other devices of varying levels of efficiency. A common air pollution control device is the wet scrubber, of which many kinds are in use, such as venturi, packed-bed, spray tower, and impingement tray.

### Table 2-6 Selected Air Pollutant Levels

<table>
<thead>
<tr>
<th>Operating Parameter</th>
<th>De Montfort Data</th>
<th>Indian Standards</th>
<th>South African Standards</th>
<th>Other Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particulate Matter</td>
<td>141 mg/Nm³ (at 8% CO₂ correction)</td>
<td>100 mg/Nm³ (at 8% CO₂ correction)</td>
<td>180 mg/Nm³ (at 8% CO₂ correction)</td>
<td>10 mg/Nm³ (at 11% O₂ correction); 53 mg/Nm³ (at 11% O₂ correction)</td>
</tr>
<tr>
<td>Opacity</td>
<td>Est. 5 - 45 %</td>
<td>-</td>
<td>-</td>
<td>10%</td>
</tr>
<tr>
<td>Soot in Particulates</td>
<td>68 %</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Carbon Monoxide</td>
<td>5020, 4680, 5280 and 4130 ppm, less than 100 to over 400 ppm</td>
<td>-</td>
<td>-</td>
<td>40 ppm (at 7% O₂ correction and 68 ºF standard temperature)</td>
</tr>
<tr>
<td>Hydrogen Chloride</td>
<td>20 mg/Nm³ (at 8% CO₂ correction)</td>
<td>33 mg/Nm³ (at 8% CO₂ correction)</td>
<td>30 mg/Nm³ (at 8% CO₂ correction)</td>
<td>10 mg/Nm³ (at 11% O₂ correction); 17 mg/Nm³ (at 11% O₂ correction)</td>
</tr>
<tr>
<td>Dioxins &amp; Furans</td>
<td>No detection limits cited</td>
<td>-</td>
<td>-</td>
<td>0.1 mg/Nm³</td>
</tr>
<tr>
<td>Cadmium</td>
<td>&lt; 1.2 mg/Nm³ (at 8% CO₂ correction)</td>
<td>-</td>
<td>0.05 mg/Nm³ (at 8% CO₂ correction)</td>
<td>0.05 mg/Nm³ (at 11% O₂ correction)</td>
</tr>
<tr>
<td>Chromium</td>
<td>0.5 mg/Nm³ (at 8% CO₂ correction)</td>
<td>-</td>
<td>0.5 mg/Nm³ (at 8% CO₂ correction)</td>
<td>0.05 mg/Nm³ (at 11% O₂ correction)</td>
</tr>
<tr>
<td>Lead</td>
<td>&lt; 2.3 mg/Nm³ (at 8% CO₂ correction)</td>
<td>-</td>
<td>0.5 mg/Nm³ (at 8% CO₂ correction)</td>
<td>0.05 mg/Nm³ (at 11% O₂ correction)</td>
</tr>
</tbody>
</table>

(a) “Laboratory Assessment of the De Montfort Small-Scale Medical Waste Incinerator for Rural Applications,” report prepared by CSIR for De Montfort University and the South African Collaborative Centre for Cold Chain Management, December 15, 1999 [excerpts of the report provided by D.J. Picken].

(b) Estimated from Bosch Smoke Number 0.5 to 4.5 on a scale of 0 to 10 assuming a linear relation between density percent and Bosch number; Bosch Smoke Number from “Temperature, Flue Gas Analysis and Smoke tests of the Modified De Montfort Incinerator,” in www.appsci.dmu.ac.uk/mwi/low/7.htm, January 2001.


(h) Particulate matter based on 69 mg/dscm, CO based on 40 ppmv, and HCl based on 15 ppmv, all at 7% oxygen correction and 68 ºF standard temperature; Standards of Performance for New Stationary Sources and Emission Guidelines for Existing Sources: Hospital / Medical / Infectious Waste Incinerators, U.S. Environmental Protection Agency, September 1997. [40 Code of Federal Regulations (CFR) part 60, subpart Ce and subpart Ec; also published in Federal Register, volume 62, beginning on page 48347, September 15, 1997]
scrubbers. A rapid quench system is sometimes used to quickly reduce the temperature of the exhaust gas below the temperature range at which dioxins and furans are formed (between 250 to 450 °C). Many incinerators also have automatic ash removal systems with wet ash sumps to minimize the risks associated with hot ash. Since dry ash is easily spread through the air during removal of bottom ash, these systems also reduce the exposure of workers to airborne ash that usually contain heavy metals, dioxins, furans and other toxic organic compounds. Since the DeMontfort incinerator was intended to be a small, low-cost system, there are no air pollution control devices to limit pollutant emissions or exposure to bottom ash.

2.5.1.6 Stack Height
A typical incinerator has a tall stack or chimney so that pollutant gases are diluted and dispersed high in the atmosphere thereby reducing their concentrations at ground level. A tall stack also decreases the danger of toxic pollutants at high concentrations entering nearby homes, clinics, or buildings through windows, doors, or ventilation intakes. This does not reduce the overall pollution but it does reduce the impact on areas in the immediate vicinity of the incinerator. According to “good engineering practice” criteria, the ideal height of a medical waste incinerator stack should be 2.5 times higher than the height of nearby structures. The DeMontfort incinerator does not meet any of the stack height requirements under different standards (see Table 2-7).

<table>
<thead>
<tr>
<th>OPERATING PARAMETER</th>
<th>DE MONTFORT DATA</th>
<th>INDIAN STANDARDS</th>
<th>SOUTH AFRICAN STANDARDS</th>
<th>OTHER STANDARDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stack Height</td>
<td>4 - 5 m above ground a</td>
<td>30 m above ground</td>
<td>3 m above the nearest building</td>
<td>2.5 times higher than height of nearest structure</td>
</tr>
</tbody>
</table>

(a) Typical DeMontfort incinerator is about 1 meter high; stacks are between 3 - 4 meters high ("Low-Cost Medical Waste Incinerator: Manufacturing, Operation and Maintenance Instructions," Information Services, The Schumacher Centre for Technology and Development, Warwickshire, UK, June 13, 2002).

2.5.1.7 Additional Comments
The main proponent of the DeMontfort incinerator, Prof. D.J. Picken, states: “It is unlikely that a simple incinerator of this nature can be guaranteed to give pollution-free exhaust gas for all types of load.” He adds: “Further improvements are likely to entail electrical power for air blowing, and automatic exhaust sampling and feedback control for reduction of emissions. All these can be obtained by purchasing municipal waste incinerators or perhaps crematoria incinerators. The cost implications are horrifying!” Picken also notes that one cannot guarantee that the DeMontfort incinerator will give “clear exhausts” in all circumstances with all waste loads, including loads containing chlorinated plastics.

The DeMontfort incinerator has not been tested for the full range of pollutants using standardized test methods as required in many environmental regulations. Nevertheless, the data currently available on the operating performance and emissions of the DeMontfort incinerator show that it is not capable of meeting many environmental standards.
2.5.2 Results of Field Investigations

In order to examine the waste management and operational practices associated with the De Montfort incinerators, HCWH conducted its own field investigation. Eight De Montfort incinerators at Salvation Army Hospitals in India were located. All eight were visited and surveyed by local waste and incinerator specialists in September and October of 2002.

The three hospitals in Kerala and the one in Tamil Nadu were surveyed by Shibu K. Nair of Thanal Conservation Action and Information Network—a public interest research organization working on environmental education and toxics. The two hospitals in Andhra Pradesh were surveyed by Satyavir Chauhan, Rajkumar Singh, and B. Srinivas Reddy of Society of Jyotsna Chauhan (JSA). JSA is a grassroots-level NGO working on environmental health issues in order to safeguard the community from the impact of pollution by promoting safe, scientific management and disposal of biomedical waste between the various stakeholders. P. Madhavan of Srishti conducted the survey at the Punjab hospital. Srishti is an NGO working on bio-medical and municipal waste management, recycling, toxics and the international waste trade. Emery Hospital in Anand, Gujarat was visited by Michael Mazgaonkar of Paryavaran Suraksha Samiti (a grass-root NGO in Gujarat).

The survey questions were written by Dr. Glenn McRae and Dr. Jorge Emmanuel. All surveyors had the same set of questions and instructions. The information cited below was gathered through interviews, observation, and photo-documentation. Although the information is telling of the shortcomings of medical incinerators in general and of low-budget ones like the De Montfort, in particular, the sample size is small and may not necessarily be representative of all such incinerators.

The field investigations commissioned by HCWH revealed several common problems with the De Montfort incinerator:

- All incinerators show signs of poor maintenance; despite being relatively new (1 to 2 years old), the incinerators are all corroded and have problems with the chamber doors and/or ash doors
- All waste generated in all of the facilities is burned in the incinerator despite segregation practices or existing segregation policies in most of the hospitals
- Invariably the ash has large quantities of unburned material including plastics, syringes, glass (and even unburned paper and gauze in some cases)
- Ash is disposed of improperly in every case
- Smoke is visible from the incinerators
- In two cases, smoke comes out mainly through the chamber door and air inlets instead of the chimney
- In all cases, the incinerator is adjacent to or near populated areas such as a children’s playground, an orphanage, hospital staff quarters, a primary school, town center, etc.

The investigation also revealed that hospital personnel are unaware or misinformed about many aspects of medical waste management. For example, some believe it is safe to burn mercury and any plastics (including PVC) in the incinerator. Others mistakenly believe that it is the law to burn all waste from the facility. Others have been told that the incinerators are smoke-less, that they do not require permits to operate, or that it is impossible to form dioxins in incinerators. None of those interviewed were aware of potential adverse health effects of incinerator emissions.

Table 2-8 presents details of the major findings of the field investigations in India.
<table>
<thead>
<tr>
<th>FACILITY</th>
<th>SALVATION ARMY MEDICAL CENTER</th>
<th>KULATHUMMEL SALVATION ARMY HOSPITAL</th>
<th>THE SALVATION ARMY EVANGELINE BOOTH LEPROSY AND GENERAL HOSPITAL</th>
<th>MAC ROBERT HOSPITAL</th>
<th>EVANGELINE BOOTH HOSPITAL (LEPROSY)</th>
<th>EVANGELINE BOOTH HOSPITAL (AMERICAN)</th>
<th>CATHERINE BOOTH HOSPITAL</th>
<th>EMERY HOSPITAL, THE SALVATION ARMY</th>
</tr>
</thead>
<tbody>
<tr>
<td>District, State</td>
<td>Kottayam, Kerala</td>
<td>Thinuva Nanthapuram, Kerala</td>
<td>Emokulam, Kerala</td>
<td>Gurdaspur, Punjab</td>
<td>Guntur, Andhra Pradesh</td>
<td>Guntur, Andhra Pradesh</td>
<td>Kanyakumari, Tamil Nadu</td>
<td>Anand, Gujarat</td>
</tr>
<tr>
<td>Age of incinerator</td>
<td>1 year</td>
<td>1 year</td>
<td>1 year</td>
<td>2 years</td>
<td>1 year</td>
<td>1 year</td>
<td>2 years</td>
<td>Very shabbily made</td>
</tr>
<tr>
<td>Condition of the incinerator</td>
<td>Ash door is broken (stick used to hold it in place); feed door is in bad condition and full of soot (large rock is used to keep it in place); all iron parts are rusted; wire mesh inside the chamber juts out keeping door from closing completely</td>
<td>Ash door has fallen apart; air inlets are clogged with ash; wire mesh inside the chamber has separated from the walls of the chamber</td>
<td>All metal parts are rusty; operator has to use two sticks to open and close the chamber door</td>
<td>Incinerator has a roof made of asbestos sheets; iron cover door is rusted</td>
<td>The incinerator is fired openly by putting kerosene into the chamber</td>
<td>The incinerator is fired openly by putting kerosene into the chamber</td>
<td>Stock height is 10 meters. The incinerator needs alterations to its design to hold the stack directly above the second chamber. The wire mesh is almost gone. Roof with tin sheets</td>
<td>Very shabbily made, still incomplete though in use. Many leaks visible (smoke leaking out) while in use. Housekeeping is very bad, waste etc. lying around, chimney is only 60 ft high.</td>
</tr>
<tr>
<td>Waste burned in the incinerator</td>
<td>All hospital waste are burned including plastics, glass, IV tubes and syringes as well as tissue and fluids from lab waste</td>
<td>Everything discarded in the hospital is burned including PVC plastics (IV sets) and mercury</td>
<td>All waste generated in the hospital is burned including PVC bags and mercury-containing apparatus and thermometers</td>
<td>All waste generated in the hospital is burned including paper, food waste, discarded medicines, needles, syringes, bandages and IV sets, tubings, blood bags and tea cups made of PVC</td>
<td>All waste generated in the hospital is being burned including PVC material (i.e. tubings, plastic cups, catheters), pharmaceuticals and drugs, needles, syringes, and chemicals</td>
<td>All waste generated in the hospital is being burned daily including 250-300 syringes and needles, 75-100 IV tubes and bottles, and cotton, gauze, infected fluids, plaster castings, food scrap and garden sweepings</td>
<td>75 kilograms of waste generated and burned daily including 250-300 syringes and needles, 75-100 IV tubes and bottles, and cotton, gauze, infected fluids, plaster castings, food scrap and garden sweepings</td>
<td>All hospital waste, including plastics, glass, sharps, IV bottles and tubes, syringes etc. Occasionally mercury</td>
</tr>
<tr>
<td>FACILITY</td>
<td>SALVATION ARMY MEDICAL CENTER</td>
<td>KULATHUMMEL SALVATION ARMY HOSPITAL</td>
<td>THE SALVATION ARMY EVANGELINE BOOTH LEPROSY AND GENERAL HOSPITALS</td>
<td>MAC ROBERT HOSPITAL</td>
<td>EVANGELINE BOOTH HOSPITAL (LEPROSY HOSPITAL)</td>
<td>EVANGELINE BOOTH HOSPITAL (AMERICAN HOSPITAL)</td>
<td>CATHERINE BOOTH HOSPITAL</td>
<td>EMERY HOSPITAL, THE SALVATION ARMY</td>
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</tr>
<tr>
<td>Segregation</td>
<td>Wet waste and dry non-infectious waste are segregated yet all are burned in the incinerator</td>
<td>Wet items, sharps, and plastic bottles are segregated but all are burned in the incinerator</td>
<td>No segregation</td>
<td>Existing segregation policy is not followed and all waste is mixed and burned in the incinerator</td>
<td>No segregation</td>
<td>No segregation</td>
<td>No segregation</td>
<td>Waste is segregated into sharps, infectious waste &amp; cotton, and plastic tubes &amp; containers. However, once moved to the storage area, all waste is mixed</td>
</tr>
<tr>
<td>Storage</td>
<td>Incinerator is used for waste storage until full</td>
<td>Mixed waste bags stored in small room, but incinerator is also used as storage</td>
<td>None</td>
<td>Waste is stored in small racks in incinerator area</td>
<td>None</td>
<td>None</td>
<td>A concrete tank 8’x4’x4’ with 3 divisions near the incinerator, but the waste is mixed</td>
<td>Storage space provided next to incinerator, three bins made of bricks and mortar</td>
</tr>
<tr>
<td>Condition of the ash</td>
<td>Full of unburned gauze, paper, plastic, IV tube parts, syringes, and glass</td>
<td>Half burned cotton, plastic tubes, needles, syringes, and glass</td>
<td>Contains pieces of glass slides, test tubes, medicine containers, paper, cotton and gauze</td>
<td>Contains bottles, glass plates, unburned needles, and unburned plastic</td>
<td>Contains a lot of unburned material including syringes, metal, plastic, and glass material</td>
<td>Contains unburned material including syringes, metal, plastic, and glass</td>
<td>Contains glass bottles, parts of IV tubes, plastic covers, containers, glass test tubes, syringes, and half burnt needles, papers, and cotton</td>
<td>Storage space provides no gazee or such visible, but lots of broken bottles, unburned plastic and packaging material. Some metal is visible</td>
</tr>
<tr>
<td>Ash disposal</td>
<td>Ash and unburned residues are dumped in an unprotected 6-ft deep pit that is 5 meters from the incinerator</td>
<td>Heaps of ash with unburned plastic and glass are dumped at the bottom of coconut trees in the hospital ground</td>
<td>Ash is dumped in nearby bushes and carried away by runoff</td>
<td>Ash is disposed in a nearby plantation</td>
<td>Ash is removed by bare hand and collected in a vessel. Then, it is put into a non-sanitary landfill</td>
<td>Ash is removed by bare hand and collected in a vessel. Then, it is put into a non-sanitary landfill</td>
<td>Ash is used like manure for coconut trees and plantains</td>
<td>No one knows what to do with the ash. So earlier they had a open pit in which they dumped the ash, now it is stored in the open next to the incinerator where it can be blown by wind and may be played with by children</td>
</tr>
<tr>
<td>FACILITY</td>
<td>SALVATION ARMY MEDICAL CENTER</td>
<td>KULATHUMMEL SALVATION ARMY HOSPITAL</td>
<td>THE SALVATION ARMY EVANGELINE BOOTH LEPROSY AND GENERAL HOSPITALS</td>
<td>MAC ROBERT HOSPITAL</td>
<td>EVANGELINE BOOTH HOSPITAL (LEPROSY HOSPITAL)</td>
<td>EVANGELINE BOOTH HOSPITAL (AMERICAN HOSPITAL)</td>
<td>CATHERINE BOOTH THE SALVATION ARMY EVANGELINE BOOTH LEPROSY AND GENERAL HOSPITALS</td>
<td>EMERY HOSPITAL, THE SALVATION ARMY</td>
</tr>
<tr>
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</tr>
<tr>
<td></td>
<td>Two days training</td>
<td>Two days training</td>
<td>Some training</td>
<td>No formal training</td>
<td>No formal training</td>
<td>No training. Simply asked to put waste in incinerator and burn using kerosene</td>
<td>Could not get information on training; no formal policy on waste management</td>
<td>Two persons from the administrative staff received trainings and then later they trained the hospital staff who do real work of waste collection and incineration</td>
</tr>
<tr>
<td>OCCUPATIONAL AND SAFETY ISSUES</td>
<td>Open pit for dumping ash and partially burned waste has no fence and is near a pathway</td>
<td>Steps to climb up and feed waste is on windward side; operator complains that smoke gets in her face whenever she feeds waste; partially burned needles and IV tubes scattered around incinerator</td>
<td>No gloves or face protection for operator</td>
<td>Operator wears gloves and a motorcycle helmet to protect from heat and smoke when opening the chamber door</td>
<td>No gloves or face protection for operator. The waste is put into the incinerator and the ash is taken out of the incinerator by bare hands</td>
<td>No gloves or face protection for operator. The waste is put into the incinerator and the ash is taken out of the incinerator by bare hands</td>
<td>Scavengers who collect and transport the waste to the incinerators wear no protective gear, gloves, or masks</td>
<td>The incinerator operator admitted that he occasionally had injuries from handling waste. Since the incinerator leaks smoke, walking around it is very hazardous which the operator has to regularly do. The incinerator is located near continuously populated area</td>
</tr>
<tr>
<td>VISIBLE EMISSIONS</td>
<td>Smoke comes out of the chamber door; white smoke comes out of the stack</td>
<td>Visible smoke</td>
<td>Visible, white smoke from stack</td>
<td>Smoke mainly comes out of the door and air inlets of the incinerator; strong smell of burning waste in the area</td>
<td>--</td>
<td>--</td>
<td>Visible, white smoke from stack</td>
<td>Smoke comes from the sides and bottom of the incinerator, also from the chimney</td>
</tr>
<tr>
<td>FACILITY</td>
<td>SALVATION ARMY MEDICAL CENTER</td>
<td>KULATHUMMEL SALVATION ARMY HOSPITAL</td>
<td>THE SALVATION ARMY EVANGELINE BOOTH LEPROSY AND GENERAL HOSPITALS</td>
<td>MAC ROBERT HOSPITAL</td>
<td>EVANGELINE BOOTH HOSPITAL (LEPROSY HOSPITAL)</td>
<td>EVANGELINE BOOTH HOSPITAL (AMERICAN HOSPITAL)</td>
<td>CATHERINE BOOTH HOSPITAL</td>
<td>EMERY HOSPITAL, THE SALVATION ARMY</td>
</tr>
<tr>
<td>----------------</td>
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<td>---------------------------------------------------------------</td>
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<td>--------------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>Runoff</td>
<td>During rains, runoff from incinerator washes down into nearby streams</td>
<td>Runoff joins municipal wastewater and flows to nearby natural drainage</td>
<td>Ash disposed in nearby bushes is carried away by runoff</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>Ash is left in the open, so during rains it would mingle with rainwater runoff and wash into pathways, and the ash would mix with the municipal drainage</td>
</tr>
<tr>
<td>Potential receptor populations</td>
<td>Incinerator is 2 m from children's playground, 10 m from orphanage, 75 m from hospital, and nearby houses</td>
<td>Incinerator is near the nurses quarters, 100 m from the hospital, 200 m from nearby house, 300 m from a crowded bus station, and about 500 m from a college</td>
<td>Incinerator is 100 m from staff quarters; 2 hospital buildings in the complex; around are vegetable, tapioca, cashew, and other crops, rubber plantations and paddies; 3 km from town</td>
<td>Incinerator is at the back of the hospital which is near to a railway station and a primary school; hospital complex includes staff quarters, nursing school, and a hostel</td>
<td>--</td>
<td>--</td>
<td>The incinerator is next to staff quarters and the school of nursing hostel (75 students). The scavengers rest in a small house next to the incinerator. 600 people reside at the hospital compound. The incinerator is in the center of a busy populated town with a number of commercial and agricultural operations, smoke reaches town</td>
<td>Surgical ward is within 15 ft of the incinerator, Out Patient Department is within 25 ft, a main street is 100 ft and residential areas are within 200 ft</td>
</tr>
<tr>
<td>FACILITY</td>
<td>SALVATION ARMY MEDICAL CENTER</td>
<td>KULATHUMMEL SALVATION ARMY HOSPITAL</td>
<td>THE SALVATION ARMY EVANGELINE BOOTH LEPROSY AND GENERAL HOSPITALS</td>
<td>MAC ROBERT HOSPITAL</td>
<td>EVANGELINE BOOTH HOSPITAL (LEPROSY HOSPITAL)</td>
<td>EVANGELINE BOOTH HOSPITAL (AMERICAN HOSPITAL)</td>
<td>CATHERINE BOOTH HOSPITAL</td>
<td>EMERY HOSPITAL, THE SALVATION ARMY</td>
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<td>------------------------------------------</td>
<td>-----------------------------------------------</td>
<td>-----------------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>Comments</td>
<td>Hospital staff are interested in alternative disposal methods</td>
<td>Hospital staff believe it is safe to burn mercury; they are interested in safe waste management</td>
<td>Nurses were told during a training program that burning plastics was safe (one began burning plastics on her stove at home) and that dioxin formation was impossible in the incinerator</td>
<td>Doctor interviewed said the incinerator has been tested and proven to be a smokeless incinerator which requires no license to operate; he has not visited the incinerator since it started operation</td>
<td>Approximately one dozen thermometers and 1-2 blood pressure apparatus are replaced annually (implying this amount of material containing mercury is burned annually)</td>
<td>Approximately two dozen thermometers and 1-2 blood pressure apparatus are replaced annually (implying this amount of material containing mercury is burned annually)</td>
<td>State Pollution Control Board (SPCB) insists on all waste being incinerated. Stray dogs used to be killed and put into the incinerator. This design will be copied into several forms and sizes since SPCB insists on incineration. Language barrier prohibited complete data collection</td>
<td>Hospital staff admit that there is very little knowledge about what exactly is happening and what should be done, e.g. they were told that since all waste is burned, the ash is absolutely harmless. They said they are only trying to follow the government guidelines and what the government officials have asked them to do.</td>
</tr>
</tbody>
</table>
Photographs taken during the site visits reinforce the findings of the investigation. These photographs, along with a few photos obtained from the World Health Organization, are shown in Figure 2-1 through 2-4.

**FIGURES 2-1–2-4: PHOTOGRAPHS FROM FIELD INVESTIGATIONS AND WHO**

- **2-1** Children’s park next to the incinerator (Kulathummel Salvation Army Hospital)
- **2-2** Warped iron wire mesh in secondary chamber (Kulathummel Salvation Army Hospital)
- **2-3** Possible molten plastic and soot indicating smoke emissions seeping out of ash door (WHO presentation, Bradley Hersh)
- **2-4** Incinerator ash with partially burned material dumped at the bottom of a coconut tree (Kulathummel Salvation Army Hospital)

N.B. The photographs taken during field investigations or from WHO are used with permission.
The field investigations and photographs reinforce the findings from the analysis of existing data, namely, that these low-cost incinerators operate at low temperatures and low combustion efficiencies. These are indicated by the reports and photos of dense black and/or white smoke, unburned materials in the ash, smoke seeping out of various openings, and apparently molten plastic flowing out of ash doors. As explained earlier, such conditions signify the release of high levels of toxic pollutants that can potentially affect health workers and nearby communities.

The general concerns about incinerators described in section 2.3 are also reflected in the findings from the field investigations. The De Montforts’ poor performance was exacerbated by lack of resources and training to maintain and repair the incinerators. In many cases, they pose an occupational health and safety risk by exposing the operator to heat, smoke, ash particles, contaminated sharps, and partially burned needles scattered around the incinerator. Ash disposal remains a serious problem.

The presence of the incinerator undermines health care waste segregation and minimization practices. As the field investigation confirms, the incinerator becomes a convenient storage chamber for accumulating waste and an excuse for burning all waste in the facility, including PVC and mercury. Moreover, because these incinerators have been erroneously promoted as smoke-less incinerators that do not produce dioxin, some facilities assume that regulations do not apply, hence undermining enforcement of environmental laws.
3 Alternative Technologies

3.1 Treatment Technology Options

The objective of this section is to show that viable alternative technologies exist and that these alternatives merit greater consideration by international organizations, health care institutions, and government ministries. The choice for decision-makers is not limited to a low-cost incinerator or a prohibitively expensive high-tech solution. This section introduces various possible low-cost options to incineration, recognizing that no one technology can serve every need. While this section focuses on technology, it is also important to note that the problem of medical waste management requires much more than just a technological solution but a systematic approach that involves waste segregation, waste minimization, planning, training, etc. as described in the next chapter of this report.

From a technology standpoint, many cleaner alternatives now exist to safely treat and dispose of medical waste. The alternatives include standard autoclaves, advanced autoclaves, microwave units, dry heat systems, chemical disinfection technologies, electron beam sterilization, etc. This report, however, will focus on low-cost technologies with potential applications in rural areas. The selection of a technology requires careful evaluation, taking into account not only cost but also current and projected waste generation rates, waste composition, existing practices, ease of application, technical requirements (utilities, maintenance, siting, etc.), training needs, as well as environmental and occupational safety issues.

The alternative technologies presented in this section include: cement encasing, encapsulation with immobilizing agents, waste burial pit with concrete cover, small portable steam treatment units with traditional grinders, point-of-use sharps technologies, and collection/transport/treatment in a centralized treatment technology.

3.1.1 Cement Encasing

In areas where volume is not a primary concern, cement encasing or cement encapsulation is an option. This method is safe as long as workers are careful in handling and transporting the waste and standard safety procedures are followed when working with cement. Some planning is needed to determine the size of the trench based on the amount of waste to be disposed of for a specific period. A storage area to accumulate the waste for that period is also required. Waste that may decompose and emit odors should be disposed in other ways unless they are generated shortly before encapsulation.

The cement encasing method involves: (1) digging a trench large enough to hold the accumulated waste; (2) adding a cement mixture at the bottom of the trench and allowing it to harden; (3) carefully placing the waste inside the trench; (4) encasing the waste completely with the cement mixture; (5) after the cement has hardened, it should be covered on top with about 15 cm of soil. A typical recipe for the cement mixture is: 1 part cement : 1 part lime : 4 parts sand : one-third to one-half part water. Using lime, which has disinfectant properties, enables cement to retain water thereby allowing the cement mixture to flow easily and fill up voids and empty spaces in the waste.
In the case of immunization waste, the following table provides an estimate of the trench volume and cement needed for disposing of the sharps waste from pentavalent vaccine immunization (DTP-HepB-Hib) which requires three doses per child. Estimates are given for immunizing 100 to 10,000 children and take into account waste vials, a 10% wastage factor, and syringes used for buffer stock.

<table>
<thead>
<tr>
<th>Number of children targeted for vaccination</th>
<th>100</th>
<th>1,000</th>
<th>5,000</th>
<th>10,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of safety boxes</td>
<td>8</td>
<td>75</td>
<td>377</td>
<td>753</td>
</tr>
<tr>
<td>Volume of sharps waste (cubic meters)</td>
<td>0.04</td>
<td>0.042</td>
<td>2.12</td>
<td>4.25</td>
</tr>
<tr>
<td>Trench volume (cubic meters)</td>
<td>0.08</td>
<td>0.85</td>
<td>4.25</td>
<td>8.49</td>
</tr>
<tr>
<td>Amount of cement needed (kg)</td>
<td>10</td>
<td>96</td>
<td>478</td>
<td>955</td>
</tr>
<tr>
<td>Approximate cost of cement, lime, and sand (US $)</td>
<td>$5</td>
<td>$43</td>
<td>$215</td>
<td>$430</td>
</tr>
</tbody>
</table>

A modification of this method is the construction of underground concrete casings or bunkers for sharps waste. Depending on the space available and the amount of sharps waste to be generated, a trench of an appropriate size is dug up. A floor made of neat cement, reinforced concrete walls, and a removable cover are constructed. The cover should be locked except when sharps waste is being placed inside the casing. In some cases, the accumulation of waste may take months or years. This method is ideal for disposing of sharps waste that has previously been disinfected. Once the casing is filled, the cover is replaced with a permanent concrete seal.

3.1.2 Encapsulation With Immobilizing Materials

Another method involves placing the sharps waste in hard containers such as metal drums (up to three-quarters full) and adding an immobilizing material such as bituminous sand, clay, or cement mortar. The container or drum is then sealed and buried in a trench or transported to the local landfill.
3.1.3 Waste Burial Pit With Concrete Cover

Small clinics or rural sites that generate small volumes of waste may use on-site waste burial pits in areas where the water table is not near the surface. The pit should have proper drainage and not be located in an area that floods. It should also be downhill or down-gradient from any nearby wells and about 50 meters away from any water sources such as rivers. The method involves: (1) digging a pit 1 to 2 meters wide and 2 to 5 meters deep; (2) lining the bottom of the pit with clay or a low-permeable material such as a geomembrane liner if available; (3) constructing an earth mound around the mouth of the hole to prevent surface water from entering the pit; (4) constructing a fence or barrier around the area to keep animals, scavengers, and children out; (5) periodically placing batches of waste inside the pit and covering each batch with a 10-cm layer of soil, or as an alternative, a mixture of lime and soil can be used as a covering layer; and (6) when the pit is about 50 cm of the ground surface, covering the waste with soil and permanently sealing it with cement.

Figure 3-2a shows the basic design for general medical waste including organic waste such as soiled bandages, bloody gauze, small tissues, etc. The bottom of the trench should be about 1.5 meters above the water table. Information on the depth of the water table in the area may be available from the water authority. The main purpose of the concrete or cement cover is to prevent scavenging. The clay layer helps prevent contamination of the groundwater. Adding lime provides a level of disinfection and discourages scavenging by animals while the pit remains open. The burial pit should only be used for infectious waste and not regular garbage to keep it from filling up quickly. While the preferred method of sealing is to use cement, another alternative is to embed a sheet of wire mesh within a final 50-cm layer of soil cover.

A variation of this method is shown in Figure 3-2b. If a geomembrane, such as a 30 mil thick (0.76 mm) high density polyethylene liner, is used, the soil underneath the liner should be smooth to prevent punctures. Between the liner and waste should be a 25 cm layer of soil stripped of rocks, sticks, and sharp materials. Alternatively, a cement floor can be used instead of a clay layer or geomembrane liner. In the case of immunization waste, the burial pit could be constructed after enough safety boxes have been accumulated thereby eliminating the problem of having to restrict access to an open pit. A 1 meter x 1 meter x 2 meter deep pit can accommodate approximately 200 5-liter safety boxes or about 20,000 used needles and syringes. (Note: This estimate needs to be confirmed in the field.)
Yet another modification of this concept may apply in rural areas where safety boxes or standard sharps containers are not available. Sharps can be collected safely in hard plastic bleach containers where the sharps waste can be left soaking in a 0.5% chlorine bleach disinfectant solution. Accumulated containers can then be placed in a waste burial pit of the appropriate size and covered with soil, concrete, and a top-soil cover.

3.1.4 Portable Steam Treatment Unit and Traditional Grinder
Autoclaves are standard equipment in hospitals and have been used for many years by health care providers to sterilize reusable medical instruments and glassware. In the last few decades, they have also been used to treat medical waste. An autoclave consists of a metal chamber sealed by a charging door and surrounded by a steam jacket. Steam is introduced into both the outside jacket and the inside chamber where waste is exposed to high temperatures for a specific period of time. A simpler version called a retort, shown in Figure 3-2C, does not have an outer jacket. Autoclaves range in size from small portable units to vast chambers capable of treating several tons of medical waste per hour. Used or reconditioned autoclaves can be purchased at much lower cost for use with medical waste.

In clinics and rural health centers where electricity may be available for a few hours of the day, it could be possible to transport a small portable autoclave to treat sharps waste. Since autoclaves are available in a wide range of capacities, the required size of the autoclave unit can be calculated based on the size of the safety boxes. For example, a cylindrical chamber autoclave with a minimum diameter of 22 cm (8.5 inches) and a minimum depth of 28 cm (11 inches) can fit one 5-liter safety box. Assuming a typical minimum treatment process of 121°C for 30 minutes, it would be possible to treat 300 syringes a day (3 safety boxes) during a two-hour period with the above-mentioned autoclave capacity. It may be necessary to use autoclavable liners to prevent waste from sticking to the inner walls or metal trays to facilitate removal of the treated waste. Alternatively, for small waste loads, the sharps waste could be collected in a metal container with an opening to allow the penetration of steam thus eliminating the cost of safety boxes.

One advantage of autoclaves is that the equipment is simple enough to be manufactured locally in developing countries with a light industrial manufacturing sector. It may also be possible to build gas-fired or kerosene-fueled autoclaves for areas that do not have electricity. Whether using gas, kerosene, electricity, locally available steam, or other energy sources, autoclaves should be tested under representative conditions to ensure microbial inactivation. For this purpose, commercially available biological monitors such as *B. stearothermophilus* spore strips can be used to verify that the steam penetration, temperature, and exposure time are sufficient to achieve high levels of disinfection. The biological indicator can be placed in the middle of the waste load as the container fills up, and after treatment, it can be carefully retrieved and tested. Once the exposure time-temperature conditions are validated, those same conditions have to be used in the field. Autoclaves should be tested periodically (e.g., on a monthly basis) as part of an inspection and maintenance schedule.
A possible alternative to explore is the use of commercial microwave units such as those sold for residential applications. Due to their high production volumes, microwave ovens would be cheaper than autoclaves. The microwave units should be large enough to fit one or more safety boxes. Enclosing the needles in safety boxes or microwavable glass containers could minimize the formation of sparks and pitting in the microwave chamber walls. Each load must include enough water to generate steam. As with autoclaves, the exposure time needed to achieve high level disinfection could be determined using biological indicators.

Traditional methods could be explored and modified for use as supplementary technologies for crushing or grinding needles and syringes after autoclave or microwave treatment. Many rural agricultural communities have traditional small-scale mills and grinders to process crops such as in the removal of husks or for pounding grain. Examples of these simple technologies are foot-operated mills, water mills, hand-operated stone grinders, or rotary grinding mills driven by horse or ox. It may be possible to crush or grind large quantities of disinfected needles and syringes using these simple devices but modifying them to ensure safety of the operator. In Mexico, bicycle power has been used in poor rural communities to run dental drills. A bicycle-run grinder could be used to destroy treated needles and syringes. Combining a portable autoclave with these simple supplementary technologies removes both the biological and physical hazards and prevents reuse. The residues from the physical destruction process could then be disposed of in burial pits or landfills.

3.1.5 Point-of-Use Needle Destruction Technologies

There are basically four types of point-of-use needle destruction technologies commercially available: mechanical needle cutters, motorized cutters, electrical spark devices, and encapsulating systems. Some of these technologies may be useful in particular situations and are presented here as possible options to complement other treatment approaches. However, these technologies are relatively new and need further evaluation.

**Mechanical needle-cutters** use a manual system to cut off needles or needle tips from syringes. One system has a handle to shears the nib from the syringe and cuts the needles into several pieces. The needle is rendered unusable and no metal piece remains at the tip. Another mechanical system is the needle clipper, a small countertop unit that uses a shearing action to clip off the needle. These small devices are cheaper but they entail some risk of needle-stick injury to the worker. Some hospital workers have found that the blade in these small units tends to get dull after several weeks or months of use. The needle parts can be soaked in a chemical disinfectant before burial. No electricity is needed for these devices.

**Motorized cutters** are similar to the mechanical cutters or clippers but they use a high-speed motor to cut off and chop up the needle portions. Because these are motor-driven, they are able to handle a wider range of needle sizes. An electrical source is needed for operation. The possibility of releasing pathogenic aerosols during the cutting process should be evaluated. As with mechanical systems, the needle portions can be disinfected and/or encapsulated prior to burial.

**Electric spark systems** typically use internal electrodes which produce an electrical spark to melt and burn off the ends of the needle for a few seconds at very high temperatures. They range from battery-run portable devices to plug-in desktop units. Most are automated for one-hand quick operation to prevent needle-stick injuries and minimize the time it would take away from the health care worker. Some systems have limitations on the size (gauge) of needles that can be handled. Some of these technologies burn off only the sharp point while others melt off most or all of the metal. The ones that only melt down the sharp tip may leave enough metal to still cause some injury. Depending on how they are designed, they cannot be used in work areas where flammable vapors are present. The residue could be in the form of pellets, granules, or powdery swarf containing metal oxides which are disposed of with regular garbage. The units contain residue pots to hold the remnants of a few dozen to a few hundred needles. The emission of combustion by-products should be further evaluated.


**Encapsulation systems** have one thing in common, namely, they result in sharps waste encased in a hardened material. Some use a solidification compound containing bleach as a disinfectant. When water is added and the solution is poured into a sharps container, the temperature rises and the contents harden into a cement mass which can later be disposed of as regular garbage. Other systems use a sharps container with a water-based solution. Once it is filled with sharps, a catalyst powder is added and the contents heat up and harden. One system combines motorized needle cutting and a hardening agent to encapsulate the chopped-up needle remnants. Another uses disposable plastic disks which are added to the sharps waste and heated to 190°C for several hours causing the plastics to melt. After the waste cools, a solid plug or disk is formed which can be disposed as regular garbage. There may be some needle points that may occasionally stick out of the solid plug and the disposable disk system adds plastic to the waste stream.

3.1.6 Centralized Treatment Technology

Rural communities can be served with a regional or district-level central facility utilizing cleaner alternatives. A system of sharps collection, transport and centralized treatment can serve both urban and rural needs. In the case of an immunization campaign, the transport system could be arranged in conjunction with the delivery of vaccine supplies and safety boxes. The safety boxes or sharps containers are brought back to a centralized facility that uses an autoclave or microwave system for treatment.

With sharps, the treated waste should also pass through a shredder or grinder to remove the physical hazard and prevent reuse. Commercial shredders are designed with hardened steel cutting knives, hooks, disks, or blades mounted on rotating shafts. These knives cut against stationary knives or against other knives mounted on one or more counter-rotating shafts. Shredders generally operate at low speed and high rotation force. A hammermill has a rotating shaft with swinging T-shaped steel hammers. As the hammermill rotates at high speed, waste is crushed by the hammers pounding against a steel plate. Commercial crushers or grinders can also be used; they have a series of rollers that operate at high speed. When the rollers are equipped with teeth or knives, they operate much like shredders.

In areas where these technologies are not available, the centralized facility could use a combination of treatment with a disinfectant and cement encasing or encapsulation. The treatment center could be located in an urban or peri-urban area or a provincial center to service health care facilities in the province, district, or region including surrounding rural areas. The capacity of the treatment technology or treatment method should be based on the amount of medical waste generated in the service territory.

Some facilities in industrialized countries have combined this approach with reusable sharps containers thereby minimizing cost and environmental impact in the long term. In one commercial operation, for example, reusable sharps containers are collected and replaced with clean ones. The sharps waste is then brought to a centralized plant where the waste is treated using a combination of steam sterilization and hammermill grinding. They offer different sizes and configurations of reusable sharps containers to adapt to the specific needs of the 260 hospitals and thousands of doctors’ offices they serve. Another commercial operation provides an integrated recycling and waste management service to a wide range of health care facilities. Their reusable sharps container has a horizontal opening for sharps, tamper-proof side locks, overfill protection, leakproof seals to prevent leakage during transport, thick puncture-resistant walls, and a design to allow the containers to be stacked for storage or transport without additional packaging. The containers are collected and transported to facilities that have automatic loading, dumping, and washing of the sharps containers. The sharps waste is then treated in autoclave-based or disinfectant-based technologies followed by grinding.

With such a system in place, the centralized technology could be used to treat not just immunization waste but also other infectious waste streams from hospitals, clinics, doctors’ offices, and other health care institutions in the area. Use of non-incineration technologies in centralized treatment facility is increasingly gaining acceptance in many parts of the world. In highly industrialized countries, the centralized facility may include computerized waste tracking, automatic conveyor systems, and a high-tech treatment technology such as an advanced autoclave (an electronically controlled autoclave that integrates high vacuum, internal shredding and mixing, drying and cooling, monitoring, waste com-
paction, or other features to the standard autoclave), large-scale microwave or chemical disinfection units, electron beam treatment, and other more expensive and complex systems.

As noted earlier, high-tech non-incineration alternatives are too expensive for many developing countries and rural settings. Instead, a simple autoclave can be used for centralized treatment. The autoclave has been used successfully for decades, they are simple enough to be manufactured locally, they can be built in many sizes to fit specific needs, they are easy to operate, and health providers are familiar with the technology. Autoclaving combined with post-treatment shredding or grinding removes both physical and biological hazards and eliminates the problem of reuse with minimal environmental impact.

Obviously, some developing countries or rural areas in those countries will not be able to put in place a system of collection, transport, and centralized treatment in the near future. The choice, however, is not between a low-cost incinerator or a high-tech centralized facility. A range of options or combination of options is available and each country or district should consider and evaluate the best mix of options to suit different conditions with the goal of protecting the patient, health care workers, the community and their environment.

### 3.2 Material Requirements and Selection Guidelines

The following are material requirements for each technology option.

- **Cement Encasing [CE]**: cement, sand, lime, water, shovel, pick, wheelbarrow
- **Encapsulation With Immobilizing Material [EI]**: drums or hard plastic containers, covers for the containers, immobilizing material (such as cement, sand, gravel, lime, water), shovel or trowel, vehicle to transport encapsulated waste
- **Waste Burial Pit [BP]**: cement, sand, lime, water, clay or geomembrane liner, shovel, pick, wire mesh, fence (posts, wire mesh or wooden fence, gate, lock)
- **Portable Steam Treatment Units [PU]**: autoclave or microwave equipment, metal tray or autoclavable liner (for the autoclave) or microwavable container (for the microwave), water, source of energy (electricity or fuel)
- **Point-of-Use Needle Destruction Technologies [ND]**: equipment; electricity, batteries, collection container for residues, chemical disinfectants, and/or solidifying agents, depending of the device
- **Point-of-Use Needle Destruction Technologies – mechanical systems [ND/m]**: equipment, collection container for remnants
- **Centralized Treatment [CT]**: autoclave or microwave, utilities, transport carts, facility and other infrastructure
- **Shredder [S]**: equipment, electricity, cart for shredded waste, facility and other infrastructure (Note: shredders supplement the treatment technologies)
- **Traditional Grinder [TG]**: equipment, may require human or animal power to operate, collection cart or container for ground up waste

Figure 3-3a shows a draft decision tree or general guidelines for technology options to be considered under diverse conditions. The purpose of the decision tree is to show the wide range of possibilities available to meet different needs. The decision tree is presented for illustrative purposes and does not include all possible scenarios in the field. It also does not take into consideration the availability of human and financial resources which are discussed in the next section.

In the chart, a sanitary or engineered landfill refers to land disposal sites designed to safeguard the environment (liners to protect groundwater, leachate collection, monitoring, etc.), controlled access, and proper training and protection provided to waste recyclers or scavengers. It is assumed that sanitary or engineered landfill operators can effectively restrict access to specific cells or areas in the landfill. The decision tree refers to other “restricted sites” which are locations other than “on site” or a sanitary or engineered landfill. These may be local dumpsites, the premises of other nearby health facilities, or other available land in which access can be restricted and human and animal exposures prevented while medical waste is being encapsulated and buried. Disposal in “restricted sites” should be minimized as they are short-term measures when no other options are available.
* Decision-makers must estimate the amount of waste generated to determine if there is enough space for burial on site; given the volume, the bottom of the burial pit should be 1.5 meters above the water table.

Note: See legend under Figure 3-3b
FIGURE 3-3B OFF-SITE TREATMENT AND DISPOSAL OPTIONS DECISION TREE

Notes: BP and CE methods assume that the site can be secured and access restricted while the pit or trench is being built. “Transport to central site” assumes that a safe and secure method of transportation is available to bring the waste to a central treatment facility. That is, the waste should be transported in enclosed containers designed to prevent spillage or leaks during transport and separated from other material. The transporter should have contingency plans in the event of spills or accidents. Some countries may require identification markings or placards, waste tracking manifests, permits, vehicle inspections, etc.
3.3 Preliminary Cost Comparisons

Many low-income countries where small-scale incineration is being promoted face severe resource limitations. Preliminary cost comparisons for selected technologies based on order-of-magnitude cost approximations will be presented in this section. In-depth cost studies are needed to develop more accurate data that account for all capital and operating costs.

Table 3-2 shows preliminary estimates for the major capital and operating costs of treating 500 safety boxes containing 50,000 syringes using different methods.

<table>
<thead>
<tr>
<th>TABLE 3-2 PRELIMINARY COST ESTIMATES</th>
<th>Estimated Capital Costs</th>
<th>Estimated Recurrent Costs for disposal of 50,000 syringes (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated Recurrent Costs for disposal of 50,000 syringes (US$)</td>
<td>Tools*</td>
<td>60</td>
</tr>
<tr>
<td>Materials**</td>
<td>290</td>
<td></td>
</tr>
<tr>
<td>Labor (3 days)</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>Safety boxes</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td>Waste Burial Pit With Concrete Cover (two pits; 1 m x 1 m x 2.5 m deep each)</td>
<td>Tools*</td>
<td>60</td>
</tr>
<tr>
<td>Materials** plus fence</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Labor (3 days)</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>Safety boxes</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td>Portable Autoclaves</td>
<td>Two Autoclaves*** (operating simultaneously)</td>
<td>4,000 to 6,000</td>
</tr>
<tr>
<td>Biological Test Incubator</td>
<td>190</td>
<td></td>
</tr>
<tr>
<td>Electricity</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Biological indicators</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Labor (21 days)</td>
<td>865</td>
<td></td>
</tr>
<tr>
<td>Safety boxes</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td>Point-of-Use Mechanical Needle-Cutter</td>
<td>Equipment</td>
<td>300</td>
</tr>
<tr>
<td>Labor (35 days)</td>
<td>1,440</td>
<td></td>
</tr>
<tr>
<td>De Montfort Incinerator</td>
<td>Incinerator (12 kg/hr; 3.5 kg wood/kg waste)</td>
<td>2,000</td>
</tr>
<tr>
<td>Kerosene (2 liters per run)</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Solid fuel (875 kg wood)</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Labor (12 days)</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>Safety boxes</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td>Sicim Incinerator</td>
<td>Incinerator (40 kg/hr; 2/3rd load of dry waste)</td>
<td>3,250</td>
</tr>
<tr>
<td>Housing and Installation</td>
<td>3,000</td>
<td></td>
</tr>
<tr>
<td>Solid fuel (500 kg wood or paper)</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>Labor (3 days)</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>Safety boxes</td>
<td>250</td>
<td></td>
</tr>
</tbody>
</table>

* Shovel, pick, and wheelbarrow; ** Cement, lime, and sand; *** Two 9” dia x 15” deep autoclaves, 70 lbs unit weight; approximate costs of two new or two used autoclaves are shown
The table below provides preliminary capital cost estimates for servicing an area that generates 1600 kg of medical waste a day. The waste could be collected, transported, and treated in a continuously operating centralized facility with an autoclave and a shredder. For incinerators burning waste on site for 8 hours a day, one would need 74 De Montfort incinerators or 15 Sicim incinerators to treat the same amount of medical waste. The corresponding capital cost estimates are shown in Table 3-3, not including installation, collection, transportation, and other costs.

<table>
<thead>
<tr>
<th>Centralized Treatment Facility</th>
<th>Capital Cost Estimate (US $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>One (1) Autoclave</td>
<td>31,000</td>
</tr>
<tr>
<td>Shredder</td>
<td>23,000</td>
</tr>
<tr>
<td>De Montfort Incinerator</td>
<td></td>
</tr>
<tr>
<td>74 Incinerators</td>
<td>148,000</td>
</tr>
<tr>
<td>Sicim Incinerator</td>
<td></td>
</tr>
<tr>
<td>15 Incinerators including housing and installation</td>
<td>93,750</td>
</tr>
</tbody>
</table>

*Comparing a centralized autoclave with a capacity of 68 kg/hr, operating 24 hrs a day, to on-site incinerators operating for 8 hours a day.*

It must be emphasized that the above figures are rough estimates and are not intended as a costing guideline; more in-depth cost studies are needed. Nevertheless, the cost approximations indicate that some non-incineration technologies and approaches may be more cost-effective than low-cost incineration. At the very least, the estimates suggest that non-burn alternatives merit further consideration.

### 3.4 Case Studies: India

In this section, some existing uses of alternatives are presented. Although the examples are from urban settings, the technologies could be adapted for use in rural areas. These case studies are all found in India.

#### 3.4.1 Waste Encapsulation: Hyderabad/Scunderabad

Two centralized treatment facilities in the twin cities of Hyderabad/Scunderabad, India use waste encapsulation for sharps and other waste. GJ Multiclave receives approximately 80–90 kgs of sharps monthly. After being autoclaved and shredded, the waste is put in bunkers made of cement. Once they are full, the bunkers are coved with cement slab. The bunkers are then sent to the landfill. Approximately one bunker (4 ft x 2 ft x 1 ft) goes to the landfill every month. Some bunkers have been kept to be used as benches. In the past, GJ Multiclave encapsulated sharps into brick-size structures which were used for raising the height of the boundary wall of their facility.

Another company, Medicare Incin Pvt Ltd, also disposes of sharps in a similar way. About 30 kg of sharps waste are received in two months. Approximately one drum (2 ft diameter 3 x ft high) costing around 150 rupees is sent to the landfill every two months.
3.4.2 Waste Burial Pit: Lions Hospital, New Delhi
Lions Hospital in New Delhi, India, uses a basic unlined waste burial pit for the disposal of sharps (needles, blades, and lancets only). The pit was constructed 1½ years ago at a cost of Rs.500 (about US$10). The pit is a simple construction made up of brick and cement with dimensions of 3ft x 3ft x 3ft. The pit is covered by a concrete slab which has a pipe attached to it through which the sharps are poured into the pit. A lid covers this opening of the pipe. The pit is located at the corner of the hospital garden and inaccessible to general public and staff. On average, about 100 needles are used in the hospital per day. The sharps are mutilated at source by needle destroyers and disinfected by 1% bleach solution and stored in puncture resistant containers. The disinfected sharps are carried for final disposal from the points of generation to the pit every two or three days. The hospital expects to use the pit for two more years (as of September 2002). After the pit gets filled, it will be filled with cement and a new one will be constructed near it.

3.4.3 Cement Encasing: St. Stephen's Hospital, New Delhi
St. Stephen’s Hospital in New Delhi, India uses a concrete casing. The hospital generates 5 liters of sharps daily. The pit for the casing is 7 ft x 4 ft x 4 ft and is located in the hospital grounds at one corner behind the parking space. The floor of the casing is made of lean concrete and the sides are made of reinforced concrete making the structure leak-resistant and impermeable. The walls are 4 ½ inches thick and are painted black on the inside. The covering is a slab 3 to 4 mm thick and made of MS (mild steel) plate with lockable plan. The covering is painted annually. To both surfaces of the pit are 3 inch thick slabs of reinforced concrete. To one side of the opening and entrenched in the reinforced concrete slab is a 1-inch diameter vent pipe.

The sharps are treated in disinfectant before being dumped into the casing. The waste handler uses protective gear and transports the disinfected sharps using a trolley. Sharps are dumped into the casing every evening. As of September 2002, the casing was 6 months old and only one-tenth filled. The hospital expects the casing to be filled within three years. It was built at a cost of Rs 20,000 (about US$500).

3.5 Summary
Incinerators can have serious environmental and health impacts on workers, surrounding communities, and the environment. The small-scale De Montfort incinerator does not maintain high temperatures and high combustion efficiencies, has very short residence times, has no pollution control equipment, and as a consequence, does not meet international standards for incinerators. Hence, these incinerators would need special exemptions from environmental regulations thereby exacerbating the dumping of dirty technologies no longer used in developed countries. Moreover, they undercut environmental laws and international conventions to protect public health and the environment and hamper the deployment of cleaner alternatives.

Field investigations show that these incinerators are poorly maintained and are operated in substandard conditions, posing an environmental health and occupational safety hazard. Disposal of the ash remains a serious problem. Furthermore, the presence of the incinerator undermines waste segregation and minimization practices.

The proponents of the De Montfort and other low-cost incinerators argue that they are meeting a need in poor rural communities that would not be able to afford high-tech incinerators. This assumes that developing countries only have inexpensive low-tech incinerators or costly high-tech incinerators as options. The continued promotion of incinerators, however, undermines the development and deployment of cleaner technologies.
For rural areas in low-income countries, simple non-burn methods such as waste burial pits with concrete covers, cement encasing, and encapsulation with immobilizing agents are possible options. Even remote rural areas may be able to avail of these simple technologies that have less adverse impact on the communities' health and environment. Other possibilities include the use of small portable autoclaves with traditional grinders or point-of-use sharps destruction technologies. In time, it may also be possible to put in place a system of collection, transport, and treatment in a centralized facility using a clean alternative technology. Some of these alternative technologies, such as basic autoclaves, can be manufactured locally. A preliminary cost estimate indicates that some of these methods may be more cost-effective than even low-cost incinerators. Some are in use in urban settings and could be adapted to rural areas.

In the next section, a comprehensive approach to the management of health care waste is illustrated utilizing the structure and format of published WHO, UNICEF, and/or SIGN documents and augmented with additional selection criteria for cleaner alternative technologies with a focus on alternatives that are environmentally preferable.
Chapter 4

Approaches to Treatment and Disposal of Health Care Waste With a Focus on Wastes from Immunizations Campaigns and Activities

This chapter is based on Chapter 8 of the WHO guide, Safe Management of Wastes from Health Care Activities (Pruss, et al., 1999); and the UNICEF guide, Management of wastes from immunisation campaign activities: Practical guidelines for planners and managers. It also draws on the initial systems thinking advanced by the SIGN task group shared in their working draft document, "First, do no harm: Introducing auto-disable syringes and assuring injection safety in national immunization systems" (draft 2002).

In the last few years important contributions have been made to understanding the necessary roles that planning, training, and good management practices play in creating safe environments. The choice of technologies to treat waste is an extension of these planning and management practices. In the following sections we follow the format and utilize information developed by WHO, SIGN, and UNICEF in previously published documents to reinforce the value of this work, deleting the default reference to “incineration/burning” as the most accepted treatment technology. The logical approach of WHO offers a pathway to safer and more sustainable treatment options.

4.1 Introduction

Incineration and waste burning had formerly been the method of choice for most hazardous health care wastes. While it is still widely used, burning waste is rapidly being replaced and has experienced significant declines as a treatment choice in the United States and Europe, and in countries, such as the Philippines where it is banned. Recently developed alternative treatment methods are becoming increasingly popular and do not have many of the disadvantages of incineration, especially the environmental impact. No one technology is appropriate in all settings.

Rural clinics and temporary immunization campaigns often do not have basic infrastructure for power, water, maintenance, spare parts or staff training required of even simple technologies. It is evident that even basic incinerators cannot be maintained properly under these conditions (see 2.5.2). In these cases, more appropriate and basic methods are available to safely and securely dispose of the wastes so that they pose neither a physical nor biological threat to workers and the public (see 3.1). Otherwise, these wastes may be dangerous as chemical and biological hazards, in addition to the physical hazards posed by needles and other sharp objects.

The key learning from observation of waste management systems is that addressing the threat associated with hazardous health-care wastes is best approached as a human management and training issue, not as a technology issue.
Any system designed to adequately address those risks will need to employ a variety of approaches and technologies. No single technology is adequate to handle all types of wastes. Whether in the context of an urban setting with adequate infrastructure or a rural clinic, the key learning from observation of waste management systems is that addressing the threat associated with hazardous health care wastes is best approached as a human management and training issue, not as a technology issue. Systems that have been implemented employing a single technology to handle wastes (such as an incinerator or burner) most often do not adequately address the need for staff training, occupational safety in handling wastes and residues from the incinerator, need for maintenance, continuing costs of operations, as well as the environmental costs to the community.

The final choice of any treatment system should be made carefully, on the basis of various factors, many of which depend on local conditions:

- disinfection efficiency;
- health and environmental considerations;
- volume and mass reduction;
- occupational health and safety considerations;
- quantity of wastes for treatment and disposal/capacity of the system;
- types of waste for treatment and disposal;
- infrastructure requirements;
- locally available treatment options and technologies;
- options available for final disposal;
- training requirements for operation of the method;
- operation and maintenance considerations;
- available space;
- location and surroundings of the treatment site and disposal facility;
- investment and operating costs;
- public acceptability;
- regulatory requirements.

All waste treatment and final disposal options have deficiencies and trade-offs. As long as wastes are produced there will be threats to human health and environmental quality. The approaches with the best results in rendering the wastes safe for disposal have a higher price tag for purchase and operation. Simple approaches to disposal that prevent scavenging of materials may take more time and resources to employ. Effective methods for disinfection of potentially infectious wastes are not appropriate for chemical wastes that are also part of the health care waste stream. The advantages of volume reduction and material destruction offered by burning, to limit scavenging, comes at a high price in terms of toxic emissions, such as heavy metals like mercury and cadmium, or other toxics such as dioxins from the combustion of chlorine-containing plastics common in health care wastes. Ash residues from burning concentrated toxic materials adds to groundwater pollution from the eventual land disposal of the ash. Operation of incinerators or other combustion technology presents a wide array of occupational hazards that are often overlooked.

The following sections offer an approach to overall planning and management of health care wastes in immunization campaigns that will lead campaign organizers through a set of decision pathways to identify and establish the best overall system to implement and the most appropriate treatment technologies (as outlined in 3.1) to employ in their specific situation.
4.2 First Things First

All approaches to waste management, treatment and disposal have to be based on systems that aim to produce as little waste as possible and ensure that those wastes that are produced are in a form that represents the least hazard, occupationally and environmentally.

Particularly in immunization campaigns, a systematic and careful approach to waste management is greatly enhanced when it is coupled with the planning for the immunization program itself.

- The delivery of the vaccine supplies can be bundled with Auto-disable (AD) syringes, that are safer for use and disposal, along with safety containers for collection of used syringes and vaccine vials
- Training of immunization campaign staff can be expanded to include safe practices in collection and treatment of wastes
- Community health education undertaken as part of the immunization program can include information and education on the hazards associated with scavenging health care wastes, especially syringes and needles
- Responsibility for coordination and safe waste management and education can be centralized in the role of immunization safety officers

Prevention is, as always the most significant step that can be taken in addressing a problem. Eliminating unnecessary therapeutic injections is a key step. Unnecessary injections contribute to the global disease burden of infectious diseases. Studies conducted in Tanzania, Indonesia and India demonstrated that between 70-90% of injections were for therapeutic treatment for which injections are unnecessary such as the injection of vitamins. At least 50% of injections were unsafe in 14 of 19 countries studied by the WHO. Unsafe injections where the syringe, needle or both, have been reused without sterilization account for 20% of all hepatitis B infections (8-16 million per year), 2.3 – 4.7 million Hepatitis C infections (HCV) and approximately 80,000 – 160,000 infections annually in the world. (Kane, 1999, WHO).

Eliminating unnecessary injection is the highest priority to prevent injection–associated infection. When injections are medically indicated, they should be administered safely. This includes safe disposal.

4.2.1 Waste Management Begins With Product Selection and Purchasing

Whatever materials and supplies are brought to the hospital, clinic, or out into the field will become waste. Careful choice of materials procured for health care programs may lead to management of smaller amounts and less hazardous wastes. Adding in consideration of “what type of waste will be produced and how hazardous will it be” as a question in selection supplies may solve some of the problems associated with health care wastes before they become problems.

4.2.2 Segregation Is the Key to Safety

Only a small amount of waste from health care activities is hazardous. If such wastes are isolated when they are produced they will not contaminate larger quantities of general waste, and the smaller amounts will be easier to manage with greater safety, more options for treatment and disposal, and with less cost.

Identify wastes needing special handling that will be generated by the planned activities. Ensure that there is a clear segregation and waste collection system provided for wastes needing different handling (i.e., puncture resistant safety boxes for syringes and other sharps; leakproof containers for vaccine vials; bags for other types of waste).
4.2.3 Proper Containerization
To be safely handled, wastes need to be properly containerized. Rigid, puncture resistant, clearly marked containers with closable/lockable openings should be provided for syringes, needles and other sharps. (NOTE: The thin cardboard boxes provided through some past immunization programs are NOT safe, and do NOT meet safety standards). The best practice is to bundle appropriate safety containers with the number of syringes that will safely fit in them at the supply center.

Depending on associated activities in immunization clinics (other treatment or diagnosis), other wastes needing special handling may be generated. The safety boxes provided for sharps will not be adequate for these wastes, and appropriate containers should be planned and provided for. The type of container (e.g., box or bag) may have to be supplemented by a secure transport container if no local treatment and disposal option is available.

Containers should be clearly labeled (universal symbol for biohazard, etc.), and color-coded as per national (or if absent, international) standards. They should be clearly marked in the local language or with a symbol locally understood to denote “extreme hazard.”

4.2.4 Secure Transportation and Storage
Ensure controlled movement of hazardous wastes through the facility/immunization site, secure storage on site while awaiting pick-up or direct transport with immunization workers, and safe and secure transportation to treatment and final disposal. Establish a quality assurance system (appropriate to the scale of the activities) to ensure that waste handling and disposal requirements are met.

When containers are full (staff training should ensure that containers are never over-filled), they need to be secured and stored in a safe, limited access location that protects them from scavenging and vectors. Full containers awaiting transport, treatment and disposal should be accounted for so that the number filled during the program matches the number transported, treated and disposed of.

Adequate and safe transport should be planned for if there is not local treatment and disposal available.

4.2.5 Workers Are Always The Front-Line Of Defense To Ensure Safe Management
All systems break down. Checks and balances are necessary to ensure safe management of wastes. The most important checks and balances are provided through rigorous and complete training of staff in proper procedures and contingencies. In many cases, the workers involved directly in health care provision in immunization campaigns will be the same workers directed to manage the wastes. In other cases there will be additional workers involved.

All workers need to participate in trainings dedicated to safe waste management.

All workers need to have basic immunizations to protect them, especially tetanus and hepatitis B vaccines.

In all too many cases local workers charged with collecting wastes or operating incinerators have not had adequate education or proper immunizations, as they were outside of the planning scope of an immunization or health program.

4.2.6 Appropriate Choices for Treatment and Disposal
Choices for treatment and disposal should be made to ensure the proper management of the wastes produced, and employed so that they will not, in turn, produce additional environmental or human health dangers. Section 3.1 details a range of such choices.
4.3 Strategy for Implementing a Waste Management Plan

The chronological steps outlined below present the key elements that must be implemented in the waste management plan of an immunization campaign, both at central level and in settings where campaigns are conducted (i.e. health care facilities and mobile settings). The suggested strategy can be summarized by:

- careful planning at the central and local levels
- clear assignment of responsibilities
- adequate briefing and training of staff
- daily monitoring so as to be able to take immediate corrective actions if necessary
- final evaluation and recommendations for future activities

4.4 Guidelines for Planners to Implement a Strategy at the Central Level

The following chronological checklist of actions provides guidelines to set up a waste management plan for an immunization campaign as well as to coordinate and evaluate it during and after the implementation phase.

STEP 1: Assess current situation and estimate needs (1 to 2 months)
- Estimate quantities of waste to be generated and treated during the vaccination campaign (see Table 4-1)
- Analyze current practices regarding segregation and handling of sharps in focal centers
- Review current status and location of health care waste treatment and disposal system(s)
- Analyze capacities of the current system to cope with additional quantities of waste generated by the campaign
- Evaluate additional material, financial and human resource needs

STEP 2: Define a strategy for waste management (1 to 3 months)
- Determine treatment and disposal options (off-site or on-site)
- Define waste transportation and central sites for waste treatment
- Outline strategy in a document including results of initial assessments, estimation of needs, plan of action, and timeframe
- Check national regulations addressing pollution control compliance for potential treatment facilities/methods. In the field, chemical treatment for disinfection combined with deep burial and/or encapsulation is a possible short-term solution for immunization campaigns. In coordinated systems, used sharps (in safety boxes) can be returned to central or provincial health facilities (return of waste can be combined with pick up of new supplies) for treatment by steam (autoclave), microwave, or chemical technology. If utilizing a technology (e.g. autoclave or chemical disinfection system) check manufacturer specifications and history of technology in similar situations
- Submit the document to local/national health authorities, involve health care facilities, and campaign partners for validation and support

STEP 3: Allocate resources and provide material (1 to 9 months)
- Allocate financial and human resources according to the strategy
- Supply safety boxes and leak-proof containers or bags for waste packaging
- Provide personal protective equipment for waste handling and treatment
- Build and/or rehabilitate infrastructures and supply equipment for waste treatment and disposal at focal centers
STEP 4 : Raise awareness and assign responsibilities (2 months)
- Establish key contacts with health authority representatives
- Designate responsibilities for the supervision of the health care waste management (HCWM) system
- Provide briefing to local authorities and managers of health care facilities
- Provide training for mobile team leaders if directly coordinated from central level

STEP 5 : Set up a monitoring system (2 months)
- Set up a central monitoring system to track sharps along the waste stream until final disposal
- Ensure a follow-up of stock positions for vaccines, syringes, and safety boxes
- Provide registration forms to health care facilities and mobile teams for self-monitoring

STEP 6 : Ensure supervision during the entire campaign
- Carry out regular missions to the field as part of routine monitoring of campaign performance
- Check daily waste management practices
- Verify registering procedures

STEP 7 : Carry out final evaluation (2 weeks)
- Implement final monitoring process
- Evaluate sustainability of the strategy used
- Write final evaluation report with recommendations for the next campaign

4.5 Guidelines for managers to improve practices at the Local Level

The following chronological checklist of actions provides recommendations for establishing a comprehensive and systematic waste management plan for a health care facility or a mobile team and to provide tools for its implementation.

STEP 1 : Estimate needs and design infrastructure (1 to 9 months)
- Estimate total quantities of wastes to be treated in the health care facility during the campaign (see Table 4-1)
- Calculate the total number of safety boxes and plastic bags required for segregation and packaging
- If Auto-disable syringes are NOT used, then consider supplying needle pullers and needle destroyer devices
- Design and secure storage area for wastes
- In health care facilities, design infrastructure for additional wastes treatment and disposal if current capacity is insufficient

STEP 2: Raise awareness and assign responsibilities (1 month)
- In health care facilities, set up a supervision board with the head nurse, pharmacist and administrator
- Assign responsibilities to medical staff/vaccinators and ancillary staff
- Appoint a waste management operator
- Give briefing and provide instructions to medical staff/vaccinator on daily routine procedures
- Outline duties and responsibilities of health care workers in job descriptions

STEP 3 : Develop a waste tracking system (1 month)
- Inventory of equipment provided
- Set up stock position forms for supplies
- Set up procedures for daily stock monitoring
STEP 4: Take protective measures for staff

- Check that waste operators wear protective clothes (thick gloves, boots, trousers or apron, long sleeve shirt)
- Check that safe practices for waste segregation are displayed in charts at waste segregation points
- Provide washing facilities for personal hygiene (minimum: soap and water for hand hygiene)
- Set-up a response system for accidental injuries
- Ensure that storage and waste treatment areas are restricted to authorized personnel

STEP 5: Set up daily routines

- Provide all vaccinators with adequate number of safety boxes and containers for the day (see Table 4-1)
- Ensure immediate disposal of used syringes without recapping needles
- Ensure adequate segregation and hermetic packaging of sharps and infectious wastes
- Ensure immediate replacement of used bags and containers when 3/4 full
- Ensure secure storage and disposal of full boxes according to procedures selected
- Check stock positions according to number of vaccines carried out

STEP 6: Implement final evaluation

Estimates for equipment requirements can be calculated using the example shown in Table 4-1 (this calculation should be repeated for each vaccine used in the national immunization schedule and for special mass campaigns):

<table>
<thead>
<tr>
<th>TABLE 4-1</th>
<th>EXAMPLE CALCULATION OF NEEDED SUPPLIES FOR DTP-HEPB-HIB VACCINE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Note: this table should be repeated and completed for each vaccine in the national immunization schedule)</td>
</tr>
<tr>
<td></td>
<td>2002</td>
</tr>
<tr>
<td>a) Total number of children under 1 year</td>
<td>871 983</td>
</tr>
<tr>
<td>b) Anticipated coverage</td>
<td>80%</td>
</tr>
<tr>
<td>c) No. of children targeted for vaccination (a x b)</td>
<td>697 586</td>
</tr>
<tr>
<td>d) Doses per child</td>
<td>3</td>
</tr>
<tr>
<td>e) Wastage factor</td>
<td>1.32</td>
</tr>
<tr>
<td>f) No. of doses required (c x d x e)</td>
<td>2 762 441</td>
</tr>
<tr>
<td>g) Doses buffer stock (f x 25%*)</td>
<td>690 610</td>
</tr>
<tr>
<td>h) Total no. of doses (f + g)</td>
<td>3 453 051</td>
</tr>
<tr>
<td>i) Doses per vial</td>
<td>2</td>
</tr>
<tr>
<td>j) Total no. vials (h ¸ i)</td>
<td>1 726 525</td>
</tr>
<tr>
<td>k) AD syringes [(c x d) + 10% wastage**]</td>
<td>2 302 034</td>
</tr>
<tr>
<td>l) AD syringes buffer stock (k x 25%*)</td>
<td>575 508</td>
</tr>
<tr>
<td>m) Total AD syringes (k + l)</td>
<td>2 877 542</td>
</tr>
<tr>
<td>n) Reconstitution syringe (disposable) (i + 10%)</td>
<td>1 899 178</td>
</tr>
<tr>
<td>o) Safety boxes [(m + n) ≥ 100] + 10%</td>
<td>52 544</td>
</tr>
</tbody>
</table>

* Buffer stock should always be maintained at 25%. The first year order establishes the buffer stock; for subsequent years the buffer stock required is calculated as the difference between anticipated use (including population growth of the target group) and the remaining buffer stock.

** 10% wastage is an indicative figure; countries should determine their wastage factor based on actual program experience and adjust the above example calculations accordingly.
4.6 Recommendations for Practical Waste Management Procedures

Waste segregation and packaging

- Always segregate sharps from non-sharps at the source
- Immediately after use, discard entire syringe with needle into a safety box without recapping needles
- Put safety boxes into plastic bags closed hermetically when full to avoid any leakage during transportation
- Put empty vials into waste containers with plastic lining to avoid leakage. Seal and mark it clearly when full

Waste Treatment and Final Disposal

- In health care facilities (located in low density populated area)
  Safety boxes (needles/syringes) and containers (of empty/expired vials) need to be supplied. Alternatively for programs not using Auto-disable syringes needle pullers and needle destroyer devises many be employed. Chemical treatment for disinfection combined with deep burial and/or encapsulation is one possible short-term solution for immunization campaigns. This process could be continued if sanitary landfills are constructed and operated in a sustainable fashion with adequate restriction of access. Depending on local conditions treatment technologies such as steam (autoclave), microwave, or chemical systems may be appropriate and cost-effective
  Note: Vials should be safely buried

- In health care facilities (located in high density populated area)
  Safety boxes (syringes) and containers (of empty/expired vials): off-site transportation to larger center with treatment facility using steam (autoclave), microwave or chemical systems with the residual waste sent to sanitary landfill after disinfection, needle cutting and encapsulation with cement mortar or another suitable substrate. The need for shredding or encapsulation of residual waste is determined by the adequacy or security of the landfill (or dump) site

- In provisional or mobile settings
  - Always ensure off-site transportation of all wastes to the health center of reference for treatment. Label the wastes, use adequate registering and delivery forms and store in secure area
  - On-site treatment/disposal should be avoided as much as possible

4.7 Treatment and Disposal Options

Once safely collected, wastes that are potentially infectious or hazardous (e.g., a sharp) will need special treatment and disposal to safeguard public health. A number of options to incineration/burning exist. Specific approaches are detailed in Section 3.1. The following section will begin with a more detailed review of land disposal, because regardless of what treatment method is chosen, all of the options require some kind of land disposal in the end. As campaigns organize to evaluate their options for managing wastes, understanding the current conditions and options for land disposal in the area they will be working in is essential.

4.7.1 Land disposal — Municipal or regional systems

If a municipality or medical authority genuinely lacks the means to treat wastes before disposal, the use of a landfill has to be regarded as an acceptable disposal route. Allowing health care waste to accumulate at hospitals or elsewhere constitutes a far higher risk of the transmission of infection than careful disposal in a municipal landfill, even if the site is not designed to the standards used in higher-income countries. The primary objections to landfill disposal of hazardous health care waste, especially untreated waste, may be cultural or religious or based on a perceived risk of the release of pathogens to air and water or on the risk of access by scavengers.

There are two distinct types of waste disposal to land— open dumps and sanitary landfills.

- Open dumps are characterized by the uncontrolled and scattered deposit of wastes at a site; this leads to acute pollution problems, fires, higher risks of disease transmission, and open access to scavengers and animals. Health care waste should not be deposited on or around open dumps.
The risk of either people or animals coming into contact with infectious pathogens is obvious, with the further risk of subsequent disease transmission, either directly through wounds, inhalation, or ingestion, or indirectly through the food chain or a pathogenic host species.

- **Sanitary landfills** are designed to have at least four advantages over open dumps: geological isolation of wastes from the environment, appropriate engineering preparations before the site is ready to accept wastes, staff present on site to control operations, and organized deposit and daily coverage of waste. Some of the rules applicable to sanitary landfills are listed in Box 4.1.

### BOX 4.1 SOME ESSENTIAL ELEMENTS FOR DESIGN AND OPERATION OF SANITARY LANDFILLS

- Access to site and working areas possible for waste delivery and site vehicles.
- Presence of site personnel capable of effective control of daily operations.
- Division of the site into manageable phases, appropriately prepared, before landfill starts.
- Adequate sealing of the base and sides of the site to minimize the movement of wastewater (leachate) off the site.
- Adequate mechanisms for leachate collection, and treatment systems if necessary.
- Organized deposit of wastes in a small area, allowing them to be spread, compacted, and covered daily.
- Surface water collection trenches around site boundaries.
- Construction of a final cover to minimize rainwater infiltration when each phase of the landfill is completed.

Disposing of certain types of health care waste (infectious waste and small quantities of pharmaceutical waste) in sanitary landfills is acceptable; sanitary landfills limit contamination of soil and of surface water and groundwater, and limit air pollution, smells, and direct contact with the public. Upgrading from open dumping directly to sophisticated sanitary landfills may be technically and financially difficult for many municipalities. It has often been found impossible to sustain such efforts from the available local resources. However, this is no reason for municipal authorities to abandon the move towards safer land disposal techniques, perhaps by a gradual approach, such as that outlined in Box 4.2.

### BOX 4.2 - PROPOSED PATHWAY FOR GRADUAL UPGRADING OF LANDFILLS

1. **From open dumping to “controlled dumping”**. This involves reduction of the working area of the site to a more manageable size (not letting the waste spread out over an extensive area), covering unneeded areas of the site with soil, extinguishing fires, and agreeing to rules governing safe access and safety precautions for scavengers if they cannot be completely excluded.

2. **From controlled dumping to “engineered landfill”**. This involves the gradual adoption of engineering techniques to prevent surface water from entering the waste, extract and spread soils to cover wastes, gather wastewater (leachate) into lagoons, spread and compact waste into thinner layers, prepare new parts of the landfill with excavation equipment, and isolate the waste from the surrounding geology (e.g. with plastic sheeting under the waste).

3. **From engineered landfill to “sanitary landfill”**. This involves the continuing refinement, with increasing design and construction complexity, of the engineering techniques begun for engineered landfill. In addition, there should be landfill gas control measures, environmental monitoring points and bore holes (for monitoring air and groundwater quality), a highly organized and well trained work force, detailed record-keeping by the site office, and, in some circumstances, on-site treatment of leachate.
In the absence of sanitary landfills, any site at or above technology level of a controlled dump could accept health care waste and still avoid measurable increase in infection risk. The minimal requirements would be the following:

- an established system for rational and organized depositing of wastes with special consideration for a secure and safe area for health care wastes;
- some engineering work already completed to prepare the site to retain its wastes more effectively;
- rapid burial of the health care waste, so that as much human or animal contact as possible is avoided.

The methods of cement encasing, encapsulation with immobilizing materials, and a waste burial pit with concrete cover have been reviewed in sections 3.1.1 through 3.1.3.

### 4.7.2 Safe burial on hospital premises

In health care establishments that use minimal programmes for health care waste management, particularly in remote locations, in temporary refugee campments, or in areas experiencing exceptional hardship, the safe burial of waste on hospital premises may be the only viable option available at the time. However, certain basic rules should still be established by the hospital management:

- Access to the disposal site should be restricted to authorized personnel only.
- The burial site should be lined with a material of low permeability, such as clay, if available, to prevent pollution of any shallow groundwater that may subsequently reach nearby wells.
- Only hazardous health care waste should be buried. If general hospital waste were also buried on the premises, available space would quickly fill up.
- Large quantities (>1kg) of chemical/ pharmaceutical wastes should not be buried at one time. Burying smaller quantities avoids serious problems of environmental pollution.
- The burial site should be managed as a landfill, with each layer of waste being covered with a layer of earth to prevent odors, as well as to prevent rodents and insects proliferating. The safety of waste burial depends critically on rational operational practices. The design and use of the burial pit are described in section 3.1. The bottom of the pit should be preferably 1.5 meters higher than the groundwater level.

It should be borne in mind that safe on-site burial is practicable only for relatively limited periods (i.e. 1–2 years), and for relatively small quantities of waste, up to 5 or 10 tonnes in total. Where these conditions are exceeded, a longer-term solution, probably involving disposal at a municipal solid waste landfill, will need to be found.

### 4.8 Summary

The success of waste management programs accompanying immunization campaigns is based much more on planning, good management, proper tools, training (and reinforcement of training) and providing a sustainable system, rather than the choice of an individual treatment technology. Disinfecting and rendering needles and other sharps non-hazardous is important. This can be accomplished by following a number of different pathways without resorting to the unhealthy practice of burning or incineration.

Health care waste management systems that have proven to work sustainably focus on first things first – eliminating unnecessary injections, proper product purchasing (e.g., bundling syringes with safety boxes), segregation, proper containerization (method and physical properties), having a secure system of storage and transportation to treatment and disposal sites, and providing workers (at all levels) with adequate training and education, and determining the necessary reinforcement to maintain the system over time. Only then can a proper choice for treatment and disposal of the wastes be made.
<table>
<thead>
<tr>
<th>METHOD</th>
<th>STRENGTHS</th>
<th>WEAKNESSES</th>
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<tbody>
<tr>
<td>Waste Burial Pit/Encapsulation or other immobilizing agent (sand, plaster)</td>
<td>● Simple&lt;br&gt;● Inexpensive&lt;br&gt;● Low tech&lt;br&gt;● Prevents unsafe needle and syringe reuse&lt;br&gt;● Prevents sharp related infections/injuries to waste handlers/scavengers&lt;br&gt;● Burial/encapsulation can be effective interim methods in rural areas&lt;br&gt;● Once encapsulated, medical waste does not pose a major infectious threat. Chemical treatments can also be used prior to encapsulation to eliminate the threat of infection</td>
<td>● Potential of being unburied&lt;br&gt;● No volume reduction&lt;br&gt;● No disinfection of wastes (unless waste is treated prior to burial)&lt;br&gt;● Pit will fill quickly during campaigns·&lt;br&gt;Not recommended for non-sharp infectious wastes&lt;br&gt;● Presents a danger to community if not properly buried&lt;br&gt;● Inappropriate in areas of heavy rain or if water table is near the surface&lt;br&gt;● May be difficult to construct waste pits in rocky or clay soils</td>
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<tr>
<td>Needle removal/Needle destruction</td>
<td>● Prevents needle reuse&lt;br&gt;● Reduces occupational risks to waste handlers and scavengers&lt;br&gt;● Plastic and steel may be recycled for other uses after treatment&lt;br&gt;● Manual technologies available</td>
<td>● Potential needle stick injuries during removal&lt;br&gt;● Used needles/syringes need further treatment for disposal&lt;br&gt;● Safety profile is not established&lt;br&gt;● Some require electricity</td>
</tr>
<tr>
<td>Melting syringes</td>
<td>● Greatly reduces volume of immunization waste&lt;br&gt;● Prevents reuse</td>
<td>● Gas emission&lt;br&gt;● Electricity required</td>
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<tr>
<td>Autoclave, Steam Sterilization, Micro-waving (with shredding)</td>
<td>● Autoclaves have been used successfully for decades to treat sharps and non-immunization health-care wastes&lt;br&gt;● Sterilizes used injection equipment&lt;br&gt;● May reduces waste volume&lt;br&gt;● Plastic may be recycled for other uses after separation&lt;br&gt;● Autoclaves cost less than incinerators to build, operate, and maintain and have no economy of scale&lt;br&gt;● Autoclaves do not need constant supervision&lt;br&gt;● Autoclaves work well at provincial or district level&lt;br&gt;● Autoclaves emit much less air emissions than burning or incineration&lt;br&gt;● When used with shredders or designed with internal shredders, autoclaves effectively remove both the physical and biological hazards associated with sharps waste&lt;br&gt;● Autoclaves are commercially available in a wide range of capacities&lt;br&gt;● A standard autoclave design is relatively simple and can be made locally in countries that have small manufacturing industries such as boiler manufacturing</td>
<td>● Higher capital cost&lt;br&gt;● Requires electricity&lt;br&gt;● Higher operational costs&lt;br&gt;● Higher maintenance&lt;br&gt;● Needs final treatment and /or disposal&lt;br&gt;● Require further treatment to avoid reuse (e.g. shredding)</td>
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This approach needs to be played out at the central level, as the campaign is planned and managed, as well as at the local level, as it is implemented. Monitoring and evaluation are essential ingredients in a successful program. Evaluating the waste management practices and systems should be an aspect of the overall function of evaluation conducted in a campaign. Using that feedback to reinforce good practices or correct inadequate ones is essential. Planners should be aware that systems established during these campaigns have a tendency to remain in place. Enforcing good practice through the campaign will lead to long-term positive results for health care programs even after the campaign has concluded.

In the end, all treatment options require wastes or waste residuals to be disposed of by burial. It is critical for planners to have an understanding of the local and regional infrastructure of land disposal to develop a complementary system that improves rather than burdens the system.

A regional systems approach to waste management for immunization campaigns can lead to positive results for workers, local communities, and the long-term health prospects of the population being served. A diagrammed sample system follows.
FIGURE 4-1   DISPOSAL OF USED SYRINGES AND NEEDLES
IN EPI PROCEDURE FOR COLLECTION, TREATMENT, AND DISPOSAL

1) Bring safety boxes filled with used syringes/needles
2) Collect new syringes/needles & new safety boxes*

ALTERNATIVE:
If return is difficult or impossible

Direct disposal/ burial in secure cell at municipal/regional sanitary landfill

*Important: Used syringes/needles should be brought back at the same time new supplies are to be picked-up (vaccines, syringes, safety boxes)
Conclusion

The management of wastes from immunization and other health programs is a serious public health issue. As increasingly large numbers of single-use syringes are generated, especially in global immunization campaigns, new focused attention is needed to develop the best methods and technologies to manage these wastes. Reliance on old procedures or technologies will no longer suffice in approaches to improving global health.

Continued reliance on highly polluting combustion technologies, such as the small-scale De Montfort incinerator, is particularly alarming. Incinerators have serious environmental and health impacts on workers, surrounding communities, and the environment. The small-scale De Montfort incinerator does not maintain high temperatures and high combustion efficiencies, has very short residence times, has no pollution control equipment, and as a consequence, does not meet international standards for incinerators. Field investigations show that these incinerators are poorly maintained and are operated in substandard conditions, posing an environmental health and occupational safety hazard. Disposal of the ash remains a serious problem. Furthermore, incinerators undermine waste segregation and minimization practices, and make the promotion of cleaner alternatives more difficult.

Many cleaner technologies that safely treat and dispose medical waste now exist including standard autoclaves, advanced autoclaves, microwave units, dry heat systems, and some chemical disinfection technologies. For rural areas and low-income developing countries, low-cost alternatives include: cement encasing, encapsulation with immobilizing agents, waste burial pit with concrete cover, small portable steam treatment units with traditional grinders, point-of-use sharps technologies, and collection/transport/treatment in a centralized treatment technology such as an autoclave and shredder. A decision tree presents the increasingly wide range of possibilities that are available to meet different needs. The cost estimations of these new approaches indicate that some non-incineration technologies are more cost-effective than small low-cost incinerators. Some of these methods, such as encapsulation, waste burial pits, and cement encasing have been in use in countries like India. Even remote rural areas may be able to avail of these simple technologies that have less adverse impact on the communities’ health and environment.

More than just technologies, a system of waste management should be integrated in the planning of global immunization campaigns at the national and local levels. The success of waste management programs depends on good planning, management, proper tools, training (and reinforcement of training) and providing a sustainable system. Sustainable health care waste management systems focus on eliminating unnecessary injections, proper product purchasing (e.g., bundling syringes with safety boxes), conducting proper segregation and containerization (method and physical properties), having a secure system of storage and transportation to treatment and disposal sites, providing workers (at all levels) with adequate training and education, and applying the necessary reinforcement to maintain the system over time. It is critical for planners to understand the local and regional infrastructure of land disposal to develop a complementary system that improves, rather than burdens the system. Disinfecting and rendering needles and other sharps non-hazardous are critical. This can be accomplished by following a number of alternative pathways without resorting to the unhealthy practice of burning or incineration.

Monitoring and evaluating waste management practices and systems, as well as reinforcing good practices or correcting inadequate ones, should be part of the overall campaign. Enforcing good practice through the campaign will lead to long-term positive results for health care programs even after an immunization campaign has concluded.
Health Care Without Harm is committed to promoting policies and procedures to minimize the environmental and health impacts of health care waste and to research and advocate safer waste disposal alternatives. For example, HCWH is working with the United Nations Development Program, the World Health Organization, and governments and non-governmental organizations in seven countries in an international project to demonstrate best techniques and practices in reducing and managing medical waste to avoid environmental releases of dioxins and mercury from health care practice. The project involves selecting hospitals and health clinics to establish policies and approaches that demonstrate best techniques and practices in health care waste management. This will include developing model hospitals and/or model rural health clinics. Then, based on the experiences gained, national (and/or regional) programs in participating countries will be developed to train experts who can replicate the program in other hospitals and health clinics. The experience will also serve as a framework for review and revision of national medical waste policies and regulations.

HCWH has also launched an international design competition to expand the range of available low-cost technologies that treat medical waste without harming the public, health workers, or the environment. The international contest for innovative treatment technologies for rural areas seeks to engage students, professors, researchers, and innovators in the fields of engineering, science, environment, and public health towards finding a solution to this global problem. The conceptual designs must be appropriate for rural use and easily replicated in less developed countries. As of October 2002, fifty-nine teams have agreed to participate in the contest. They represent 33 universities, 7 technical colleges or institutes, 7 engineering groups or consulting engineers, 4 health institutions, and 8 non-governmental organizations, private firms or individuals from 28 different countries. An international panel of judges will select the best designs that will be made available in the public domain in Spring 2003.

HCWH continues to seek out partnerships and creative collaborations with international, national and local agencies and organizations to further research, develop, and promote safer waste disposal methods and waste management systems.
Endnotes

1. Giugliano et al., Chemosphere 46, 1321 (2002); Abad et al., Chemosphere 40, 1143 (2000).
5. The De Montfort University Incinerator: Lessons from the field,” ibid.
6. “Laboratory Assessment of the De Montfort Small-Scale Medical Waste Incinerator for Rural Applications,” December 15, 1999 [excerpts of the report provided by D.J. Picken who provided permission to cite information from the report]; tests were conducted at CSIR for De Montfort University and the South African Collaborative Centre for Cold Chain Management.
16. Personal communication (via e-mail) to J. Emmanuel from Prof. D.J. Picken, July 24, 2002.
17. J. Emmanuel, Non-Incineration Medical Waste Treatment Technologies, Health Care Without Harm, Washington, DC, August 2001; see www.noharm.org
20. Based on information provided by Ravi Agarwal, Shristi, New Delhi, India, September 2002.
24. Adapted with minor modifications from the UNICEF guide, Management of wastes from immunization campaign


